



Conference Proceedings

BEHAVE 2025

*the 8th European Conference on
Behaviour Change for Energy Efficiency*



European Energy Network

A voluntary network of European energy agencies



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Foreword to the Proceedings of the Behave 2025 conference

Sylvain Waserman, Chairman - ADEME, French Agency for Ecological Transition



Dear readers,

It is my great privilege to introduce you to the official Proceedings of the 8th Behave Conference of the European Energy Network (EnR) and to present to you this collection of high-quality extended abstracts. As Chairman of the French Agency for Ecological Transition (ADEME), I am proud that we had the opportunity to host this edition in Paris, France. Behave is the flagship event of the EnR Network

bringing together around 400 participants from across Europe and beyond demonstrating the relevance and importance of the Network's work.

To adapt to the inevitable consequences of climate change and to limit its already tangible effects, changes in our lifestyles and in the collective organisation of our society are necessary, beyond purely technical innovations. This is why we decided to broaden the scope of Behave: from energy efficiency to sufficiency, and from behaviour change to broaden lifestyles changes, which are essential to ensuring a just and inclusive transition to carbon neutrality. It is important to promote the social, technical, economic and institutional conditions that will facilitate the adoption of more moderate lifestyles and make them more desirable and accessible.

Rethinking our production and consumption models is a sine qua non condition for the transition ahead, and sufficiency offers a concrete pathway to achieve it, as a strategic lever for economic sovereignty and resilience. Sufficiency seeks to meet individual and collective needs while reducing pressure on resources, biodiversity, greenhouse gas emissions, as well as our dependence on raw materials. In doing so, it strengthens the sovereignty and long-term resilience of territories.

There is far more to gain than to lose from climate action in France, Europe and across the world. The concept of a 'just transition', enshrined in the preamble to the Paris Agreement, reflects this reality. The priority now is to ensure that the transition actually takes place, as this is a major public interest objective, one that will ultimately determine all others. Nevertheless, the transition may also entail negative effects on the profitability and viability of certain economic activities, as well as on living standards and social inclusion. Research in the social sciences and humanities is essential to properly assess these impacts, understand how to reduce or mitigate them, and place them in perspective alongside the many co-benefits generated by the transition.

We aim to continue the dialogue on these issues at the 8th edition of the Behave conference. Scientific knowledge, an essential source of reliable expertise, is more necessary than ever in a democracy to inform public debate and to design and implement policies that are effective, efficient and aligned with the needs of citizens, public authorities, economic actors, and civil society. Exchanges between the research community and practitioners can offer valuable insights for shaping and delivering effective policies.

Since 2009, Behave has successfully brought together researchers and decision-makers from politics and business to share innovative solutions and make progress together. Behave 2025 will once again provide an opportunity to continue this exchange. I wish you an insightful reading of these proceedings and a productive conference!



Foreword to the Proceedings of the Behave 2025 conference

Irina Uzun-Dupouey, Head of Unit for European Cooperation - ADEME, French Agency for Ecological Transition



I am grateful for the opportunity to lead the 8th edition of the Behave Conference on 11th -12th December 2025 in Paris, France. As Chair of the Behave Organising Committee, I worked with great people to make this important event a success for the European Energy Network. Behave is an important conference for national energy agencies in Europe, as it provides a unique forum for policymakers, academia, industry and practitioners to share ideas and experiences in promoting effective solutions for reducing CO₂ emissions and mitigating climate change.

This year's edition has a broad scope, and the title "From energy efficiency to sufficiency: the need for a change in lifestyles to ensure a just transition to carbon neutrality" emphasizes the issues we would like to discuss with stakeholders. The call for proposals, launched in the framework of the Behave conference, shows that these topics are of interest and are gaining momentum.

We are proud to have received 233 contributions from many countries all over Europe and beyond. Behave 2025, as in previous editions, was tailored to bring together researchers in multiple disciplines, policymakers, practitioners and professionals in the field of ecological transition and behaviour change. These conference proceedings comprise extended abstracts that have been peer-reviewed by a Scientific Committee consisting of members from numerous European universities, the European Commission and a sustainable energy organisation in New Zealand. This publication includes selected extended abstracts presented at the conference, either in parallel sessions or via posters.

Before you delve into reading, I would like to extend my gratitude to many people who contributed to this edition's organisation. I would like to thank the Sustainable Energy Authority of Ireland, the 2025 EnR President – especially, Carol Geraghty and Declan Meally; Rebecca van Leeuwen from RVO/Netherlands Enterprise Agency, Chair of the EnR Working Group Behaviour Change and my co-Chair in the EnR Committee, as well as other EnR Network member agencies of the EnR Committee. I would also like to thank the EnR Working Group Chairs for their continued support and collaboration – you are at the heart of our network!

I would also like to thank the members of the Scientific Committee, in particular, Marta Lopes, Paolo Bertoldi, Sea Rotmann, Nathalie Ortar, Lory Barile and Lisa Ryan, for all their hard work throughout the call for proposals and beyond. I also thank the EnR partner, the IEA Technology Collaboration Programme on User-Centred Energy Systems, and, especially, Samuel Thomas, Head of Secretariat, for his great support and cooperation.

Finally, I would like to thank my team at ADEME/ French Agency for Ecological Transition – for their great work provided in the National Committee and beyond – in particular, David Thibeau from the Professional Stakeholders' Mobilisation unit (Executive Directorate of Mobilisation for Ecological Transition); Solange Martin, Anaïs Rocci and Patrick Jolivet from the Executive Directorate of Forecast and Research; Marie Hervier Collas from the Sustainable Consumption Unit of the Circular Economy Directorate, and Philippe Masset, Director of the Europe and International Affairs Directorate, as well as my fellow Europe and International Directorate colleagues – especially, Corinne Carretero and Véronique Tétu, for making this conference a remarkable success.

Foreword to the Proceedings of the Behave 2025 conference

From energy efficiency to sufficiency: the need for a change in lifestyles to ensure a just transition to carbon neutrality



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Behave 2025 is the 8th edition of the biannual EnR event focusing on the application of behavioural insights in policies, programmes and actions to foster energy efficiency and combat climate change. This conference edition has broadened its scope from energy efficiency to sufficiency under all its forms within different sectors – energy, housing, transport, food, digital - highlighting the importance of promoting lifestyles change to ensure a just transition to carbon neutrality.

Behave 2025 will bring together over 400 participants from across Europe and further beyond. The Behave call for proposals attracted 233 extended abstracts, spanning research, practice and policy-focused work.

Contributions were received in various thematic priorities of the conference:

- Instruments, interventions and evaluation of behaviour change and evolution in social practices in the fields of energy and the environment. This includes multidisciplinary approaches to behaviour and social practices; behavioural solutions within organisations; economic analyses of behavioural interventions (e.g., cost-effectiveness and efficiency); and the scalability and long-term sustainability of policy experiments, including spillover and snowball effects.
- Just and inclusive transition, including challenges and stakeholder ownership; energy poverty and vulnerable consumers; public participation in shaping energy and environmental policies; civil society-led initiatives; and community engagement.
- Acceptability and ownership of public policies by stakeholders and the public as well as of low-carbon projects and technologies, norms, standards and strategies in determining decarbonisation decisions in industries and, more broadly, businesses.
- Sufficiency practices in the ecological transition; the role of infrastructures in enabling conditions, social dynamics, and collective practices for sufficiency; sufficiency in the design, production and distribution of goods and services; instruments used by public authorities to promote and support sufficiency practices at different territorial levels.
- Foresight exercises and the role of scenarios for carbon neutrality on decision-making and public action; positive narratives on transition and sufficiency, changing imaginations.

These proceedings showcase a wide range of perspectives on how to support lifestyle changes and advance the transition to clean energy. Together, the contributions highlight the diversity of potential solutions and the multifaceted complex challenges in this field. They underscore the need for meaningful changes in behaviours and social practices to improve energy efficiency, accelerate the shift to renewable energy, and promote sufficiency in a just and inclusive manner.



We extend our sincere thanks to all authors and participants for their valuable contributions, which we believe will provide strong momentum for continued and impactful action in this field.

On behalf of the Scientific Committee, we welcome you to Behave 2025 and wish you a successful conference!

Paris, 11th -12th December 2025



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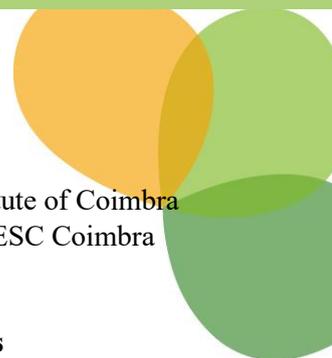
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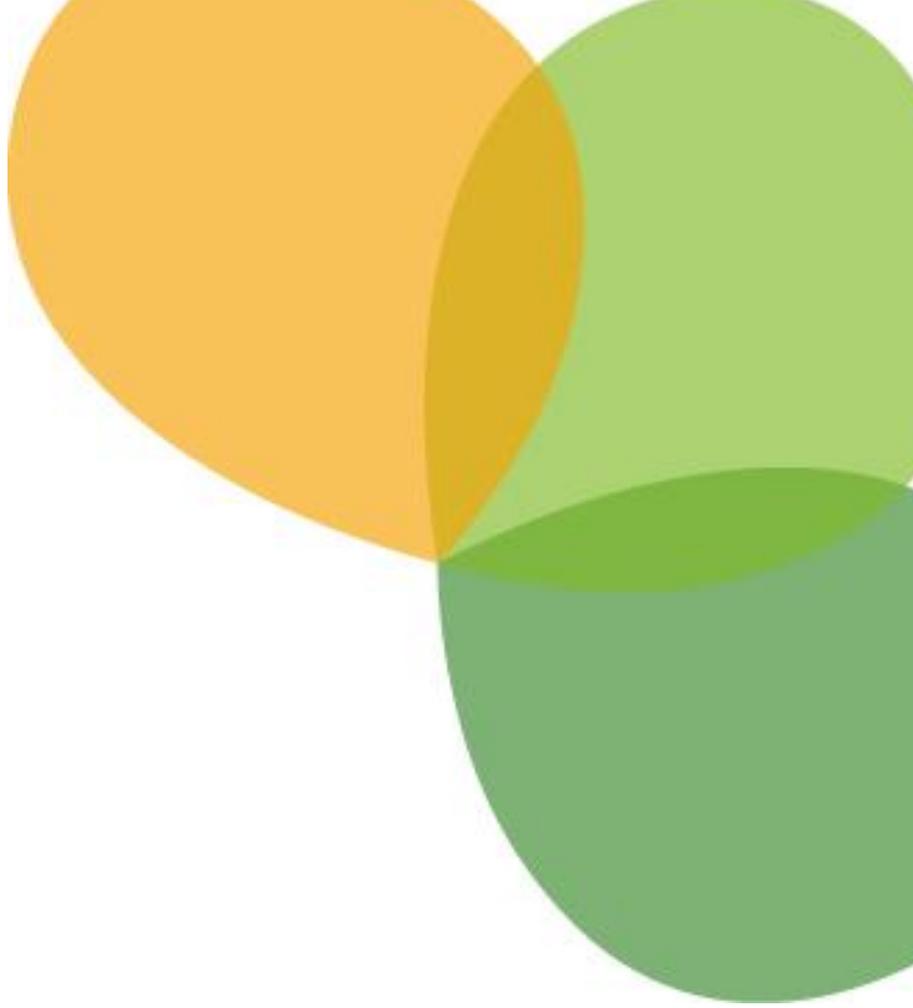


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EXTENDED ABSTRACTS

Introduced in sessions



Conceptualizing energy efficiency adoption of homeowners: a theoretical ABM framework incorporating uncertainty

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Agent-based, Energy efficiency, Behaviour, Decarbonisation, Uncertainty

Extended Abstract

1. INTRODUCTION

While the residential sector accounts for approximately 30% of total energy consumption in the world [1], the desired level of energy efficiency in households has yet to be achieved[2]. We need a clearer understanding of how to quickly and cost-effectively shift towards a decarbonized residential sector by encouraging the widespread use of energy-efficient practices. Nevertheless, even with ambitious goals and accessible technologies, the pace of homeowner retrofit adoption remains slow. Homeowners’ retrofit decisions are influenced by more than cost–benefit considerations, with uncertainty acting as a major barrier. However, seeing others adopt retrofits can reduce this uncertainty and encourage adoption through social learning.

It is therefore crucial to understand and model how micro-level homeowner decisions are shaped under uncertainty and social influence, so that policies (financial incentives, information campaigns, etc.) can be designed to more effectively overcome these barriers. Computational social science approaches, particularly agent-based modeling, offer a promising way to capture these complex human factors in technology adoption.

Despite growing interest in ABM for retrofit modeling, most models oversimplify decision processes, fail to capture evolving beliefs, and inadequately address the multifaceted nature of uncertainty. According to the uncertainty categorization of Baustert et al. [3] and Akbari et al. [4] uncertainty can manifest in various forms, such as aleatory uncertainties (arising from inherent variability and randomness) [4], [5], [6], [7] and epistemic uncertainties (stemming from knowledge gaps) [8], [9], [10], [11]. However, only a small body of research has explicitly addressed these uncertainties, and many of these distinct types remain largely unexamined in



the existing literature. On the other hand, only a limited number of models account for evolving opinions over time, and none fully address uncertainty from multiple perspectives. This is a critical shortcoming, as real-world decisions are dynamic. Homeowners adjust their opinions and uncertainty levels over time through social interactions and learning. Moreover, a recent review found that only a small fraction of published energy retrofit ABMs were validated or calibrated with real-world data. Many models rely purely on theoretical behavioral assumptions without empirical grounding, raising concerns about their predictive validity [12].

Additionally, to our knowledge, no prior study has simultaneously integrated discrete choice modeling, microsimulation, and the Relative Agreement algorithm within an agent-based framework. . The relative agreement model, first proposed by Deffuant et al. (2002) [13] characterizes each individual’s attitude by an opinion (x_i) and uncertainty (U_i); To date, only three studies have applied it in a similar context [14], [15], [16]. Discrete choice models (DCMs), long established in econometrics since the 1970s, offer statistical estimates of individuals’ preferences and behavior. In the scope of this paper, Araghi et al. [17] demonstrated how to couple DCMs with agent-based simulations to govern agent decision-making. Lastly, spatial microsimulation, a well-established method in social science and urban studies that facilitates detailed population estimation within small geographic units using limited micro-level data [18] has previously been integrated with agent-based social simulation in only one study [19].

Given the above gaps, the aim of this research is to develop and demonstrate a computational model that more realistically simulates residential retrofit adoption under uncertainty and social influence. In fact, its key contribution is the explicit modelling of uncertainty alongside the embedding of empirically based decision rules into dynamic social and spatial structures. To achieve this, we construct an agent-based model informed by discrete choice–based decision rules, generate a synthetic population through microsimulation, and incorporate social network–driven opinion dynamics to capture the role of peer effects and information diffusion. Figure 1 encapsulates the holistic workflow: we analyze survey data using a discrete choice model (DCM) to derive agents’ decision rules and generate a synthetic population, embed it in a small-world network, and apply the Relative Agreement algorithm to simulate opinion and uncertainty dynamics; finally, agents with DCM-derived utilities, updated beliefs, and uncertainty scores enter an agent-based model to make probabilistic retrofit adoption decisions through interactions with neighbors and the built environment.

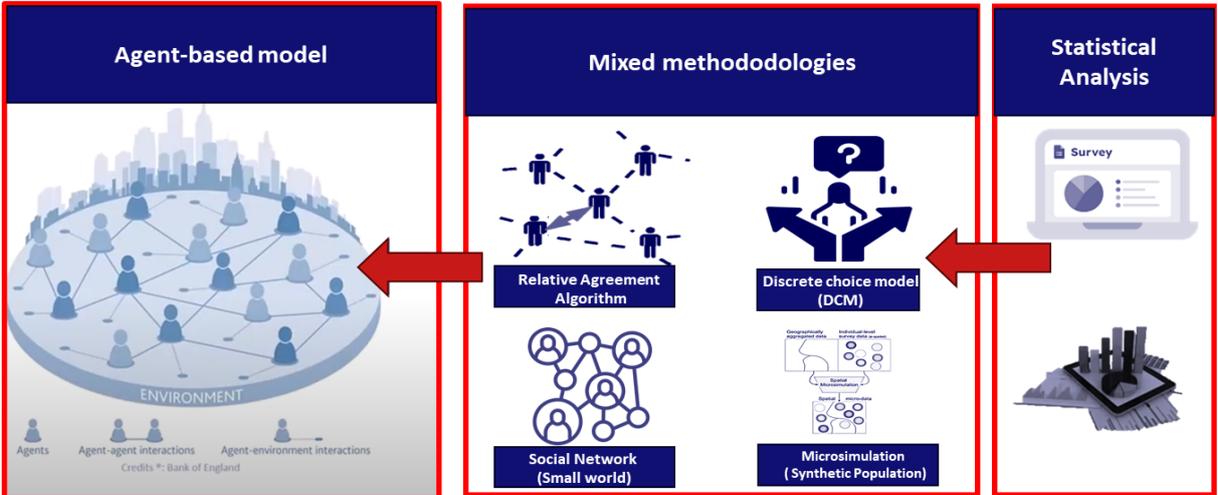


Fig1. Informing ABMs with discrete choice–based decision rules, generated synthetic population using microsimulation, and social-network-driven opinion dynamics

2. AGENT-BASED SIMULATION FRAMEWORK

Figure 2 illustrates the complete simulation framework, outlining the integration of economic feasibility, behavioural uncertainty, social influence via relative agreement, and probabilistic adoption within an agent-based modeling environment. The simulation model begins with the initialization of geospatial and agent-specific data. Inputs include a geographic map of Eindhoven in GeoJSON format, population density by neighborhood, and synthesized agent characteristics drawn from real-world demographic distributions.

First, each homeowner agent is assigned attributes such as age, income, education level, housing type, energy label, year of construction, and a willingness-to-pay (WTP) for retrofit technologies. In addition to these socioeconomic characteristics, agents also possess cognitive traits—namely, an initial opinion value and three uncertainty components (U1, U2, U3), reflecting behavioral hesitation toward technology adoption. Based on neighborhood boundaries and population density, agents are spatially distributed and linked to their respective NeighbourhoodAgents. A social network is formed by connecting agents within a certain exposure distance to simulate local peer influence.

At each simulation time step, agents begin by recalculating their WTP and comparing it to the minimum cost of available retrofit options. If the agent cannot afford any option, it becomes eligible for a randomized subsidy intended to simulate public financial support mechanisms. Based on their updated WTP, agents then determine a feasible choice set of affordable technologies. Parallel to this economic filtering, agents interact with a small number of randomly selected neighbors in their social network. Using the Relative Agreement (RA) algorithm, agents evaluate whether a neighbor is more confident, i.e., has lower average uncertainty, and, if so, may adjust their opinion and uncertainty values accordingly. Once social influence is applied, agents calculate a utility score for each option in the feasible set using a predefined equation based on personal attributes. These utilities are converted into probabilities via a sigmoid function. Agents then make probabilistic adoption decisions using [20]. If adoption occurs, the cost is deducted from WTP, and agents may continue adopting additional options if their budget allows.

After each adoption decision, agents update their internal states, including adopted technologies and remaining willingness to pay. These updates feed into the next simulation step. The process repeats over multiple time steps, capturing how adoption patterns evolve across space and time. The model records outputs such as the number of adopters by technology type, neighborhood-level adoption rates, changes in opinions and uncertainty, and the impact of subsidies on adoption. These results support analysis of how economic capacity, cognitive flexibility, and social influence drive the spread of sustainable retrofit technologies.



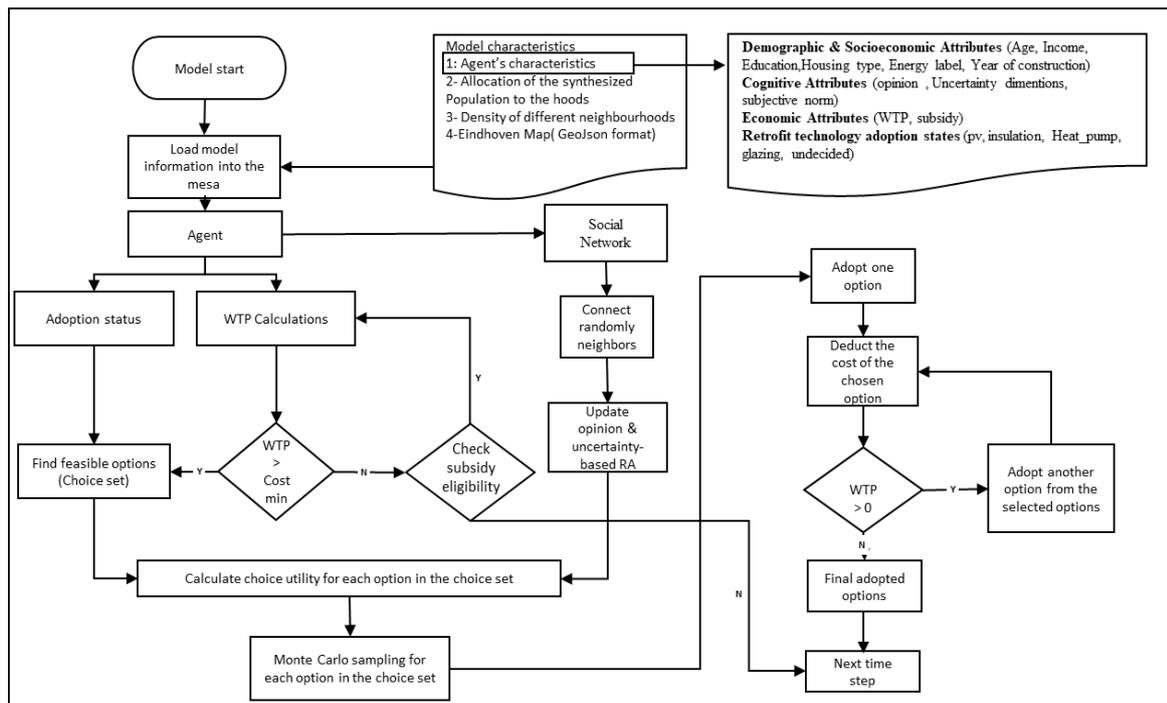


Fig2. Agent-based simulation framework for residential retrofit adoption under economic, social, and behavioural uncertainty

3. CONCLUSION

Although implementation is planned for future work, this framework makes a theoretical contribution by integrating discrete choice modeling, microsimulation, opinion dynamics, and agent-based modeling into a unified platform. It deepens understanding of how heterogeneous preferences, social influence, and multidimensional uncertainty interact to shape adoption dynamics. Future applications include calibrating the discrete choice component with real survey data, generating a spatially explicit synthetic population, and simulating evolving opinions and uncertainty diffusion. This would enable systematic policy experiments to evaluate interventions such as financial incentives and support decision-making for accelerating residential retrofit uptake in diverse urban settings.

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Elevating Indigenous Voices in the Just Energy Transition

Theme 2, sub-topic 2a), 2b), 2c), 2d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Equity, Energy Justice, Indigenous, Just Transition, Community Engagement, Narratives

Extended abstract

1. INTRODUCTION

A just energy transition is key to achieving universal energy access, as emphasised in the UN’s Sustainable Development Goals. However, energy poverty affects over four billion people across the globe [1], often resulting from a combination of low incomes, high energy pricing, and energy-inefficient housing. A lack of standard frameworks to identify energy-poor audiences has made it difficult to develop effective interventions [2].

The Hard-to-Reach (HTR) Energy Users Task of the Users TCP by the International Energy Agency (IEA) is a global collaboration aiming to identify hidden energy users and ways to better engage them to achieve a just energy transition. Here, it collaborated with the Users TCP’s EmPOWERing All Task, which focuses on integrating gender perspectives to promote a more inclusive energy transition.

Building trusted relationships and working directly with community members and frontline organisations when designing and implementing energy interventions has emerged as a crucial strategy to better reach priority audiences [3]. Thus, the two Tasks held a joint workshop in Northern Sweden to elevate local Indigenous voices and explore the tension between the “green” and “just” aspects of the energy transition.

Indigenous peoples have faced significant challenges around energy systems due to historical colonialism, marginalisation, and systemic inequities [4]. In Sweden, a push for decarbonisation and electrification has resulted in the expansion of renewable energy generation [4,5] and mining facilities to supply materials for Low Carbon Energy Technologies [6] that have adverse impacts on the traditional livelihoods of Indigenous Sámi, who rely on the land for reindeer herding.



We present some workshop insights here, having directly engaged with community members to glean Indigenous perspectives on the energy transition. These learnings will inform further research around how Indigenous stories can get subsumed by broader global narratives promoting the “green and just energy transition”.

2. WORKSHOP OVERVIEW

2.1. Purpose

A main purpose of the HTR Task is engaging hidden energy users and building connections with community and frontline providers—especially Indigenous stakeholders. A key deliverable is to hold three international expert workshops. The Task has held two workshops to date—the first was hosted jointly by the Consortium of Energy Efficiency and the U.S. Department of Energy in June 2024, and the second by the Swedish Energy Agency in June 2025. While both workshops elevated local and global Indigenous voices, the focus of this presentation will be on the more recent workshop, which featured direct input from the Gabna reindeer herders in Kiruna.

Collaborating with Indigenous subject matter experts from the EmPOWERing All Task to brainstorm how to address problematic approaches and narratives supports both Tasks in developing recommendations for policy makers and intervention designers that more fully support the just transition.

2.2. Methodology

The workshop was held as participatory field research in Kiruna—a town undergoing unprecedented transformation and relocation due to mining. From June 14th-16th 2025, workshop attendees visited local communities, businesses, and government agencies to discuss how to strengthen democratic processes to include marginalised energy users to ensure a more “just” green energy transition.

The workshop opened with a discussion with a municipality representative on June 14th. On June 15th, after getting an expert’s overview on the Swedish colonial history relating to energy issues and Sápmi [see also 4], attendees embarked on a field trip to hear how the green energy transition is affecting Sámi, and what the proposed new Per Geijer mine would mean for the Gabna reindeer herding community [7]. They later met to discuss increased polarisation, conflicting narratives, and consequences for the Sámi and other Indigenous peoples, guided by the expertise of Kristina Sehlin McNeil (Assistant Director at Várdduo-Centre för Sámi Research).

Attendees also discussed potential future collaborations across the HTR and EmPOWERing All Tasks. Mikajosefin, a member of the Sámi youth association (Sáminuorra) gave her perspective on the Swedish energy transition, as part of a global discussion on Indigenous challenges with Mark Hardin from the Mashpee Wampanoag tribe (U.S.) and Hinerangi Pere from the Waikato Tāinui iwi (Aotearoa New Zealand). On June 16th, participants visited the Kiruna Kin Museum and recently moved town hall, hearing from an Indigenous curator whose village had been displaced to make way for mining.

2.3. Data Collected / Findings

During the workshop, several key findings emerged. “Green Colonisation” was discussed in the context of non-solved, partly historical, and partly continuing impacts on the Indigenous Sámi communities [4,5,6,7]. While mines, hydro dams, and wind farms may be essential to Europe’s green energy transition, they threaten Sámi communities’ way of life and millennia of culture and traditions.



In the past, many large-scale hydro power plants have flooded homes, landscapes, and reindeer pastures, with other Indigenous lands becoming degraded and fragmented [4,5]. The current iron ore mine, the largest in the world, has already destroyed significant amounts of reindeer migration routes and led to the displacement of a large part of the city of Kiruna [8].

The nearby proposed new Per Geijer mine, is the largest critical rare earths deposit in Europe. The European Critical Raw Materials Act (CRMA) “designates strategic projects (such as this mine) to increase EU capacity to extract, process and recycle strategic raw materials” [9]. The risk assessment has “not included human rights, nor social and cultural impacts, of the project... [the mining company] has not yet proposed measures to prevent or mitigate adverse impacts on reindeer herding” [7]. Historically, the legal standing of Indigenous Sámi in Sweden has been weak, which has been flagged as a potential human rights violation [4,5,7].

During the workshop, the two Sámi representatives from Gabna reindeer herding community described their role in the decisions that will impact their livelihood as “inclusion without agency.” Although they are consulted about these changes, they cannot veto projects, they are not compensated for their time, and decision-makers can abort the discussion if there is no consensus. The prevailing narrative is “othering” not just Northern and Southern Swedes with regards to their stance in the green energy transition [10], but also paints reindeer herding Sámi as “elites”.

3. CONCLUSIONS / RECOMMENDATIONS

While any push to decarbonise and further the green energy transition is hailed as a positive, these efforts often impact local communities and hidden energy users in adverse ways. Even efforts to include priority audience perspectives can fall short if not fully thought through—e.g., while the Sámi are consulted about changes, they do not have real legal power. To achieve a truly just transition, it is necessary to meaningfully and fully engage with Indigenous communities by listening and learning from them and making them a part of the process through co-design, integrating Indigenous knowledge alongside scientific inquiry. It is imperative to properly compensate them for their time and efforts. Further, it is crucial to map and highlight the cumulative impact of all the green transition projects, not just individually, but through a broader energy justice lens.

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Low-Threshold Energy Consultations and Appliance Replacement for Vulnerable Households: Insights from an Austrian Support Scheme

Theme 2, sub-topic 2b – Energy poverty and vulnerable consumers

Academic contribution Policy/practice contribution

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Keywords: Energy Efficiency, Energy Poverty, Energy Consulting, Funding Program, Austria

Extended abstract:

Improving energy efficiency is a key lever for effective climate policy. Equally important, however, are its contributions to enabling a just and inclusive transition and preventing or mitigating energy poverty [1]. Many public or regional energy efficiency funding schemes in Austria rarely focus explicitly on vulnerable or low-income households, which often face specific living conditions and barriers to accessing public funding schemes, as most of them target higher income groups or behaviours and practices referring to these groups [2].

In response to this challenge, the Austrian Climate and Energy Fund launched the program "*Energy Saving at Home – Consultation and Appliance Replacement*" in 2023. Its primary aim is to reduce energy costs and improve energy efficiency in low-income, vulnerable or energy-poor households. The program provides personalized, needs-based energy consultations carried out in the beneficiaries' homes, and includes the replacement of up to two outdated, defective, or inefficient appliances with new, energy-efficient models. Importantly, the program is designed to minimize effort for participants: it requires no pre-financing or co-payments and offers additional information on available social support services to improve overall household well-being.

Program structure and delivery

The Climate and Energy Fund implements the program in collaboration with several stakeholders, most notably the social organization Caritas and the household appliance supplier Electronic Partner. Caritas is responsible for identifying and engaging target households and conducting the initial consultations, while Electronic Partner manages appliance procurement and logistics through a national retailer network containing of 134 regional retailers.

Households gain access to the program through an initial consultation at a local Caritas office, where eligibility is checked and the funding agreement is signed. Caritas may also refer beneficiaries to other relevant support services and institutions (e.g. local authorities, energy supplier) or provide advice in other challenging circumstances.

Subsequently, the Caritas assigns a trained energy advisor that contacts the household to schedule an in-home consultation. These advisors – either certified energy consultants or



specially trained social workers – offer tailored advice on energy-saving practices, switching energy providers, improving living conditions, and utilizing other social support schemes. The special training for social workers is supplied by the government and contains diverse learning-modules, e.g. concerning heating-systems or deep understanding of energy bills. The consultation within the beneficiaries household also includes selecting up to two for replacement, ordered jointly with the beneficiaries to suit the household's needs. Only refrigerators, fridge-freezers, freezers, electric stoves, washing machines and dishwashers can be replaced by the program.

Appliances are delivered and installed by local retailers within the network of Electronic Partner, who also remove and dispose of the old equipment. Households do not bear any financial burden at any point during the process.

Program strengths and accessibility

The program's decentralized structure and the involvement of multiple stakeholders are key success factors. Initial consultations take place at the Caritas offices throughout Austria, where vulnerable households can also receive advice on other relevant issues and access broader social support services. Energy consultations are conducted by certified energy advisors or specially trained social workers who complete a dedicated training module in "social energy consultation." Caritas is responsible not only for coordinating both the consultation and appliance replacement processes but also acts as the sole point of contact for beneficiaries. Additionally, Caritas handles all financial transactions with appliance retailers and the administrative body of the Climate and Energy Fund.

Notably, the program also includes tenants – an often overlooked group in energy efficiency schemes. When appliances belong to landlords, arrangements are made in advance regarding their disposal or storage and the ownership of new appliances in case of tenant relocation. Selling old appliances is prohibited.

The program is promoted by Caritas and the Climate and Energy Fund through materials in different languages. Caritas also conducts targeted outreach campaigns in selected neighborhoods and with partner organizations to reach elderly or energy-poor populations more effectively. Moreover, the program is introduced at relevant stakeholder events to encourage referrals from municipalities and public bodies.

Preliminary results and evaluation

A central objective of the program is to encourage low-income and vulnerable households to use household energy more efficiently – primarily through personalized energy consultations and appliance replacement. This is intended to help reduce individual energy costs while contributing to a decrease in overall energy consumption in Austria. However, it is important to note that many vulnerable households already consume relatively little energy due to financial constraints, which inherently limits the potential for further savings.

Unlike many other schemes, *"Energy Saving at Home – Consultation and Appliance Replacement"* stands out for its low-threshold, regionally accessible approach and its simplified application process. It avoids complex income assessments, relying instead on clear eligibility criteria and personal support from Caritas. Beneficiaries are accompanied throughout the entire process and are not required to make any financial contribution – making the program a unique model compared to similar initiatives, such as Germany's "Stromspar-Check".

To date, nearly 13,000 households have received initial consultations, and approximately 12,000 have received full energy consultations. Over 16,000 appliances have been replaced.



Beneficiary backgrounds and living conditions are highly diverse, varying significantly across regions.

An evaluation of the program is currently conducted. Its goal is to assess whether low-income and vulnerable households are being adequately reached, and whether the services and measures offered can be optimized to improve both targeting accuracy and beneficiary satisfaction. The evaluation is based, among other things, on documentation from the energy consultations, which provides insights into the living conditions of participating households – particularly regarding energy costs and consumption, building conditions, savings potential, and the most frequently addressed consultation topics.

At the same time, the evaluation aims to identify ways to improve the implementation process and reduce potential inefficiencies. A key challenge of the program is the considerable administrative effort required from participating actors, stemming from its intentionally low-barrier design aimed at facilitating access for vulnerable households. Initial results from this evaluation are expected by the end of the year.

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A study on consumer acceptance of direct load control - a load off one's mind?

Theme 3, sub-topic 3b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: automatic control, acceptance, drivers, barriers, flexibility, demand response

Extended abstract

1. Introduction

The increasing share of intermittent renewable energy sources presents a major challenge for maintaining grid balance, underscoring the need for greater demand flexibility [1], [2], [3]. Demand Response (DR) is gaining policy interest for its potential to shift electricity use through economic incentives [4], [5], [6]. DR is commonly divided into implicit DR, where consumers manually adjust usage in response to dynamic pricing, and explicit DR (or Direct Load Control, DLC), where utilities or aggregators remotely manage specific loads like heat pumps and electric vehicle charging [7], [8].

In the residential sector - the focus of this study - DR potential varies widely across and within programs [9], [10], [11], [12], [13]. Participation is shaped not just by financial incentives but also by social and psychological factors such as norms, control, and personal values [14], [15], [16], [17]. Compared to implicit DR, DLC requires less consumer effort and offers more reliable flexibility [18], [19], [20], [8], [21]. Yet, consumer participation in DLC remains low, indicating a need for deeper insight into user perspectives [8], [22].

Consumer perspectives on DLC have been examined across diverse disciplines and methods, revealing a complex interplay of motivations, barriers, and enablers affecting



willingness to participate (e.g. [23], [24], [25], [26], [27], [28], [29], [30], [31]. Financial benefits are the most commonly cited motivator [32], [33], [34], [35], [36], followed by environmental concerns [37], [38], [15]. Other motivators include interest in automation [9], [39], [36], [40], local sustainability [37], [41], [42], increased energy awareness [43], and comfort [44].

Barriers often relate to perceived loss of control, as consumers are reluctant to surrender autonomy over devices [45], [8], [39], [46]. Acceptance tends to increase when override options or opt-outs are available [47], [48], [45], [27], [49]. Concerns over privacy and data security are also significant [50], [51], [52], [53], [54], [55]. Trust in service providers is a crucial enabling factor [47], [48], [56]. Consumers are more likely to participate when providers demonstrate transparency, technical competence, and clear communication about program benefits [26], [8], [57] [58], [59].

Mistrust - whether before or after enrolment - can act as a major barrier [59]. Trust is also influenced by consumers' understanding of electricity systems and the role of DLC in addressing broader energy challenges [60], [61], [26]. The growing recognition of the 'Social License to Operate' concept has brought attention to broader public acceptance of DLC and the need for trust, transparency, and alignment with societal values [62], [63], [64].

Building on this body of work, the present study adopts a quantitative approach to further explore households' views and increase knowledge on their willingness to invest, motivations and barriers, as well as interest in and acceptance of DLC by an independent aggregator or electricity supplier.

2. Methodology

To assess households' view on DLC, a large-scale survey was conducted. The sample included nearly 40,000 customers from four distribution system operators, mostly households not yet using DLC - referred to as potential flexibility providers - and about 10,000 customers of an independent aggregator, considered active flexibility providers. Response rates were 3.3–3.9% for the former and 14.4% for the latter.

The higher response rate among active flexibility providers likely reflects greater interest in the topic, as most had already invested in solar panels, electric vehicles, or home batteries. Among potential flexibility providers, fewer had taken such steps, though still more than the general population (see Table 1).

Table 1: Investment in home batteries, solar panels and electric cars among active and potential flexibility providers as well as the population in general

Investment	Active flexibility providers	Potential flexibility providers	Population in general
Has home battery	96%	6%	~1%
Has solar panels	99%	22%	~10%
Has electric vehicle	52%	27%	~11%

Gender distribution also differed: female respondents were notably underrepresented overall, and even more so among active flexibility providers (see Figure 1). This likely reflects both a male-dominated aggregator customer base and greater male interest in energy technology.

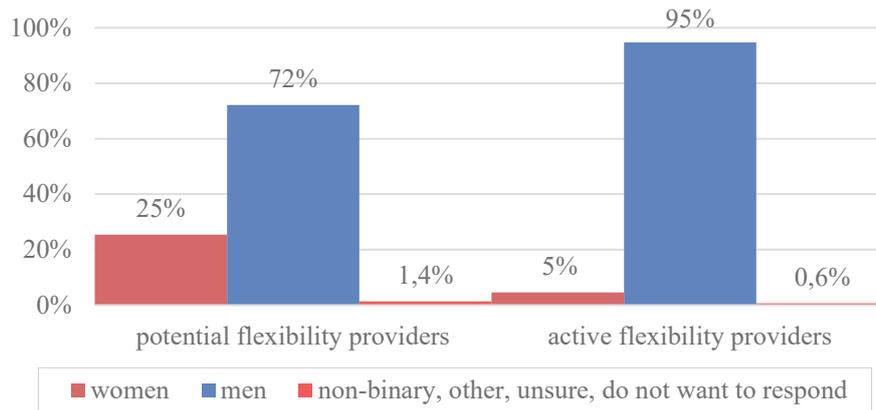


Figure 1: Distribution of gender across the two groups of households

Besides gender, the sample was not fully representative in terms of age, education, income, household size, origin, and housing. Respondents tended to be older, higher-income, more educated, and more likely to live in single-family homes and be of Swedish origin.

To explore preferences when it comes to business models for DLC, the survey included Discrete Choice Experiments (DCEs) related to electric heating, electric vehicles, and home batteries. Table 2 outlines the five attributes used in each experiment.

Table 2: Overview of attributes and their levels in the three discrete choice experiments

Attribute	Level 1	Level 2
Electric heating		
Max number of control events	Once per day	Unlimited
Possibility to temporarily regain control	Never	Always
Financial compensation [monthly average]	SEK 500	SEK 1,500
Impact on indoor temperature	No impact	Impact
Controlling actor	Electricity supplier	Independent aggregator
Electric vehicle		
Max number of paused chargings	Every charging	Every 5th charging
Max extended charging time	30 minutes	3 hours
Financial compensation [monthly average]	SEK 500	SEK 1,500
Possibility to temporarily regain control	Never	Always
Controlling actor	Car manufacturer	Independent aggregator
Home battery		
Control events	Nighttime	Always
Possibility to temporarily regain control	Never	Always
Financial compensation [monthly average]	SEK 500	SEK 1,500
Contract termination notice period	1 month	3 months
Controlling actor	Electricity supplier	Independent aggregator

Each DCE asked respondents to choose between different combinations of attribute levels, such as “high” vs. “low” compensation. One attribute concerned the preferred type of actor offering the service, and respondents also rated their trust in each actor, which was later used as a numerical variable.

Eighteen profiles (combinations of attributes) were selected and grouped into six sets of three, and respondents had to choose one profile from each set. Even when no option was appealing, the forced choice format yielded valuable data on relative preferences.

To assess which attributes influenced choices most, a conditional logit model was used. This method estimates how attributes affect the likelihood of a profile being selected, such as how compensation levels impact decisions. The profiles were well-balanced in the sense that they enabled a clear estimation of the attribute effects. To avoid confusion and ensure reliable results, it was also ensured that the attributes were not too similar to each other.

3. Results

The results of the survey study show that there is a fairly widespread perception among households that flexible electricity use can lead to reduced climate impact and a more sustainable energy system. This perception is significantly more common among active than potential flexibility providers. This also applies to their approach to the grid capacity challenge and their belief in flexible consumption as part of the solution.

Households are fairly willing to temporarily reduce or shift their electricity use manually, and they are comparatively even more willing to invest in technology for the purpose of DLC. When it comes to the willingness to delegate the control of electricity use to an external party, this willingness is relatively limited.

The factor that has the greatest impact on households' willingness to engage in DLC is the potential to reduce their electricity costs, followed by trust in the actor in question and a desire to reduce their electricity consumption. The factor that constitutes the greatest barrier to DLC is a perceived loss of control over the loads at hand. Contrary to expectations, lack of knowledge did not have a significant effect on the willingness to engage in DLC.

Interest in DLC tends to be highest among men with high levels of education and income. Whether their interest in energy-related innovations has influenced their decision to invest in technology for DLC purposes, or whether the causality is the other way around, is unclear, but there is a clear correlation.

The results from the analyses using the conditional logit model regarding DLC of electric heating, electric vehicles, and home batteries show that all attributes had a significant impact on households' choice of profiles, although the direction and strength of the effects varied (see Table 3).



Table 3: The respective impact of attributes on the choice of profiles for DLC

Probability that the attributes influence the choice of profiles for DLC of electric heating		
Attribute	OR*	CI**
Maximum number of control events [unlimited]	1.46	1.39 – 1.52
Possibility to temporarily regain control [always]	3.15	2.99 – 3.31
Financial compensation [SEK 1500]	2.67	2.54 – 2.82
Impact on indoor temperature [yes]	0.64	0.61 – 0.67
Trust in controlling actor [aggregator]	1.06	1.04 – 1.07
Observations		22,764
R ² Nagelkerke***		0.181
Probability that the attributes influence the choice of profiles for DLC of electric vehicles		
Maximum number of paused charging sessions [each session]	1.33	1.26 – 1.41
Maximum extended charging time [3 hours]	0.89	0.84 – 0.94
Monthly financial compensation [SEK 1500]	7.16	6.60 – 7.77
Possibility to temporarily regain control [always]	5.37	4.98 – 5.78
Trust in controlling actor [aggregator]	1.10	1.09 – 1.12
Observations		15,321
R ² Nagelkerke***		0.331
Probability that the attributes influence the choice of profiles for DLC of home batteries		
Control [always]	1.24	1.18 – 1.30
Possibility to temporarily regain control [always]	2.52	2.40 – 2.64
Monthly financial compensation [SEK 1500]	5.17	4.87 – 5.48
Contract termination notice period [3 months]	0.76	0.73 – 0.80
Trust in controlling actor [aggregator?]	1.08	1.07 – 1.10
Observations		24,209
R ² Nagelkerke***		0.222
* Odds Ratio (OR) is a statistical measure used to quantify the strength of the association between two events, usually an exposure and an outcome. It is especially common in logistic regression and case–control studies in medicine and the social sciences.		
** A confidence interval (CI) is a range that, with a certain level of confidence, is expected to contain the true value of a population parameter, such as a mean, proportion, or odds ratio. A 95% confidence interval, for example, means that if the experiment were repeated many times, approximately 95% of the calculated intervals would contain the true parameter value.		
*** Nagelkerke R ² , also known as Nagelkerke’s pseudo-R ² , is a measure of how well a logistic regression model (or other non-linear regression model) explains the variation in the dependent variable. It is an extension of Cox & Snell R ² , adjusted to reach a maximum value of 1, making it easier to interpret and compare with the classical R ² from linear regression.		

Households tend to have slightly more trust in independent aggregators than other actors when choosing offers related to LDC. However, the difference is small, and the choice is more strongly influenced by other factors than trust, such as the level of financial compensation and the possibility to regain control over the flexibility resource in question when needed.

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The "Espaços Energia / Energy Spaces" Initiative: Fostering Behavioural Change and Energy Efficiency at the Local Level in Portugal

“Academic contribution”

“Policy/practice contribution”

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Themes:

Theme 1 “Instruments, interventions and evaluation of behaviour change and evolution in social practices in the field of energy and the environment”, sub-topic 1d) “Choice and impact of public policies” or

Theme 2. “Instruments, interventions and evaluation in terms of a just and inclusive transition”, sub-topic 2b) Energy poverty and vulnerable consumers or c) Public participation in the development of energy and environmental policies or

Theme 6 “Foresight, modelling and positive narratives”: c) Regulation and reduction of advertising, positive narratives on transition and sufficiency, changing imaginations

Keywords: Energy Efficiency, Renewable Energy, Citizen Engagement, Energy Literacy, Energy Poverty, Behavioural Change

Extended abstract

Portugal is firmly committed to achieving carbon neutrality by 2045, advancing its original 2050 target. This national ambition is structured within the National Energy and Climate Plan 2021-2030 (PNEC 2030), which outlines five interlinked pillars: decarbonisation, energy efficiency, security of supply, internal energy market integration, and innovation and competitiveness. Among these, energy efficiency stands as a key priority, fundamental to reducing consumption and fostering a more autonomous and sustainable energy system.

The energy transition demands behavioural change, citizen empowerment, and the promotion of sustainable habits. Within this context, the REPowerEU Plan, launched in May 2022 as a response to energy market disruptions and geopolitical instability, reinforced the urgency of energy transition measures across Europe. Portugal incorporated this plan into its Recovery and Resilience Plan (PRR), where the reform RP-C21-r44 outlined the creation of “Espaços Energia” (Energy Spaces) – one-stop-shops for energy efficiency.

The "Espaços Energia" initiative aims to provide accessible support to citizens in adopting energy efficiency and renewable energy measures, enhancing energy literacy and stimulating behavioural change. This aligns with several goals of the PNEC 2030, including:

- Reducing primary energy consumption in a cost-effective way;
- Increasing the use of renewable energy sources;
- Enabling a fair and inclusive transition, particularly by tackling energy poverty and involving citizens as active agents of change.

The initiative was co-developed through a design-thinking approach that involved more than 20 institutions from the energy, social, and public sectors. It is coordinated by ADENE – Agência para a Energia, with strategic partnerships including the National Association of Municipalities (ANMP), National Association of Parishes (ANAFRE), National Confederation



of Solidarity Institutions (CNIS) and the National Network of Energy and Environment Agencies (RNAE).

The application of Design Thinking ensured that solutions are citizen-centered and responsive to real-world needs. This methodology involved extensive co-creation sessions, bringing together over diverse organizations and numerous stakeholders, including government, academia, industry, and civil society. Through this collaborative and iterative process, Design Thinking enabled the development of a base model for the EE's functions, service structure, governance, financing, and physical/virtual interfaces, as well as variants of this model tailored to different territories. This approach fostered an innovative and practical design, promoting deep understanding of user needs and ensuring the resulting spaces would genuinely empower citizens in energy efficiency and sustainable behaviors.

The services offered by the Espaços Energia (EE) are divided into:

- Mandatory Services, such as:
 - Technical advice on energy equipment and solutions;
 - Support in evaluating commercial proposals;
 - Guidance on financial incentives;
 - Interpretation of energy bills;
 - Basic information on renewable energy and self-consumption.
- Optional Services, depending on local capacity, including:
 - Energy efficiency in small businesses and buildings;
 - Circular water use and sustainable mobility;
 - Community energy management;
 - Smart energy solutions;
 - Application support for funding;
 - Promotion of green jobs and support for vulnerable consumers.

To facilitate citizen access, a digital platform and website were developed, and a dedicated training programme (Academia ADENE) was launched to capacitate EE technicians, ensuring consistent and high-quality service delivery.



Figure 1 – Rede Espaço Energia's Website

The Call for Tenders 01/2025 from the Environmental Fund is crucial for the establishment and initial operation of the "Espaços Energia" (EE) network in Portugal. This notice, which is a key reform (RP-C21-r44) within Portugal's REPowerEU chapter of the Recovery and Resilience Plan (PRR), directly aims to support the creation of one-stop-shops for citizens concerning energy efficiency. Its primary contribution is to guarantee the necessary financing for the creation and initial operation of at least 50 physical "Espaços Energia", providing non-

reimbursable grants to eligible promoting entities such as municipalities, intermunicipal entities, parish councils, and other local or regional bodies, or national public/private entities in consortium. By allocating funds from the Environmental Fund, the notice ensures that these entities can swiftly and effectively operationalize their services to empower citizens in energy efficiency and renewable energies, promote energy literacy, and foster sustainable behaviors, thereby combating energy poverty and accelerating local decarbonization.

As of March 31, 2025, a total of 115 physical Espaços Energia are operational across Portugal, surpassing the original targets of the PRR. This success highlights the initiative’s scalability and adaptability, as well as its contribution to Portugal’s energy independence and decarbonisation pathway.



Figure 2 - Energy Spaces brought to life

Importantly, the EE model enhances public understanding of energy use, promotes sustainable behavioural shifts, and directly addresses energy poverty, one of the core challenges in ensuring a just transition. The initiative includes monitoring mechanisms, with performance data being reported to the National Observatory for Energy Poverty (ONPE) to support evidence-based policymaking.

In conclusion, the "Espaços Energia" initiative is a practical and scalable model for fostering behavioural change and citizen participation in the energy transition. It exemplifies how local-level action, supported by national strategy and cross-sectoral collaboration, can lead to significant progress in energy efficiency, renewable energy adoption, and social inclusion. Its success thus far marks a milestone in implementing the PNEC 2030 and REPowerEU objectives, and offers valuable insights for replication in other EU contexts.

Reframing sufficiency: The role of co-benefits and the affluent in accelerating sustainable consumption

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Keywords: Sufficiency, Co-benefits, Sustainable Consumption, Framing, Affluence

Extended abstract

Excessive consumption is a major driver of greenhouse gas emissions [1]. Particularly in high-income countries, consumption levels far exceed what is environmentally sustainable [2]. To ensure well-being for all within planetary boundaries a shift in consumption patterns is needed, especially in the global north. We need to move towards sufficiency - the idea of "living with enough". However, in consumption-oriented cultures, sufficiency remains a politically and socially sensitive topic. Consuming less is often perceived as a sacrifice, while exposure to advertisements reinforce the norm of purchasing more than necessary.

The affluent hold a pivotal key to the transition toward sufficiency-oriented lifestyles. A growing body of research shows that the wealthiest 10% of the global population are responsible for nearly half of global greenhouse gas emissions - both through consumption and investment patterns [3, 4]. Their environmental impact far exceeds their proportional share and disproportionately drives climate extremes and planetary boundary transgressions [5].

But their relevance goes beyond emissions alone. Affluent individuals also shape norms around "the good life", influence policy and investment decisions, and often occupy powerful positions as investors, organizational leaders, and role models [6]. While their emissions are disproportionately high, they also possess greater carbon capability - the capacity to act, influence others, and adopt low-carbon alternatives more swiftly than other groups [5]. Engaging affluent individuals and households in rethinking consumption, embracing sufficiency, and leveraging their influence could unlock substantial and rapid emissions reductions, and help catalyze a broader cultural and systemic shift.

One promising strategy to increase societal acceptance of sufficiency is to frame it not as a loss, but as a source of gains - for individuals, society, and nature. Co-benefits could play a key role in this by highlighting the non-environmental advantages of reduced consumption, such as individual benefits or benefits for nature or society [7]. Research suggests that especially messages emphasizing personal benefits such as more free time and more well-being can be effective in encouraging sufficiency behavior [8]. These framings may help in creating a positive sufficiency narrative.

Objective

In our study, we explore the role of co-benefits in shaping the perception and experience of sufficiency among Dutch consumers, with a particular focus on the affluent segment. By identifying which co-benefits are most frequently experienced and valued, we aim to contribute developing more effective ways to communicate sufficiency and promote sustainable behavior in practice.

Method



A representative sample (n = 1203) of the Dutch population was surveyed about co-benefits. Additional high-income participants were recruited, resulting in 267 participants in the top 10% income group. The research focused on three consumer domains; travel, food and clothing. Participants were asked about, among others, their values, current behavior, willingness to change, and perceived co-benefits in each domain.

Perceived co-benefits of climate-friendly behavior were assessed through three domain-specific items related to travel, food and drink, and clothing. Each item was introduced with a brief example of sustainable behavior relevant to the domain (e.g., taking the train, choosing plant-based products, or buying second-hand clothing). For example, the travel question read;

“If I were to choose a more climate-friendly option in travel for climate reasons, such as taking the train, electric (shared) transport, or bicycle, then... (please select up to three options).”

Participants selected up to three co-benefits from a randomized list of 14 response options:

I save money (1), I become healthier (2), It aligns with what is important to me (3), I have more time for family and friends (4), I contribute to fair labor conditions (e.g., no child labor) (5), I help create a better world for future generations (6), I reduce societal costs (e.g., from water or air pollution) (7), I feel more connected to nature (8), I am seen as a role model by others (9), I help preserve animals and plants (biodiversity) (10), I help mitigate climate change (11), I reduce the use of water, land, or raw materials (12), Other, namely [open field] (13), I experience no benefits (14).

Preliminary results

Most frequently mentioned co-benefits across all three domains were ensuring a better world for future generations (intergenerational justice), reducing the use of water, land and resources and saving money.

Focusing on the top 10% income group reveals several differences in how co-benefits are perceived. Compared to lower and middle-income groups, this group more often identified the reduction of the use of water, land, and resources as a co-benefit across all domains. They also reported "being seen as a role model" more often, particularly in the travel domain.

Conversely, the top 10% income group is less likely to perceive co-benefits related to biodiversity, especially in the travel and food & drinks domain. Compared to other income groups, the top 10% income group is less likely to perceive saving money as a co-benefit in the travel and clothing domain. In the clothing domain specifically, they mentioned the co-benefit labor conditions less frequently than other groups. In the food domain, they more often cited health as a relevant co-benefit.

First conclusions and upcoming research

Our findings confirm that co-benefits can play a crucial role in shaping how sufficiency is perceived and experienced by consumers, and thus in advancing climate-friendly behavior. However, these benefits are not perceived uniformly across income groups. The affluent - a group whose consumption patterns are disproportionately responsible for environmental degradation - perceive different co-benefits than the rest of the population. Most notably, they value the reduction of the use of water, land, and raw materials more consistently across domains, and are more likely to see themselves as role models in the travel domain. Meanwhile, co-benefits such as biodiversity protection and fair labor conditions resonate less with this group.

To accelerate the transition toward sufficiency-oriented lifestyles, it is vital to tailor communication and interventions to the specific motivations and perceived benefits of high-



income groups. Our results suggest that messages emphasizing resource efficiency, social recognition, and intergenerational responsibility may resonate more with this audience. At the same time, a broader transformation will require addressing the structural drivers of overconsumption, including the social norms and systems that currently valorize affluence.

Building on the insights from our co-benefits study, we are conducting two intervention projects aimed at translating sufficiency into concrete action among affluent consumers.

The first project, in collaboration with sustainable travel agency Better Places, focuses on reducing air travel among high-income holidaymakers. Using domain-specific co-benefits that resonate with this group—such as resource efficiency and social recognition—we are developing and testing sufficiency-framed narratives at key digital touchpoints in the customer journey (e.g., email, website). Target behaviors include opting for train travel and choosing closer holiday destinations.

The second project, commissioned by the Dutch Ministry of Infrastructure and Water Management, targets circular consumption behaviors in the domains of textiles, electronics, and furniture. In collaboration with a creative agency, we develop interventions that (1) raise awareness of the climate impact of affluent consumption patterns, (2) leverage social norms by showing that others are already acting, and (3) connect sustainable choices to existing altruistic and biospheric values.

Together, these studies aim to operationalize sufficiency for high-impact groups by framing “less” as a pathway to more meaning, coherence, and climate impact.

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Understanding The Factorial Structure of Attitudes Towards Renewable Energy Community Configurations

3b) Acceptability and ownership of energy and environmental policies, Stakeholder and public acceptability and ownership of low-carbon projects and technologies (e.g. wind energy deployment, biomass projects, geothermal energy projects, including compensation schemes, financial ownership, flexibility, demand response)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Renewable Energy Community, Exploratory Factor Analysis, Energy Consumer Preferences, Energy Transition, Energy Community Models

Extended abstract

1. INTRODUCTION

Renewable Energy Communities (RECs) have become an essential component of the European Union's strategy for accelerating the clean energy transition. While economic incentives remain important drivers, the willingness of citizens to join RECs is strongly shaped by psychological and behavioral factors. Previous research has primarily focused on general attitudes toward renewable energy, leaving a gap in understanding how individuals perceive different REC operational models. In this study, we distinguish three main REC models: (1) Peer-to-Peer (P2P) Energy Trading, where households exchange surplus energy within local boundaries, (2) Shared Renewable Energy Installations, and (3) Demand Side Response (DSR) model. These models vary in complexity and the level of user involvement, which can significantly influence participation. Our attitude measures were designed to represent key characteristics underlying these three REC configurations, though not in a direct one-to-one mapping. Instead, they capture the essential trade-offs and decision dimensions that differentiate these operational models.

This study investigates the latent dimensions underlying such preferences through exploratory factor analysis, providing a framework for designing REC models that align with diverse user expectations.



2. METHODOLOGY

Data were collected through a Computer-Assisted Web Interview (CAWI) conducted in November 2024 using quota sampling from the Ariadna online panel. The survey targeted homeowners who either owned photovoltaic (PV) systems or intended to install one within the next year, ensuring respondent relevance to REC participation.

After quality screening, which excluded 113 participants exhibiting straight-lining behavior on psychometric scales, the final sample comprised $N = 924$ respondents. The sample was characterized by a high educational profile (55.8% held a bachelor's degree or higher). Regarding residence, 40.9% lived in rural areas, while only 8.6% resided in the largest cities (450k+). Most respondents (75.5%) lived in detached houses. With respect to PV ownership, 59.4% already had PV systems, and 40.6% were planning to install one.

Attitudes were measured through eight bipolar items on a seven-point semantic differential scale (1 = strong preference for the left option, 7 = strong preference for the right option), selected from an initial pool of nine variables. Each item represented a trade-off between two contrasting REC operational variants. The dimensions were designed to capture key behavioral and structural aspects of RECs that characterize the three main REC models under investigation:

- *Decision-Making Approach* - Manual control by community members vs. Automated decisions managed by an app or algorithm;
- *Data Sharing and Digital Management* - Complete privacy and manual savings management vs. App-based savings optimization in exchange for data sharing;
- *Participation Structure and Time Commitment* - Active, individual participation with higher time investment and larger profits vs. Group participation requiring less time and accepting smaller financial gains;
- *Financial Risk and Responsibility* - Full individual investment and responsibility for infrastructure vs. Shared financial risk within a group; no ownership of installations (lower cost, no liability);
- *Profit Orientation* - Maximizing individual financial returns vs. Reinvesting profits into local social or community projects;
- *Initial Investment Level* - Higher upfront investment in photovoltaics for greater financial returns vs. Lower initial investment with reduced REC profits;
- *Organizational Structure* - Individual decision-making with personal responsibility for infrastructure vs. Group participation with shared decision-making and distributed risks;
- *Infrastructure Ownership* - REC-owned production installations ensuring energy independence (with associated costs) vs. External ownership avoiding financial responsibility but limiting autonomy.

Each of these trade-offs reflects critical organizational choices faced when designing REC models. Respondents were asked to position themselves on each continuum according to their personal preference.

An Exploratory Factor Analysis (EFA) was conducted in R using the psych package. The number of factors to extract was determined via Parallel Analysis, which supported a three-factor solution. Factors were extracted using the Minimum Residual method with an oblique oblimin rotation, reflecting the theoretical expectation of correlated dimensions. Model fit was assessed using the Tucker-Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA).

3. RESULTS

The three-factor model demonstrated excellent fit (TLI = 0.97, RMSEA = 0.045), confirming the adequacy of the solution. The factors accounted for 42%, 35%, and 23% of the variance, respectively:



- Factor 1: Delegating Control (42%) – Captures preferences for automation, such as algorithms or apps managing energy decisions, optimizing consumption, and handling financial operations versus direct personal control.
- Factor 2: Convenience & Shared Risk (35%) – Reflects a preference for collective participation models that reduce personal risk and time involvement, even when associated with smaller financial returns.
- Factor 3: Community Investment (23%) – Represents a tendency toward low initial investments, social reinvestment of profits, and avoidance of individual financial responsibility, as opposed to profit-maximizing individualism.

The factors were moderately and positively correlated ($r = 0.43-0.56$), suggesting that while conceptually distinct, these dimensions often coexist in individual preference structures.

To validate the factorial structure and examine its relationship with REC acceptance, we conducted correlation analyses between the three attitude dimensions and both overall REC acceptance (based on Theory of Planned Behavior measures) and cost perception beliefs. The three factors showed distinct correlation patterns: Factor 1 (Delegating Control) demonstrated a moderate positive correlation with overall REC acceptance ($r = 0.23$, $p < .001$) and minimal correlation with cost concerns ($r = 0.07$, $p < .05$). Factor 2 (Convenience & Shared Risk) exhibited the strongest positive relationship with overall acceptance ($r = 0.34$, $p < .001$) while showing a slight negative correlation with cost perception ($r = -0.10$, $p < .01$). Factor 3 (Community Investment) displayed the weakest correlation with overall acceptance ($r = 0.10$, $p < .01$) but the strongest positive correlation with cost concerns ($r = 0.20$, $p < .001$).

4. DISCUSSION AND CONCLUSION

This study moves beyond the simplistic dichotomy of “pro-REC vs. anti-REC” attitudes and advances acceptance understanding by revealing three distinct psychological dimensions underlying citizen preferences. The differential correlation patterns validate our multidimensional approach: Convenience & Shared Risk showed the strongest positive relationship with overall acceptance and negative correlation with cost concerns, suggesting cooperative models reducing individual burden may most effectively promote participation. Conversely, Community Investment's weak acceptance correlation but strong cost concern association reveals a barrier—those attracted to low-investment, socially-oriented models are most cost-sensitive.

These insights have direct policy implications. REC developers should offer multiple participation models aligned with different attitudinal profiles: automation-enabled options for those comfortable delegating control, cooperative structures for risk-averse convenience-seekers, and low-barrier community-benefit models for investment-limited participants. Recognizing these diverse psychological orientations enables more inclusive REC configurations that overcome participation barriers and accelerate the EU's energy transition objectives.



Energy Waste Triad: conceptual framework and literature review

Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Domestic, Energy waste, Definition, Conceptual framework, Literature review, Energy Efficiency

Extended abstract

Introduction and background:

The domestic energy sector plays a pivotal role in global energy consumption and associated carbon emissions. In the UK, households account for approximately one-third of total energy use and one-quarter of carbon emissions. Globally, the residential sector is responsible for 22% of energy use and 17% of CO₂ emissions. As the climate crisis grows more urgent, reducing domestic energy use offers a major opportunity for mitigation. To act effectively, we need to define what can be reduced.

We propose to use the term ‘energy waste’ rather than alternatives like ‘energy efficiency’ to explicitly frame the issue as the problem requiring action: to reduce whatever is defined as waste. Although the term ‘energy waste’ appears frequently in academic and policy discourse on domestic energy use, it is rarely defined or critically examined. Where it does appear, the focus tends to be narrow: either addressing inefficiencies in energy conversion processes or misalignment between designed and actual operational energy use in buildings. In this paper, we bridge this conceptual gap, by developing a more holistic understanding of energy waste.

Methodology

We developed a new framework following an iterative analytical approach, a simplified presentation of which comprised of three steps. We first pursued developing a conceptual understanding of the phenomenon based on our expert understanding of the subject and



preliminarily outlined three lenses:

- Energy chain: We started with the traditional ‘energy chain’, which captures conversion, transmission and distribution losses from ‘primary energy’ sources (fossil fuels, various forms of renewable energy from direct and indirect solar energy, nuclear and geothermal) to ‘secondary energy’ suitable for human use (electricity, refined petroleum), to ‘final energy’ delivered to homes, to ‘useful energy’ converted by end-use devices for end use.
- Service system: We then shifted focus from the energy chain to energy services, recognising that people use energy-dependant services, not energy itself. In line with existing literature, we understand energy services as functions performed using energy, directly or indirectly, that enable, facilitate or add value to human experiences, which are means to meet human demands. This lens allowed us to consider how various inputs, both energy and non-energy, can be organised to deliver a system of services effectively. For example, access to work or shops may involve not only different transport modes, but also different urban forms.
- Sociology of consumption: Finally, we turned our attention to the questions of how and why the energy is used. Given its prominence in energy research, we thought that theories of social practice can be useful to explore these questions. Practice theory suggests that energy demand and use is not an individualised behaviour, but is socio-technically structured, as it is part of, and an outcome of, social practices.

Our second methodological step was to position our emerging conceptual understanding within the broader literature. We conducted a search on 6 June 2025 using the Web of Science database with the search string: “energy waste*” AND (home* OR house* OR domestic OR dwelling* OR residential). The search yielded 311 papers. After excluding non-English publications, conference proceedings, and records that did not address energy waste in dwellings (based on titles, abstracts and full texts), 119 papers remained for in-depth analysis. Strikingly, only one of these papers offered an explicit definition of energy waste. In more than half of the papers, the term was used within ‘energy management’ discourse, with the remaining papers almost equally split between the first and second lenses. This likely reflects variation in terminology, with different aspects of the phenomenon often discussed under different terms like *energy efficiency*, *conservation*, *management* or *savings*. This represents a limitation, and future searches should include these terms to capture a broader range of perspectives.

The review revealed four key dichotomies that underpin understandings of energy waste:

- Supply-side vs demand-side perspectives
- Top-down vs bottom-up approaches
- Linear vs systems thinking
- Technical vs social dimensions

Time has also emerged as an important dimension against which energy waste should be considered. Finally, we used these insights to revise our initial framework and stabilise emerging concepts.

Results

The revised framework – Energy Waste Triad – comprises three interrelated components (Figure 1 and Table 1): (1) energy conversion chain, (2) service system, (3) sufficiency,



which should be considered along the full lifecycle of the building (Table 2).

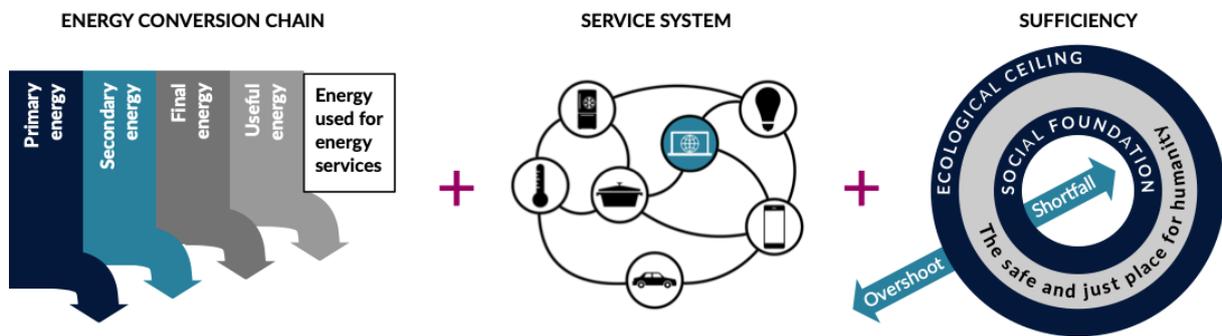


Figure 1. Energy Waste Triad.

Table 1. Energy Waste Triad: core characteristics.

Characteristics	Energy Waste Triad		
	Energy conversion chain	Service system	Sufficiency
Focus	Technical system managing resources	Socio-technical systems System scales: - <i>Micro</i> : materials and technologies - <i>Meso</i> : building - <i>Macro</i> : neighbourhood or city	Problematism of energy need; sociology of consumption
Energy waste cause	Technical inefficiencies.	Inefficient system design and utilisation	Excessive system design and use

Table 2. Energy Waste Triad: opportunities to reduce energy waste across building lifecycle stages.

Building lifecycle stages	Energy Waste Triad		
	Energy conversion chain	Service system	Sufficiency
Materials extraction and manufacturing	Reduce embodied energy in materials and technologies	Use local sources materials	Shift focus from meeting demand to living within means
Design	Specify high-efficiency end-use technologies	Design for service efficiency with minimal resource input Consider waste heat recovery in system design	Assess how new technologies create additional demand
Construction	Use local, low-embodied-energy materials and systems	Use offsite and modular construction to cut energy use	Challenge material wasteful, fast construction practices
Operation and use	Ensure operation of energy systems to their specifications	Reduce energy intensity per service delivered	Enable reflective engagement via energy monitoring and feedback
Maintenance and renovation	Use durable materials to reduce renovation frequency	Utilise modular construction to reduce the need for full replacements	Challenge frequency of renovation cycle Challenge using renovation to expand property size
Demolition	Reuse and recycle materials	Develop neighbourhood systems to support reuse	Evaluate and improve sharing economy practices
<i>Transport</i>	<i>Consider energy use for transport throughout building lifecycle</i>		

Concluding thoughts and future steps

Energy waste remains a difficult phenomenon to address, partly because energy itself is invisible. Unlike material waste, it lacks physical presence and is harder to quantify in meaningful social terms. The Energy Waste Triad offers a conceptual tool to articulate, structure, and communicate the many dimensions of energy waste.

This paper is part of the Energy Demand Observatory and Laboratory (EDOL) project. EDOL offers a valuable chance to test the Energy Waste Triad in practice. It gathers data from over 2,000 households. The data includes detailed gas and electricity consumption, internal temperature, humidity and survey answers on energy use, comfort and appliance ownership. Though the dataset does not capture all energy uses or all household members' behaviours, it allows initial testing of the three energy waste lenses. This work will guide future improvements to the framework. It will also reveal gaps in existing data collection efforts for the EDOL project.

Acknowledgements

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Assessing Sustainability and Behavioural Trends in the Maltese 4- and 5star Hospitality Sector

Theme 1, sub-topic 1b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sustainability, Resource efficiency, Hospitality, Technical Survey, Guest Survey

Extended abstract

1. INTRODUCTION

The hospitality sector, increasingly aware of environmental concerns, is focusing on improving resource efficiency so as to reduce its environmental impact. In Malta, where tourism is a vital economic pillar, the hospitality sector significantly influences the local environment. Although resource-efficient practices are known, their actual implementation and effectiveness remain uncertain. To address this gap, this research investigates sustainability practices and behavioural trends in 4- and 5-star hotels, using specifically tailored questionnaires to explore the perspectives of both hotel management and guests on sustainability.

1. OVERVIEW OF THE MALTESE 4 AND 5-STAR HOTEL INDUSTRY

A look at the most recent statistics of the Maltese hospitality sector [1], specifically the 4- and 5-star hotel sector, as presented in Figure 1, shows the results of a thriving 2.5bn€ industry.

2. METHODOLOGY

Over recent years, research on energy use in the local hospitality sector has grown, with studies such as Magro and Borg’s [2] analysis of CHP systems in hotels, Gonzalez and Yousif’s [3] case study on a sustainable hotel in Gozo, and the Interreg DETOCS project [4] focusing on tourism decarbonisation. However, there remains a significant gap in local



research addressing behavioural patterns in hotel management and guest practices. To address this, the current study prioritised the collection of primary data through questionnaires. As a result, a detailed field study using two custom-designed questionnaires was implemented:

- i. A technical questionnaire aimed at hotels’ top management, consisting of 35 mostly closed-ended questions, incorporating a mix of general ‘Yes’/‘No’ questions and Likert scale questions sub-structured in 3 distinct sections, namely, (a) Energy and Water Practices, (b) Perception and Behaviour, and (c) Energy Audits and Funding Schemes; and
- ii. A guest-focused questionnaire comprising 9 Likert scale structured questions aimed at gathering insights into hotel guests’ awareness of sustainable practices within the hotels they were staying in. The questionnaire explored guests’ views on hotel sustainability efforts and the influence social media marketing and green certifications had on their booking decisions.

The management questionnaire was conducted through phone recruitment and, in some cases, follow-up meetings, while the guest questionnaire was distributed in paper or online form during the check-out process.



Figure 1. Infographic: 4 and 5-star hotel sector performance over 2019-2023 period (Author AI Generated)

3. RESULTS AND FINDINGS

What follows are the main findings of the study carried out.

1.1. Management Technical Survey Results

1.1.1. Overview of Results and ECO Certification

Fifteen 4- and 5-star hotels accepted to participate in the study, 8 of which are ECO certified. Eco-certification for hotels is a process whereby a third-party agency verifies that a hotel meets specific sustainability criteria, demonstrating its commitment to environmental and social responsibility. In Malta, there are currently three sustainability certifications which are endorsed by the local licensing authority, the Malta Tourism Authority, namely, the EU

Ecolabel, Green Key, and Global Sustainable Tourism Council (GSTC) [5], with a total of 17 4- and 5-star ECO certified hotels. Despite lacking any certification, those hotels without an ECO credential still demonstrated a strong commitment towards resource efficiency, including measuring energy consumption by use and having implemented some form of energy and, or water efficiency measures, program or technical system (e.g. use of energy-efficiency lighting, water conserving fixtures, etc.). Amongst those hotels which had an ECO certification, four showed an environmental commitment over and above what is required from being certified.

1.1.2. Behavioural Trends

Apart from gauging what resulted as being a robust commitment towards environmental sustainability, which was clear from the responses received, the questionnaire also delved into management perspective on the importance of various sustainable practices as shown in Figure 2.

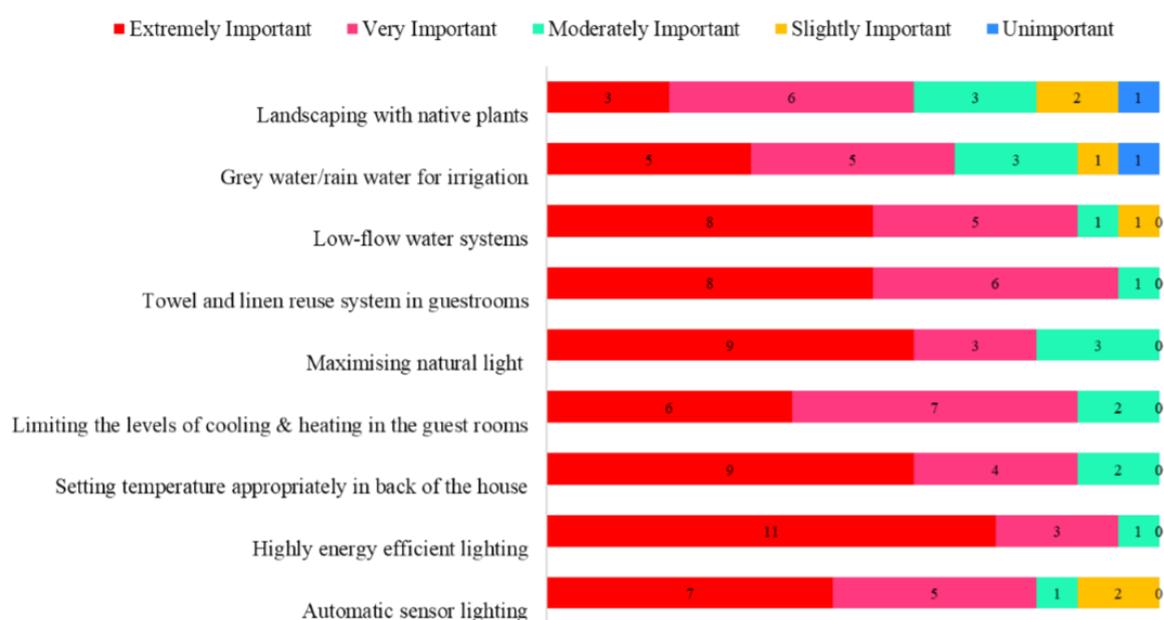


Figure 2: Managements’ perspective on the importance of a number of common sustainable practices

Hotel management commonly prioritised sustainable practices like ‘*maximising natural light*’ and ‘*using energy-efficient lighting*’. Less emphasis was placed on landscaping with native plants and limiting room temperature controls, often due to spatial constraints and concerns about guest comfort. Most hotels (80%) had conducted energy audits, leading to major sustainability improvements such as upgrading heating systems to heat pumps, adjusting chiller and boiler settings, adopting LED lighting, and integrating renewable energy and room management systems. Only 50% of hotels had applied for energy or water improvement funding, citing complex application processes and concerns about eligibility for larger organisations as barriers.

1.2. Guests’ Survey Results

1.2.1. Overview of Results on Sustainable Practices

From the 15 participating hotels, only two distributed surveys with their guests, collecting 44 responses. The majority of respondents were between 60 and 70 years old, with most visiting



for leisure purposes and many choosing to stay for a week or longer. A significant majority of surveyed guests, 88.6%, identified themselves as environmentally conscious consumers. Surveyed on their views on the most impactful sustainable practices in hotels, there was a clear consensus that lighting-related initiatives were the most effective, as illustrated in Figure 3. In particular, respondents rated practices such as utilizing natural daylight, implementing energyefficient lighting, and installing automatic lighting sensing as highly effective in enhancing sustainability within hotel environments, likely because these are clearly visible technical aspects which are easily understandable by the majority of guests.

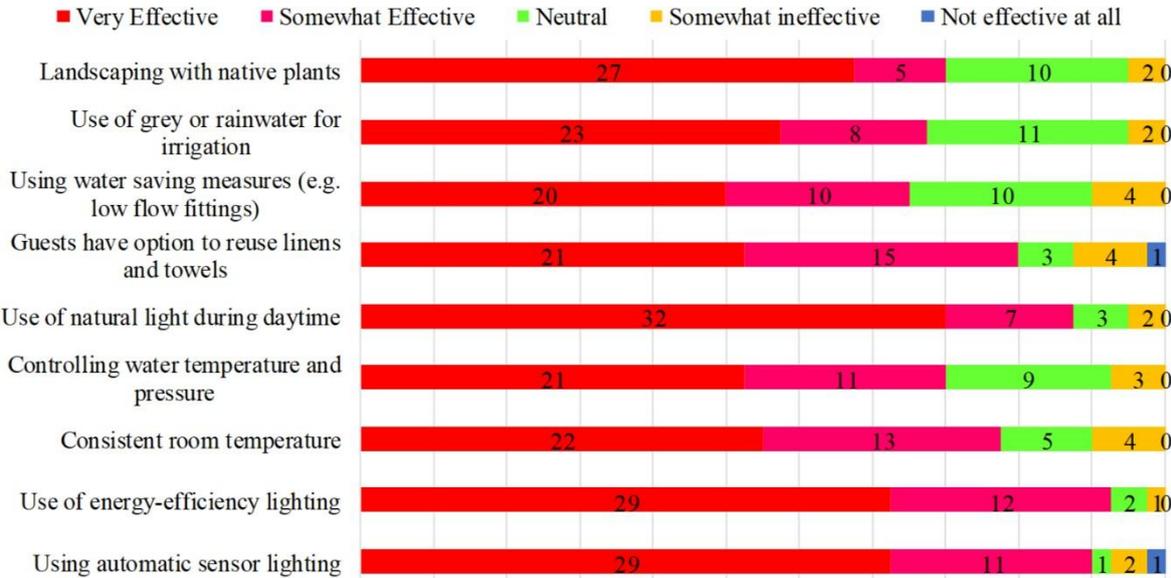


Figure 3: Guests’ perspective on the most impactful sustainable practices within hotels in general

1.2.2. Guests’ Behavioural Trends

Within the same guests’ survey, guests were asked about their behavioural aptitude towards their hotel’s sustainability efforts and the impact of social media on their choices. Below are the main take-away from the results obtained:

- Overall, guests were highly satisfied with their hotel's environmental endeavours, and most guests agreed that their hotel's sustainable practices had a positive effect on their comfort; and
- While many guests were satisfied with their hotel's social media marketing of its green credentials, fewer felt the hotel effectively communicated details about these efforts.
- A positive correlation, with a p-value of 0.048 based on a Spearman’s correlation test was observed between the hotel's green marketing on social media and guests' preference for sustainable hotels, highlighting the influence of effective green marketing on guest behaviour and choices.

1.3. Comparing Management and Guests’ Perspective on Sustainability Practices

Comparing the results for the first two positive Likert scale responses for both management (i.e. extremely important, very important) and guests’ (i.e. very effective, somewhat effective) perspective on sustainability practices used within hotels, yields some interesting results with some alignment and some disagreement. As shown in Figure 4, both groups see lighting efficiency as important, however respondent groups then differ on the importance given to various water-saving measures. Possible reasons for this, include misunderstanding water use

impact on resource-efficiency locally and guests prioritizing comfort (e.g. wanting fresh linens and towels daily).

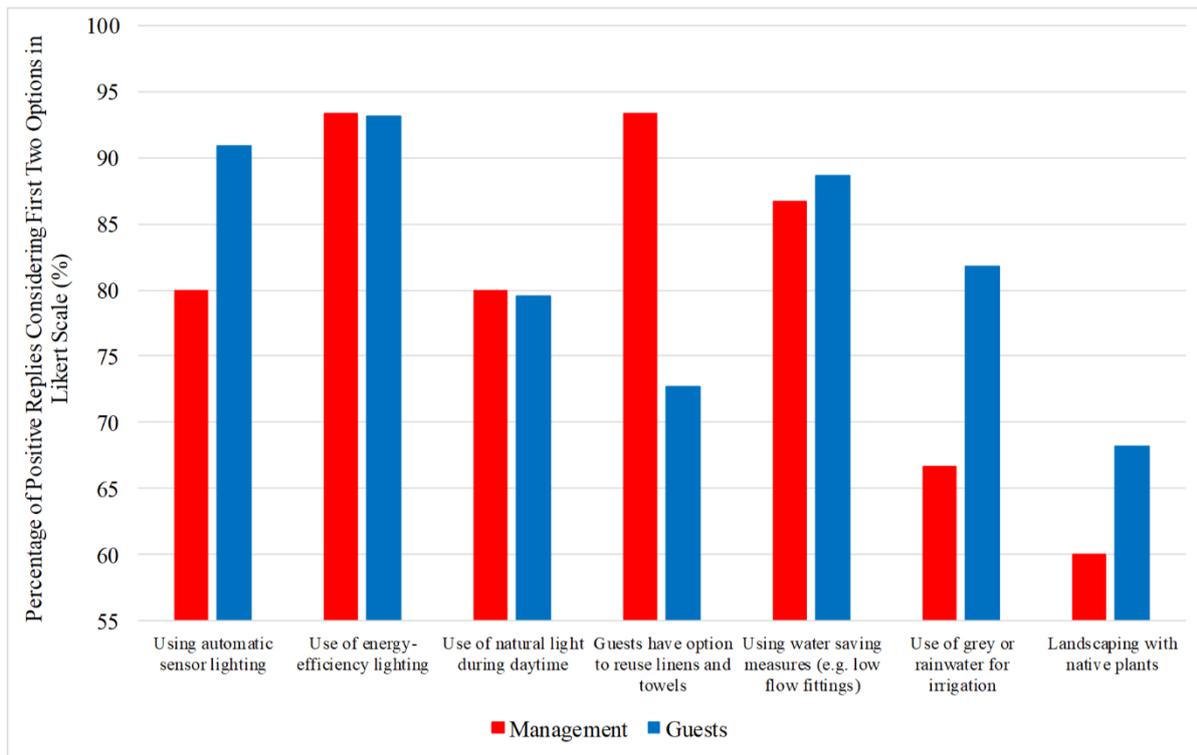


Figure 4: Comparison management and guests’ perspective on sustainable practices

4. CONCLUSIONS

The hospitality industry in the Maltese Islands is increasingly adopting sustainable practices, though balancing environmental conservation with guest satisfaction remains challenging. This study, based on surveys from local 4- and 5-star hotels targeting both hotel management and guests, reveals that both ECO certified and non-certified hotels are actively pursuing energy efficiency and sustainability initiatives. Nonetheless, hotel management widely acknowledges the importance of sustainability, supported by internal practices and embracing sustainable behaviour. Guest feedback highlights a strong link between environmental awareness and hotel choice, with lighting initiatives notably enhancing satisfaction and social media praise.

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Main lessons from energy performance contracting projects

Theme 4, sub-topic 4a

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy Performance Contracting, Energy Service Companies, Product-Service Systems

Extended abstract

1. INTRODUCTION

In their last Directive on energy efficiency, the European Parliament and the Council recommend promoting energy performance contracting for renovation of both private and public buildings. “*Energy performance contracting means a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where the works, supply or service in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or another agreed energy performance criterion, such as financial savings*” [1].

For public authorities who intend to renovate and improve the energy performance of their building stock, EPC projects bring at least two advantages compared with traditional renovation projects / energy service contracts: 1/ The energy service provider guarantees cost savings achieved through the optimisation of building automation installations and investment in energy systems and/or insulation solutions. 2/ The totality or part of the investment is recovered by energy savings.

EPC can also be considered as a new form of product-service systems (PSS). Indeed, PSS can be associated to “product-oriented services”, “user-oriented services” or “result-oriented services” [2]. The business model proposed by ESCOs (Energy Service Companies) is based on guaranteed energy savings, financing and a remuneration linked to the energy savings achieved [3].

In France, even if the ESCO market is very dynamic, most energy service contracts are not performance based [4].

Ademe, the French ecological transition agency, supported in 2016, the creation of the French National Observatory for EPC (ONCPE). The aim was to analyse the evolution of the market for EPC, to offer feedback and to promote the development of a culture of energy performance and the dissemination of this contractual tool to market players. Most projects identified in the data base concern heavy refurbishment projects integrating works on energy systems and building envelop [5]. For these projects, the level of investment is usually high and financed by public authorities. The payback period is longer than the contract. The energy service provider is frequently a consortium gathering a contractor (in charge of the works), an operator and a design office.



For the last two years, the aim of ONCPE was to focus on qualitative analysis and to propose case studies. The aim of the paper will be to present the main lessons drawn from seven in-depth case studies which are detailed on ONCPE website.

2. EPC: RESULTS OF SEVEN IN-DEPTH CASE STUDIES

2.1. Methodology

Data collection is based on interviews with executives in charge of managing and administering the contract for the public authorities and the private operators. The interviews focused on the organisation of the market procurement, the organisation of the consortium and the client, the implementation and operation of the EPC and the results. The aim was also to identify the lessons learned from the projects. Interviews were carried out in 2023 and 2024. All projects were at least launched four years before to get sufficient feedback from the operational stage (each energy service provider is in charge of both the maintenance and the operation).

2.2. Main characteristics of EPC

Table 1: The seven EPC in a snapshot

Public authorities	Buildings	Year and length of procurement	Length of the EPC	Energy efficiency actions	Works (in Euros)	Energy saving
Social housing Company	383 dwellings	2017 - 7 months	10 years	Works on building envelops & equipment, energy awareness	11 millions	37%
Departmental Council	53 buildings	2014 - 2 months	28 months	Monitoring, optimisation of existing equipment, energy awareness	361 000	19%
Departmental Council	5 secondary schools	2017 - 10 months	10 years	Works on building envelops & equipment, energy awareness	28 millions	Around 40%
Health authority	1 hospital and 1 retirement home	2020 - 12 months	10 years	Works on equipment, energy awareness	340 000	16%
Regional Council	15 high schools	2008 - 12 months	20 years (private financing)	Works on building envelops & equipment, energy awareness	41,8 millions	Between 29 and 39%
Social housing company	952 dwellings	2015 - 19 months	10 years	Works on building envelops & equipment, energy awareness	12,8 millions	58% (and 75% of renewable energy)
Retirement establishment (Private)	64 retirement homes	2016 - 6 months	8 years	Works on equipment, energy awareness	-	32%

3. LESSONS LEARNED

Each project cannot be comparable since they concern different types of buildings and users. Investment costs and energy saving solutions also vary extremely from one project to the other. However, some general trends can emerge from these individual case studies:

The length of the procurement period is longer than for basic energy service contracts. The complexity of the projects, data collection, the modelling attached to the measurement &

verification plans, the establishment of an accurate energy-use baseline, the procurement approach (a competitive dialogue was used in six of the seven projects) contribute to lengthen this period.

Energy savings obtained are always above the contractual target.

Results are better when the operator is associated to the works and is involved before the beginning of its contract.

Four of the seven projects required large investments (new windows and insulation of the walls and the roof). In such situation, there is no possibility to compensate the costs by the energy savings. However, public authorities consider these investments are unavoidable to keep the value of their assets.

All operators consider that users play an important role in the performance reached. Consequently, a specific budget dedicated to communication and energy awareness actions is provided.

Consultants assisting public authorities play a key role in the success of these projects. Most public authorities never experienced EPC. Consultants help them to lead the competitive dialogue, to challenge the candidates, to identify the risks associated to these contracts and to handle the M&V plans.

When projects concern several buildings, specific incentives are introduced to avoid the negligence of the operator and a focus on the “easiest” buildings.

The main risks concern the loss of information between the procurement procedure and the operational stage. When the public project team involved in the set-up of the contract is not involved during the operation, this led to a loss of knowledge. The extension of the contract of the consultants involved during the procurement procedure is a way for public authorities to reduce this risk which is also quite frequent because most EPC are long term contracts. Similarly, private operators frequently faced high internal turnover among technicians in charge of maintenance and operation. Even if the information is available in the centralised control station, there is a need to know about building characteristics, equipment in use and occupants’ behaviour. Thus, private operators may also face a loss of corporate knowledge and expertise.

4. CONCLUSION

The paper investigates the performance of EPC through the analysis of seven projects. The results show that EPC is successful in achieving energy performance. It can be considered as a new form of business model where the remuneration of the energy service provider is based on demonstrated performance and the level of energy savings. It encourages reduced consumption since in these contracts, the operator is also selling a level of temperature instead of a volume of energy.

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Why Accept Limits? Exploring Perceptions of What is Just and What is Enough through French Households' Modes of Consumption

Theme 5, sub-topic 5a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: sufficiency, household, consumption, limits

Extended abstract

1. General context

Stated as a public problem [1], [2] in the French public space, sufficiency encounters other competing notions such as “progress” or “innovation” and some framed as solutions like “innovation” or “efficiency”. And different definitions of sufficiency coexisting [3], it leaves some space for interpretation.

On the one hand, understood as living within ecological limits while ensuring a decent life for all [1], sufficiency has gained general attraction as a necessary complement – or competitor – to efficiency and technological innovation [6], [7]. One result is the recognition that the ecological and energy transitions required to meet climate targets and ensure planetary sustainability are not merely technical challenges, but also fundamentally social and political [2].

On the other hand, sufficiency somehow implies a different approach to the business-as-usual economic development, especially suggesting limits to consumption [8] and probable major changes in modes of consumption [9].

2. Scope and objective

Discussing limits, notably the existence of maximums that do not threaten others' good life can be problematic in liberal societies [10], [11]. Limits can be politically sensitive [12] and contested [13], especially when they are not publicly supported through collective policies and validated by the perception that everyone contributes equally [14], [15], [16]. Limits and the idea of justice – or at least of equally shared burden – thus share a common line of thought.

Public resistance to sufficiency policies often stems not from ignorance or denial, but from perceived unfairness in how these policies are designed and implemented [17]. How households perceive the fairness of sufficiency-oriented policies and how benefits are distributed [17], [18] shape their willingness to share the burden of transitions and their degree of public support i.e. the legitimacy of national policies designed to steer individual



and structural change [19].

Besides, as modes of consumption are socially, politically and economically situated [20] – even when paying attention to environmental issues [21], [22] – sufficiency cannot be tackled as a one-size-fits-all policies. If considered seriously, sufficiency must take into account socio-spatial variables and already existing and situated modes of consumption [23].

The main hypothesis of this paper is that the households' perception of sufficiency as a means for transitions first depends on the materiality of their modes of consumption; second, on their political perception of the society. The social acceptability and framing of upper or lower limits depend closely on the households' means of living and consuming as well as how they think politically.

This hypothesis makes it possible to articulate sociological as well as political science approaches; and to go beyond the simplistic opposition between imposed and chosen sufficiency. It also enables the understanding of some now well-established cases e.g. low-income households often practicing sufficiency out of necessity, yet feeling stigmatized by policies that frame sufficiency as a moral choice rather than a structural constraint. Or high-income households defending decarbonised way of life as a moral individual choice, yet having practises that are harmful to the environment.

3. Research Objectives

One research question drives this research: how modes of consumption and political perceptions interact with each other to influence the perception of sufficiency?

Following previous work [23], we address four dimensions of the quality and quantity of material life (quantity and intensity of use of home equipment; mobility; food; and other consumption and waste management). Those dimensions account for about three-quarters of a household's carbon footprint [24] and include habits subjected to strong citizenship injunctions [25].

Four modes of consumption are thus identified in mainland France in 2024. They are then confronted to other variables such as socio-demographic, political, attitudinal, and support for sufficiency policies. The methodology and the data available allow for some quantification of the relationship between modes of consumption, perceived justice and willingness to share the burden of transitions. Some national policy tools (e.g. consumption caps, sufficiency incentives...) are estimated in terms of fairness, legitimacy but also possibility and capacity by households. In the end, the paper aims at developing a typology of justice-sensitive sufficiency adopters.

4. Methodological framework

To answer this question, a survey was conducted in 2024 gathering 7.028 individuals in mainland France. It was administered online, using the quota method. The sample is representative of the population of France aged 18 years old and over, allowing for statistical inference. The design of the questionnaire drew on previous questionnaires established either in academic and public research for conducting similar enquiries into consumption, lifestyles and environmental issues.

Statistical analysis by geometric data analysis (GDA) and ascending hierarchical clustering



[Back to table of contents](#)

(AHC) [26], [27] carried out on the data allowed the construction of the four different modes of consumption in France. Each is characterized by different types of energy-consuming practices and degrees of sufficiency or profligacy. The results concerning those modes of consumption are already published [23]. This paper aims at going one step further by understanding the articulation between those modes of consumption and the perception of what is enough and what is just, thus measuring the feasibility of some public policies discussed at different degrees in the French public space. Modelling is mainly used here.

5. Main results

Households belonging to different modes of consumption make different judgments about sufficiency and the limits to be set. Likewise, their relationship to politics and public policies is not identical and ranges from effectiveness to justice, individual to collective actions, obligation to incentive... The question of who should do what and to what extent is therefore not shared by everyone. In the end, our main hypothesis is verified: modes of consumption are structural variables of the perception of sufficiency. But within, this perception is also modulated by more political variables.

The analysis suggests that material abundance does not correlate with a sense of “enoughness”. Indeed, high-income households with the most important practices in terms of quantity and quality are less likely to accept limits whatever their design. On the other hand, households with fewer possessions are more likely to support the idea of limits. Generally, there seems to be a deep reluctance to accept strict binding consumption caps.

This paper is useful in the perspective of a democratic discussion on the limits to consumption [28] by showing the diverse starting points of the different groups that form French society. For some, setting boundaries is more difficult to accept. More generally, this paper also enables to empirically decline (and de-generalize) the notion of planetary boundaries framework [5] contrary to theoretical [29] or normative [30] approaches.

6. Conclusions and recommendations

If taken seriously, sufficiency must explicitly address energy justice. And for sufficiency policies to be effective, materials as well as political variables must be tackled. The research also suggests that sufficiency can reinforce social inequalities if not carefully framed, hence the importance to address injustices. In this context, institutions and perceived reciprocity are key to sufficiency acceptance; and sufficiency is more acceptable when framed as equitable. Making decision-making spaces and policy design or processes more inclusive, and accounting for differentiated responsibilities must be emphasized.

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Public Participation in Municipal Energy Transition: the Case of Lac-Mégantic’s reconstruction

Theme 2 & 3, sub-topic 2c & 3a

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy Transition, Inclusive transition, Instruments, Governance, Municipal, Decarbonization

Extended abstract

Introduction

The town of Lac-Mégantic in Quebec, Canada, is known for having been the site of a major rail disaster about a decade ago, caused by a runaway train carrying 7.7 million liters of crude oil that derailed in the downtown area, resulting in the deaths of 47 people¹. The reconstruction was carried out with a focus on adopting renewable energy sources to move away from carbon-based energy, which was at the root of the tragedy. Lac-Mégantic became home to Hydro-Québec’s² first and only all-electric microgrid allowing for the local production and consumption of solar energy. Moreover, the municipal apparatus has been adapted, and citizens involved in transforming their town into a living laboratory for municipal energy transition. This small, rural, remote municipality struggling against demographic decline, has risen again thanks to remarkable citizen mobilization centered on inclusive energy transition. Continuing the citizen consultations initiated during the reconstruction, the town established a citizen committee, InnovCITÉ (Innovation Committee for Ecological Transition). As a discussion and reflection group, a center for ideation and innovation, and a training ground for citizen ambassadors, the committee co-constructs a new governance model for the transition with multiple stakeholders. In this regard, it serves as a model and has become a subject of research.

For four years, benefiting from significant resources provided by the federal Smart Renewables and Electrification Pathways Program (SREPs, CAN \$2.5 million), with Hydro-Québec as the main partner, the town and the committee have led numerous initiatives promoting inclusive energy transition. More than thirty initiatives have been identified, including the development of community housing equipped with technologies that support energy flexibility, partnerships with indigenous communities, the organization of an energy transition week for citizens, local businesses, and regional municipalities, the creation of a citizen service portal, and more. Notably, Lac-Mégantic was among the first municipalities to engage in wind energy projects, which enjoy strong social acceptance. These projects generate royalties for the municipality,

¹ [Lac-Mégantic marks 10-year anniversary of rail disaster that killed 47 people - The Globe and Mail.](#)

² Hydro-Québec is the state-owned corporation responsible for electricity generation, transmission, and distribution in Quebec.



which are reinvested in the energy transition through grants for renovation or electric mobility projects. As part of a participatory research project, researchers from Hydro-Québec’s research center were able to attend the committee’s monthly meetings, participate in various activities, and conduct semi-structured interviews with its members. These different methods allow us to characterize an ongoing energy transition and draw useful lessons from it. In this presentation, we will briefly describe Lac-Mégantic and its history, as well as the events that led to the reconstruction of its downtown with a focus on energy transition. We will show how engaged citizens were placed at the heart of this transition, list their various initiatives—some more innovative than others—and analyze their impacts. Through an analysis of the energy transition as a municipal public policy, we will highlight two key issues: governance challenges as perceived by municipal officials, and more specifically, resource-related challenges.

Citizen Participation

Building on its long-standing experience in this area, the municipality established a new citizen committee, chaired—as required by law—by elected officials, composed of co-opted citizens, and supported by municipal employees. According to Arnstein’s ladder of citizen participation¹, citizen involvement in Lac-Mégantic is particularly active and significant. Committee members are engaged at multiple levels, from deliberation to active participation in initiatives. The committee has a discretionary budget, and some initiatives are carried out under its control after approval by the municipal council, such as the provision of municipal grants. It is also continuously informed and consulted regarding energy transition initiatives.

Numerous, Innovative and Inclusive Initiatives

Over thirty initiatives have been launched in the past four years, varying in scale and targeting different categories: youth, seniors, low-income households, entrepreneurs, local merchants, etc. These include among others the drafting of a transition plan, organizing an energy transition week to engage citizens, setting up a citizen help desk to guide residents toward available grants, expanding communication tools (e.g., videos made by high school students, online games), electrifying transportation and equipment, and developing energy-efficient or electricity-generating infrastructure (such as the fire station and housing units). There are also economic development projects centered on the energy transition. Some of the more innovative initiatives deserve special attention, such as using revenue from a wind farm to subsidize citizen purchases that support the energy transition (e.g., electrification of equipment, heat pumps). The origin of the distributed funds is consistently highlighted to make the wind farm’s contribution tangible and to strengthen its social acceptance. The fact that the subsidies are financed without additional tax pressure also contributes to its acceptability.

Governance Challenges

Such a transition cannot occur without an appropriate organizational structure. The municipality experimented with several governance models, with mixed satisfaction. However, the core bodies of the transition—municipal council, civil servants, the committee, and Hydro-Québec—have remained stable; it is rather their coordination that has fluctuated. Two key factors partly explain these fluctuations: the challenge of aligning ecological and energy transitions, and the availability of resources. We observed imbalances and tensions between the energy and ecological transitions. These were amplified by Hydro-Québec’s very active



involvement and the influx of resources for the energy transition, while some citizens are more motivated by values associated with ecological transition.

Resource Challenges

The issue of resources is unavoidable when analyzing public policy. Here, we use a framework proposed by Knoepfel *et al.*². With the help of this heuristic tool, we can illustrate how the monetary resources provided by the SREPs program were gradually transformed into human resources (with the handicap of recruitment challenges and the benefit of return trajectories) and organization, how citizens contributed as supplementary human resources—particularly by bringing their experiences and skills—and how the deadlines imposed by funding programs and their short-term objectives posed challenges, while the energy transition itself unfolds over the long term. In fact, resource challenges—which are typically about resource scarcity—have, for the municipality of Lac-Mégantic, become challenges of resource management, resource transformation, and now resource sustainability.

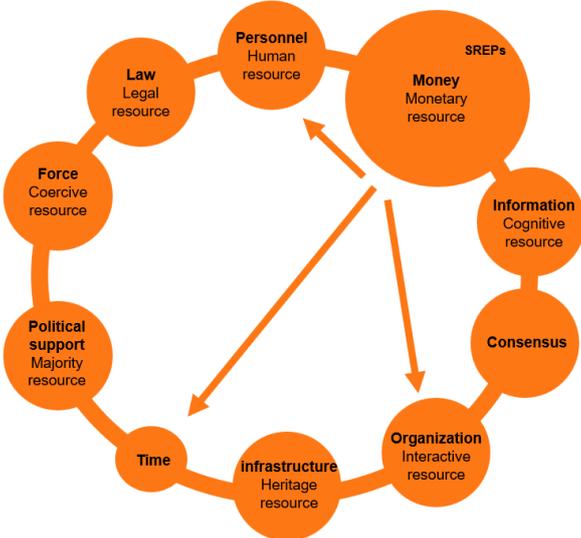


Figure 1: public policy resources framework

Conclusions

The town of Lac-Mégantic firmly positions itself as a model for municipal energy transition in Québec and elsewhere. Regarding the strong public participation, it could also claim to be a model for public involvement. This reality should be especially relevant for communities undergoing reconstruction, particularly following disasters³, cases that may become more frequent due to the effects of climate change, think about the recent fires in Los Angeles or Jasper.

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When Words Save Watts: Government Communication and Household Electricity Use

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Theme 1, sub-topic 1b)

“Academic contribution”

Keywords: Behaviour, Energy Conservation, Electricity, Residential

1. Overview

The European energy crisis of 2022–2023 marked a pivotal moment, with ripple effects that extended across markets, industries, and households. Triggered by a confluence of geopolitical disruptions, including the significant curtailment of natural gas imports from Russia following its invasion of Ukraine, the crisis exposed heavy reliance on natural gas and thus highlighted the pressing need for security of energy supply. In response to this multifaceted crisis, characterized by surging energy prices and inflationary pressures, European governments implemented a range of measures aimed at mitigating the impact on both economies and consumers. France, in particular, adopted an energy conservation program through its *Plan de Sobriété et Énergétique*, which aimed to incentive reduction in energy demand. The program had two main strands: a national call for a 10% reduction in energy consumption and, more specifically for households, a media campaign entitled *Pour la planète, chaque geste compte*, translated as *For the planet, every gesture counts*. The aim of the campaign was to encourage energy saving through energy saving tips, the main one being to lower the temperature of heating appliances to 19°C. Moreover, political largely tried to incentive energy saving through their personal behavior. For example on the morning of Tuesday 27 September 2022, the Minister for the Economy and Finance explained on national radio that he planned to wear turtlenecks in his ministry: a question of sobriety in an era of energy restrictions.³ Beyond the program itself, the French government deployed a large narrative around the energy crisis and the need for energy savings (see for example the interview of the Prime Minister on the 5 december 2022 at the French Television⁴)

During this 2022-2023 winter, gas and electricity consumption, adjusted for weather variations, fell by 12.2% between 1 August 2022 and 31 July 2023, compared to the 2018-2019 reference year. More specifically, electricity consumption in households decreased by 11% between 2019-2021 and 2022-2023. The aim of this paper is twofold: firstly, to decompose the decrease in residential electricity consumption in France during the winter of 2022-2023, and secondly, to assess the potential influence of energy-saving incentives from political statements, whether based on the narrative of energy saving tips or energy crisis.

While theory suggests that energy conservation incentives may be effective, the empirical evidence seems to indicate important differences in effectiveness. Indeed, several meta-analysis tried to show and explain these differences in effectiveness [1, 2, 3, 4]. Based on these meta-analyses, four broad categories emerge: monetary incentives, goal-setting,

³ Bruno Le Maire vante son col roulé, question de sobriété

⁴ Interview de M. Gabriel Attal, ministre chargé des comptes publics, à BFMTV le 5 décembre 2022, sur la crise énergétique, l'inflation, le Covid, la lutte contre les fraudes et les cyberattaques.



feedback, and information strategies. Despite the growing interest in the 2022-2023 energy crisis and its macroeconomic consequences, as well as its impact on consumer behaviour, limited research has empirically analysed the direct effects of energy conservation policies on household energy consumption during this period. The European literature on energy demand management during the crisis focuses largely on the macroeconomic effects of energy price volatility and the behavioral shifts in energy consumption, yet there remains a gap in understanding how policy measures, such as informational strategies and goal setting incentives, directly influence residential consumption patterns. Previous studies, such as those by [5] and [6], examine consumer behavior but do not fully integrate the role of policy interventions in driving conservation. This paper aims to bridge this gap by assessing the effects of the French government's energy conservation incentives, with a focus on the impacts of price signals and political statements on residential electricity consumption.

2. Methodology

Drawing on the framework of [7] and [8], adapted to the French electricity retail market, the study employs an Autoregressive Distributed Lag (ARDL) model. It is well-suited to capture both the short-term and long-term dynamics of the relationship between energy consumption and explanatory variables such as price changes and political statements. The model is applied to a dataset covering the period from 2019 to 2023, with a particular focus on retail electricity prices, political speeches about energy conservation, and broader discussions surrounding the energy crisis. By utilizing this empirical approach, the paper aims to quantify the effects of price and political shock variables on energy consumption patterns in the residential sector.

The methodological contribution is twofold: first, it relies on a semi-supervised classification of over 12,000 political speeches using XGBoost to identify those related to energy conservation efforts. Second, this vector is integrated into the ARDL model to refine the decomposition of consumption reduction.

3. Key findings

This paper offers new insights into the drivers of reduced residential electricity consumption in France during the 2022-2023 energy crisis. By decomposing the 11 TWh reduction observed in household electricity use, the analysis quantifies the relative contributions of price increases, political communication, and weather conditions. The results show that price signals accounted for the largest share of the reduction (6 TWh), while unusually mild temperatures explained 2.4 TWh. Importantly, political statements related to the energy crisis—those emphasizing scarcity and potential risks—contributed an additional 2 TWh reduction. In contrast, political statements focused solely on energy-saving tips or general conservation messages had no measurable impact on consumption.

Moreover, a counterfactual analysis reveals that, even in the absence of the tariff shield, electricity consumption would have been higher without the conservation efforts driven by political signals deployed during the crisis. In other words, non-monetary incentives played a critical role in driving demand reduction at a time when price signals alone were not yet sufficient to influence consumption, especially in late 2022. This finding underscores the effectiveness of political communication in generating immediate behavioral responses, particularly before the full impact of price adjustments materializes. However, generic conservation messages, when not anchored in a context of urgency or crisis, appear insufficient to change behavior at scale.



This analysis also reveals important heterogeneity in responsiveness across household tariff profiles. Only households on off-peak tariffs reacted significantly to both price changes and crisis communications. In contrast, households with base tariff profiles showed limited flexibility and no significant reduction in consumption. This suggests that structural factors, such as tariff types and consumption patterns, shape households' ability to respond to external shocks. From a policy perspective, these results highlight the importance of sustained and well-targeted communication strategies during energy crises. One-off announcements are unlikely to deliver lasting impacts; instead, repeated messaging around the urgency of the situation is necessary to maintain reduced consumption over time. Moreover, price signals remain a powerful tool but require reinforcement to sustain their effects. Finally, the limited impact of general energy conservation messages suggests a need to rethink how these campaigns are designed and communicated, especially outside of crisis periods. Overall, the findings call for differentiated policy approaches that account for household profiles and structural constraints, ensuring that demand-side measures are both effective and equitable in times of crisis.

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Toward eco-sufficiency: merging distributive justice and ecological boundaries

Theme 5, sub-topic 1d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Sufficiency, Social choice theory

Extended abstract

1. Context and motivation

The concept of sufficiency emerged within ecological thought in the 1990s [1, 2], where it was proposed as an alternative to dominant environmental strategies centered on technological solutions. Since the early 2000s, sufficiency has received growing attention in both academic and policy arenas, particularly in response to growing concerns about climate change [3].

Despite its increasing visibility, sufficiency remains a contested concept, with varying definitions and interpretations. The literature generally distinguishes between two main perspectives: *sufficiency-as-state* and *sufficiency-as-means* [4, 5]. The first perspective, refers to a desired state in which resource use remains within ecological limits while ensuring that everyone’s basic needs are met fairly [6]. This implies respecting both a lower limit, below which well-being is compromised, and an upper limit, beyond which resource use becomes environmentally unsustainable. The second perspective interprets sufficiency as a set of measures or strategies aimed at reducing absolute resource use [7, 8].

These two interpretations are closely linked: achieving *sufficiency-as-state* requires *sufficiency-oriented* actions, especially as technological strategies alone fall short for fair and sustainable transitions [9]. Yet, the transformative potential of *sufficiency-as-means* depends on how it is defined, especially regarding its framing as a voluntary and individual approach [10]. While a growing body of research challenges this understanding and argues for embedding sufficiency within political and institutional frameworks, the individual and voluntarist view remains influential. It continues to shape policy-making and is often reflected in modelling approaches based on rational choice theory, where a representative agent seeks to maximize utility through consumption choices [11, 12]. However, while such models provide useful insights into individual decision-making mechanisms, they may be limited in addressing the social equity dimensions of sufficiency.

These reflections underscore the limitations of framing sufficiency solely as a matter of individual voluntary action. In response, we propose an original framework rooted in social choice theory and distributive justice. Building on *sufficiency*, which defines a lower threshold of well-being, we extend this approach by incorporating an ecological upper bound, thereby introducing the concept of *eco-sufficiency*. We formalize this framework using social welfare functions that aggregate individual outcomes into a collective decision-



making criterion. This approach moves beyond traditional cost-benefit logic and individualistic sufficiency models and enables the evaluation of the distributional impacts of public policies.

2. Sufficiencyarianism

Sufficiencyarianism is a well-established theory of distributive justice, originally developed by Frankfurt [13] as a critique of egalitarianism. Rather than aiming for strict equality, it argues that justice requires ensuring everyone has *enough*. Over time, the concept has evolved, incorporating elements from prioritarianism.

Several authors have attempted to formalize sufficiencyarianism using axiological and axiomatic methods. These approaches typically rely on a welfarist framework, treating utility as interpersonally comparable lifetime well-being, and define sufficiencyarianism as a ranking over utility distributions.⁵ The most comprehensive formalization to date is proposed by Bossert et al. [14]. Their *critical-level sufficiencyarianism* introduces a sufficiency threshold $\theta \in \mathbb{R}$, giving absolute priority to individuals below it. Utilities above the threshold matter only in tie-breaks, reflecting a lexical structure. Formally, a utility distribution for $n \in \mathbb{N}$ individuals is given by the vector $u = (u_1, \dots, u_n) \in \mathbb{R}^n$, where each u_i represents individual lifetime well-being. The set of all possible distributions is given by $\Omega = \bigcup_{n \in \mathbb{N}} \mathbb{R}^n$. The sufficiencyarian ordering R is a reflexive, complete, and transitive binary relation on Ω , where uRv expresses that social state u is at least as desirable as the state v .

An ordering R is critical-level sufficiencyarian if there exists a continuous and increasing function g concave such that, for all population sizes n and m and for all distributions $u = (u_1, \dots, u_n)$ and $v = (v_1, \dots, v_m)$, we have uRv if and only if :

$$\sum_{i \in L^n(u)} [g(u_i) - g(\theta)] > \sum_{i \in L^m(v)} [g(v_i) - g(\theta)]$$

Or

$$\sum_{i \in L^n(u)} [g(u_i) - g(\theta)] = \sum_{i \in L^m(v)} [g(v_i) - g(\theta)]$$

and

$$\sum_{i \in H^n(u)} [g(u_i) - g(\theta)] \geq \sum_{i \in H^m(v)} [g(v_i) - g(\theta)]$$

Where:

$$L^n(u) = \{i \in \{1, \dots, n\} \mid u_i \leq \theta\},$$

$$H^n(u) = \{i \in \{1, \dots, n\} \mid u_i > \theta\}.$$

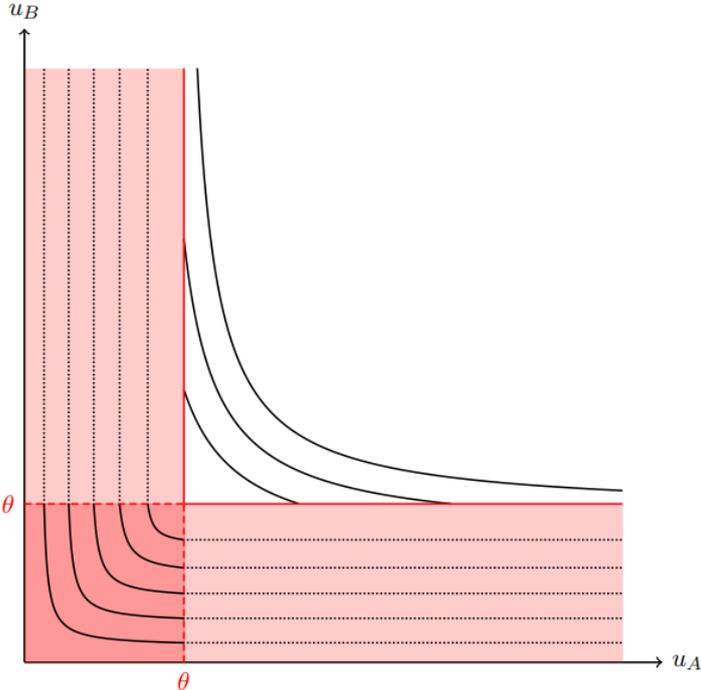
This principle can be illustrated using Roemer's indifference curve map [15], a geometric representation of distributive ethics. An indifference curve connects all social states $u = (u_A, u_B)$ that are considered equally desirable according to a given ethical criterion. These curves can thus be interpreted as iso-welfare curves, describing combinations of individual welfare levels that are ethically equivalent. In Figure 2 we propose to illustrate a

⁵ Within this framework, a social state is represented by a list of individual utilities, and evaluating the distribution of utility is equivalent to evaluating the social state itself.



sufficientarian indifference map derived from the sufficientarian ordering defined by Bossert et al.

Figure 2: Indifference curve map of the sufficientarian ordering defined by Bossert et al.



Note: The ordering proposed by Bossert et al. satisfies the Pareto criterion, meaning that social welfare increases as one moves toward iso-welfare curves located further up and to the right. (In the diagram, the indifference curves are depicted as dashed lines in the pink-shaded areas, indicating that no two points within those regions are ethically equivalent under Bossert et al.'s ordering.)

3. Towards an eco-sufficientarian framework

In this study we seek to adapt the sufficientarian framework to incorporate the upper bound of sufficiency.

We show that this requires shifting from the *timeless* perspective used by Bossert et al. (in which a utility distribution represents the lifetime welfares of the whole humanity) to a temporally situated approach. In a timeless view, one could argue that environmental degradation is already implicitly captured, since it eventually affects lifetime utility.

Under this temporally situated lens, the upper bound can be understood as a way to account for intergenerational concerns without explicitly modeling future individuals' utilities. It allows us to define acceptable limits to consumption without having to predict precisely how environmental degradation will translate into individual well-being. This upper bound, conceived as the ecological carrying capacity, reflects a strong version of the precautionary principle, grounded in a highly risk-averse approach.

To formalize the upper bound, we adopt a resourcist approach, linking individual well-being to resource use. Let $u_i = W_i(x_i)$, where x_i is the resource consumption of individual i , and W_i a concave welfare function. Environmental degradation is given by:

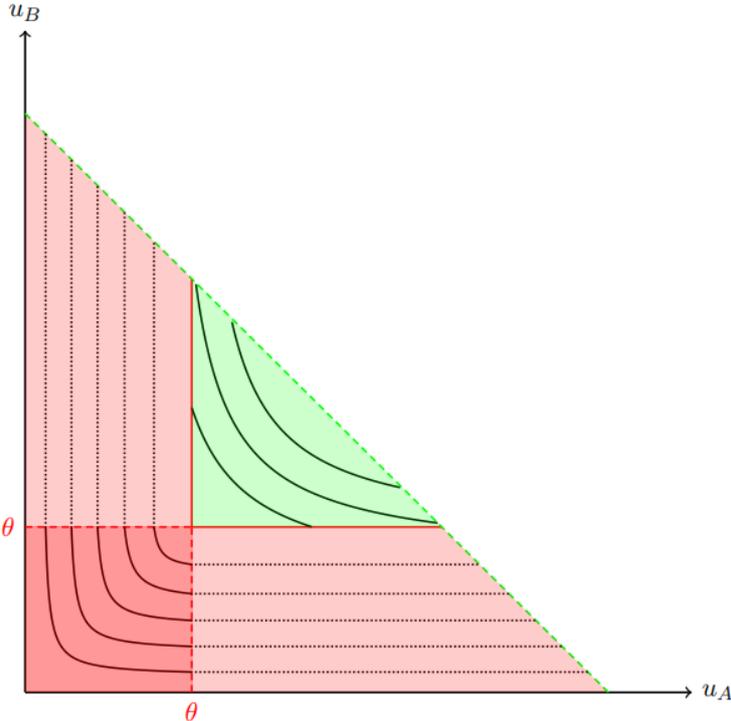
$$D = f\left(\sum_{i=1}^n x_i\right)$$

with f increasing and convex. Given the environmental threshold L , the set of admissible social states $u = (u_1, \dots, u_n)$ satisfies:

$$\left(\sum_{i=1}^n W_i^{-1}(u_i) \right) \leq L$$

Figure 3 presents a simple case where f is assumed to be the identity function, as well as the W_A and W_B welfare functions. The green portion, delimited by the upper bound and the lower bound for both individuals A and B, corresponds to the set of social states in which sufficiency-as-state is achieved.

Figure 3: Adding the upper bound in the sufficientarian indifference curve map



In this context, a sufficiency policy can be interpreted as a measure that enables reaching the green area. This framework can be applied at different scales and allows for the assessment of the potential of sufficiency policies in terms of both environmental and social impacts.

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Domestic EV Charging and Energy Technology Co-Adoption

Theme 3, sub-topic a, b, Theme 5, sub-topic b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Electric Vehicles, Domestic Energy, Behaviour, Low Carbon Transition, Technology

Extended abstract

1. Research Aims and Methodology

Private electric vehicle (EV) drivers in the UK, Europe and elsewhere usually charge their EVs at home using their domestic electricity [1],[2]. Furthermore, many studies (e.g. [3],[4]), suggest that, where possible, home-based EV charging will continue to dominate charging practices as the diffusion of EVs shifts from early adopters to the early majority [5]. As a result, not only is transport’s energy source changing, but also the location of its delivery and accompanying social practices. However, there is little research into home charging practices.

In a small study in Oxfordshire, one of the authors found that the more changes early adopters make to their practices of parking and charging as compared to parking (and fuelling) conventional cars, the greater their satisfaction with EV adoption [6]. The changes described include the use of solar photovoltaics (PV) or dedicated time-of-use tariffs to maximise cost savings when charging their EV. This finding highlights how the adoption and possession of other technologies and innovations designed to support and accelerate the domestic energy transition may also support and accelerate EV adoption. Yet studies of the interactions between the possession and use of EVs and other elements of the domestic



energy transition are also limited.

As the Energy Demand Observatory and Laboratory (EDOL) project aims to improve “understanding of how and why energy is used in homes”, it offers an unparalleled opportunity to investigate how EVs fit within the social dynamics of home energy use. This paper starts this investigation by analysing patterns of co-adoption of EVs, home chargers, solar PV, batteries and time-of-use tariffs. It considers how co-adoption affects whether, how and when EV-owning households charge at home.

As a preliminary step in the EDOL recruitment, an extensive survey was sent to a regionally representative panel of over 11,600 households from across the Great Britain who agreed to be part of the Smart Energy Research Lab (SERL). SERL collects half-hourly data from these households’ smart meters on an ongoing basis. Between March and June 2025, 3,806 SERL participants responded to the new survey. Of these, 405 households indicated that they currently own or have access to an EV (hereafter referred to as ‘EV owners’), answering questions on where and when they usually charge their vehicle. The survey also includes information on household characteristics, some of which are associated with EV adoption.

Our approach comprises of three stages. First, we segment EV owners by their adoption of various combinations of energy transition technologies. Time-of-use tariffs are included in this term for ease of reference and to reflect that this is a key low-carbon energy policy that affects the social dynamics of charging practices. Second, using descriptive statistics and multinomial logistic regression (MNL) modelling, we consider whether EV charging practices and household characteristics differ between designated technology co-ownership segments. Finally, by linking these segments with the smart meter data, we assess the patterns of domestic energy use that result from the adoption of EVs and accompanying technologies.

2. Technology (co-)adoption analysis and findings

Among the 405 EV owners, 76% have an EV home charger, 61% a time-of-use tariff, 41% solar PV, and 26% battery storage. There are sixteen possible combinations of EV owners with zero to four of these technologies. The most common combination in the sample is a home charger and time-of-use tariff, followed by EV owners who have all four technologies, then those who have a home charger only. The remaining combinations with a home charger make up a fourth segment, and the co-ownership combinations that do not include a home charger make up the fifth segment. Finally, the number of households with EVs, but no other related technologies is the smallest of the six groups retained for further analysis (Figure 1).



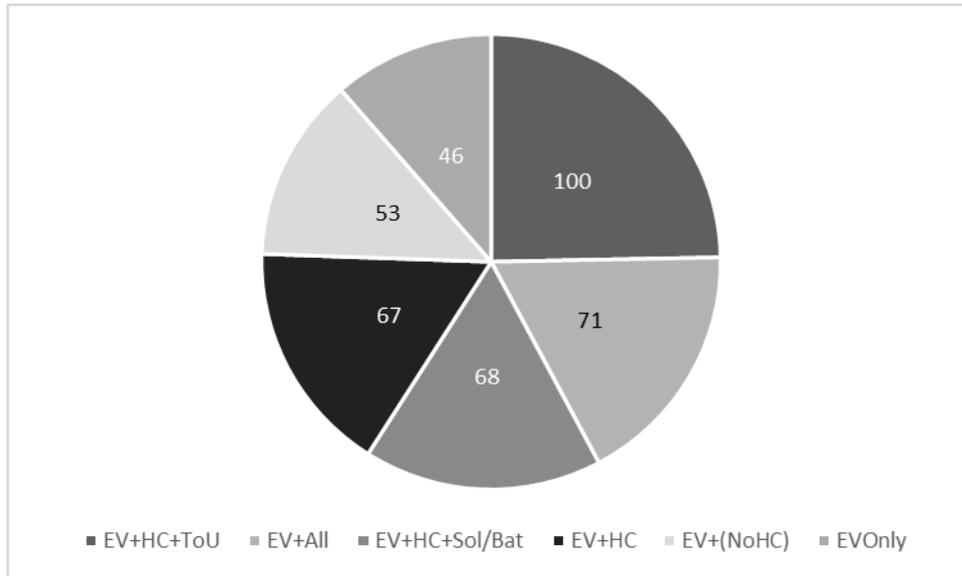


Figure 1: Number of EV owners segmented by co-ownership of energy technologies

EV owners with storage, solar and / or time-of use tariff, but without a home charger are gathered into the ‘EV+(NoHC)’ segment because they are likely to either charge away from home or to ‘trickle’ charge using a domestic plug over a much longer period per kilowatt-hour. The ‘EVOnly’ group will have to make similar choices, but also face potentially higher electricity costs, as they have neither production nor storage capacity, nor a time-of-use tariff with usually cheaper overnight rates. Indeed, only 46% of the EVOnly segment plug in at home, compared to 87% of EV owners in the EV+(NoHC) segment – even though the latter don’t have a home charger. Of the EVOnly segment who do trickle charge at home, slightly less than half charge mostly overnight (between 8pm and 7am), compared to two thirds or more of the other five segments.

Table 1 shows a selection of descriptive statistics for household characteristics by segment.

	EV Only	EV+(NoHC)	EV+HC	EV+HC+Sol/Bat	EV+HC+ ToU	All
	n = 46	n = 53	n = 67	n = 68	n = 100	n = 71
Households w children (%)	26%	19%	22%	13%	19%	23%
Households all 65+ (%)	11%	21%	18%	15%	6%	9%
Tenure = own / mortgage	91%	100%	99%	100%	100%	96%
Non-EV cars / hhold (mean)	0.52	0.68	0.57	0.88	0.62	0.61
Private parking	67%	92%	91%	99%	97%	99%
Charge via domestic plug	46%	87%	0%	0%	0%	0%
EV charge time (mode)	Not charge at home	Mostly overnight				

Table 1: Descriptive statistics for EV owners grouped by technology co-adoption

The six segments form the categorical dependent variable, with ‘EVOnly’ as the reference case, to test the significance of the relationships between technology co-ownership and

covariates such as those shown in Table 1. The first MNL model includes a dummy variable indicating whether the first two segments usually charge from a domestic plug or not (the other segments use home chargers). If they do not usually charge at home, this is included as a category in the EV charge time variable, as the ‘when’ question only applies to those charging domestically with or without a home charger. The results suggest that over a third (McFadden’s $R^2 = 0.36$) of the differences between the six segments can be explained by these two derived variables for charging practices (model fit statistics: AIC: 959.7; BIC: 1059.8). Further MNL models test the variables related to other household characteristics.

The last stage of analysis considers the energy profiles of the different groups. Previous analysis indicates that EV owners in the baseline SERL sample without solar PV have higher consumption than non-EV owners, which peaks in the middle of the night:

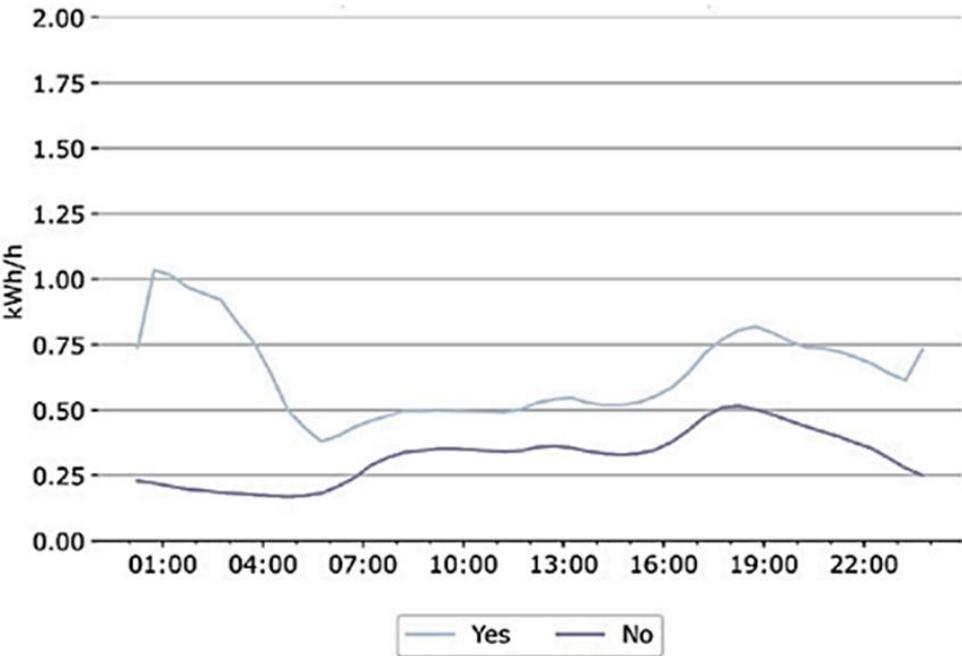


Figure 40 Mean electricity imports by electric vehicle ownership in 2023. These homes have gas central heating and do not have PV.

Figure 2: Prepared by one of the authors and published in SERL stats report, Vol 2 [7]

Different combinations of co-ownership of technologies, including time-of-use tariffs, affect not only EV owners’ charging practices, but also their energy use profiles. Statistically significant differences in the characteristics of households suggests that these practices are also socially dynamic and contextual – highlighting the importance of further research into the interactions between EV ownership and other consumption practices at the household level. Finally, this work demonstrates that low-carbon policies and technologies for transport cannot be siloed from their energy counterparts, but must be considered in a holistic manner.

4. Acknowledgements

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Resource efficiency audits: methodology development and application to pilots

Theme 1, sub-topic 1b) and 1c)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Resource efficiency, Pilot audits, KPIs, Decision-making

Extended abstract

The study highlights the essential role of integrated resource audits in connecting energy, water, and material efficiency strategies. By establishing a comprehensive evaluation framework, the proposed methodology facilitates the implementation of effective resource management measures, enhancing industrial competitiveness, sustainability, and alignment with environmental and economic objectives. This methodology was also applied through on-site pilot resource audits, encouraging measurements to accurately quantify key performance indicators (KPIs), fully assessing the associated savings’ potential and the willingness to implement recommended efficiency measures.

The work presented was developed under the Horizon 2020 [LEAP4SME](#) (grant agreement n.º 893924) and LIFE-CET [LEAPto11](#) (grant agreement n.º 101121013) projects, funded by the European Union.

1. INTRODUCTION

Resource efficiency audits have the capacity to boost the implementation of energy, water and materials efficiency measures, therefore increasing the companies’ competitiveness and diminishing the uncertainties of externalities. Commonly, as audits are only ‘energy driven’, the potential to address other benefits and combine strategies between energy, water and materials efficiency is mainly neglected. This limits the opportunities for continuous improvement, not only in energy management but also in areas such as water availability, waste and wastewater reduction, CO₂ emissions reduction, maintenance cost optimization, and enhancement of working conditions, among others.

The work developed introduces a novel integrated resource audit methodology designed to align companies’ operations with circular economy principles while promoting more efficient production processes and delivering environmental benefits. Also, by testing the model into pilot audits it is possible to: (1) understand which are the points that need to be improved, (2) verify the methodology viability, and (3) better understand the decision-making behaviour factors in enterprises, through direct interviews/surveys to top management and resource management technical staff.



2. METHODOLOGY

The first step of the resource audit is to set up an initial meeting to clearly define the audit's boundaries, engaging from the beginning the relevant staff (including the company's top-management). During this meeting, the overall methodology of the resource efficiency audit and its process should be presented, the person responsible for supporting the auditors nominated, and a pre-audit questionnaire requesting specific information from the organization shared. This first contact with the audited company is also a valuable opportunity to start to assess the barriers and drivers to resource audits implementation, as well as which factors may boost the companies' willingness to implement efficiency measures. Afterwards, site visits will be performed during which the auditing team will collect information that will allow them to effectively calculate the resource efficiency KPIs.

The defined KPIs are applied across different evaluation levels (D to A), acknowledging that they may not be equally applicable to all companies and sectors. With this configuration, enterprises may advance as the KPIs match to their own specific case and/or as they have data available or a specific interest. These KPIs enable the accurate quantification of potential energy, water and materials savings per year, while also supporting the proposal of tailored efficiency measures for each enterprise. Moreover, KPIs leverage existing data, using information collectable during an audit procedure, or that is already available and systematized within the companies' legal or voluntary requirements (e.g., ISO standards, environmental licensing, etc.). The scenario that corresponds to the level D evaluation can be applied to most of the economic sectors and for some economic sectors or companies, this evaluation level could be sufficient, even if higher evaluation levels are applicable. This depends on the characteristics of the enterprise, and the willingness to pursue a higher level of evaluation.

Table 1 presents the KPIs according to the evaluation level where they can be applied. As the evaluation is cumulative, each level must include the KPIs from the previous ones.

Table 1. Evaluation levels and KPIs

Evaluation level	KPI
Level D	Energy intensity [kWh/€]
	Carbon intensity [t CO _{2e} /kWh]
	Energy specific consumption [kWh/P.U.]
	Renewable energy production [%]
	Total water consumption [m ³]
	Water consumption per GVA [m ³ /€]
	Water productivity [€/m ³]
	Water costs in the total costs incurred [%]
	Waste valorization rate [%]
	Level C
Materials productivity [€/P.U.]	
Level B	Byproducts in production process [%]
	Materials specific consumption [kg/P.U.]
	Water specific consumption [m ³ /P.U.]
	Water specific cost [€/P.U.]
	Energy specific cost resulting from the use of water [€/m ³]
	Specific cost of water delivered [€/m ³]
Level A	Energy specific consumption from the water use [kWh/m ³]
	Alternative water sources used [%]
	Wastewater treated and reused [%]

Following the fieldwork, a report summarizing the collected data and treated information (namely, efficiency measures identified and potential resource savings) is elaborated. Finally,



a closing meeting with the technical staff involved, as well as the top management, is scheduled to convey all the key points of the audit performed. Moreover, during the closing meeting (or immediately before) a survey is to be shared with the top management and resource management technical staff involved, to evaluate their decision-making behaviour factors and in what measure the participation as pilot during LEAPto11 project influenced them.

3. RESULTS

The proposed methodology is being applied to real organizations, through pilot resource audits, to test and improve the audit procedure. The development of pilot cases is fundamental to understand which are the points that need to be adjusted, refined, or adapted, as well as to verify the methodology viability. A pilot study validates the assumptions made, collecting feedback from a real context, and identifying technical or operational issues.

Currently, the pilot audits are still underway. The LEAPto11 partners conducting pilot audits (ADENE, CRES, EIHP and EWA) will perform at least 3 pilot studies under different dimensions' entities (comprising SMEs and non-SMEs). Moreover, to allow benchmarking and comparisons between countries, one activity sector will be transversal to all countries (the agri-food sector).

Nevertheless, from the initial meetings already held with the pilot companies, it is possible to infer that the perceived common barriers to resource audits implementation are: (1) economical (e.g. initial investment, cost of the recommended efficiency measures, associated payback time) and (2) organizational (e.g. lack of human resources, integration with other current obligations). On the other hand, the drivers to this implementation are: (1) economical (e.g. financing programmes and fiscal incentives), (2) organizational (e.g. strategic investment), and (3) market driven (e.g. client request, competition with other companies). Finally, the factors that may boost the companies' willingness to implement efficiency measures are (with no particular order): (1) legal impositions, (2) cost reductions (maintenance and resources), (3) operation times reduction, (4) clients pressure, (5) environmental awareness, and (6) company's own policies.

4. CONCLUSIONS

The final stage of this work will concentrate on quantifying resource efficiency, encouraging measurements to accurately quantify KPIs, fully assessing energy, water and raw materials savings' potential. In addition, it will be possible to evaluate the pilot companies decision-making behaviour factors and in what measure the participation as pilot during the LEAPto11 project influenced them, namely through the survey that is to be shared with the top management and resource management technical staff involved. However, it is already possible to conclude that common barriers to resource audits implementation could be economical and organizational, as the drivers are also economical, organization and market-driven, as it would be expected. Also, aspects such as cost and operation times reduction, legal impositions, environmental awareness, and client pressure can act as a boost to implement the identified efficiency measures.

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Exploring Energy Efficiency perception: findings from 2025 Italian Survey

Theme 1, sub-topic 1d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Behaviour, awareness, influence, communication

Extended abstract

The 2025 survey carried out by the Italian Research Institute Demopolis, on behalf of ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development), is the highest point of a complex, multi-year research project linked to the *Italian National Training and Information Program on Energy Efficiency*. The Program is coordinated by ENEA and promoted by the Ministry of Environment and Energy Security [1].

The aim of the survey is to evaluate how communication, information, and training actions—particularly those under the “*Italia in Classe A*” campaign promoted by ENEA - have affected Italian citizens’ awareness and behaviors [2] concerning energy use, energy-saving measures, and sustainable building renovation.

The research covered five years, starting in 2020, with follow-up surveys in 2024 and 2025. It sought to track shifts in awareness, attitudes, and behaviors related to households’ energy efficiency [3]. This study has been focused not only on the impact of economic incentives (e.g., Tax reduction, subsidies), but also the influence of public communication efforts in shaping behaviors [4].

Demopolis investigated a representative sample of Italian households, by conducting 3036 interviews in 2020, 3800 in 2024 and 4260 interviews in 2025.

Key trends and shifts in Public Awareness

Comparative data collected across the three surveys show a significant and continuous improvement in Italian households’ familiarity with energy efficiency topic. Among the most notable findings:

- The percentage of individuals who consider themselves “poorly informed” about energy efficiency dropped by more than 10 percentage points (Fig.1).
- Knowledge of energy rates of home they live in increased by approximately 22% (Fig.2).
- Awareness of the energy label of domestic appliances increased about 24.5%.



There was a 10% increase in people who consider their domestic appliances satisfactory from the energy efficiency perspective.

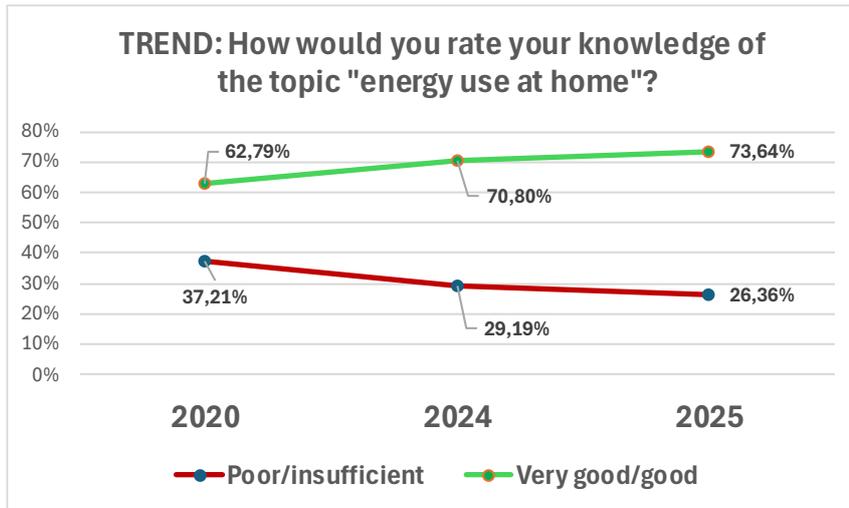


Fig. 1 -Self-perception of information on energy use at home

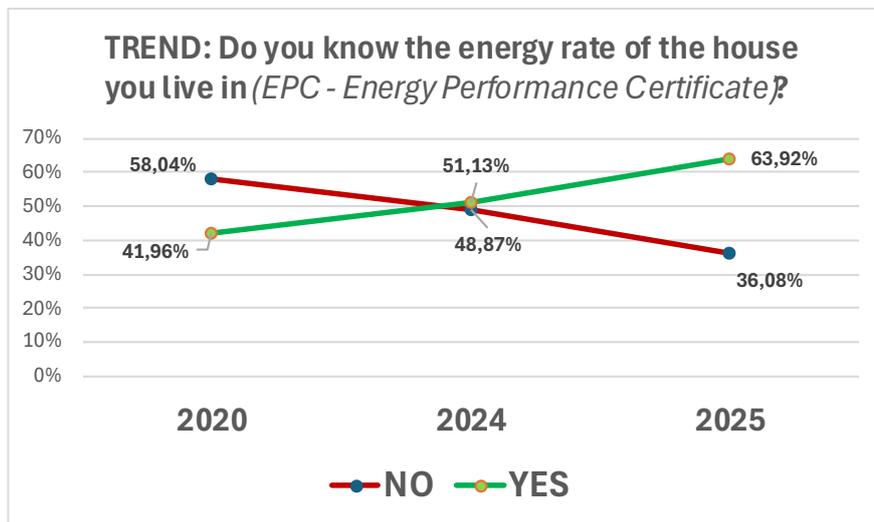


Fig. 2 – Knowledge of EPC in private dwellings

Moreover, positive evaluations of home energy performance improved as well. For example:

Appreciation for energy-efficient windows increased by around 5.7%.

Awareness of thermal insulation quality rose by 3,5%, despite a slight decline compared to the previous year.

This suggests that, beyond economic motivations, institutional communication has played a significant role by fostering informed decision-making about home refurbishment and lifestyle improvement towards energy saving.

The role of Information campaigns

A crucial challenge in analyzing the results is to distinguish knowledge acquired directly through institutional campaigns from knowledge obtained via personal involvement in energy retrofiting projects. However, the convergence of initiatives—especially those several actions carried out in the framework of Italian Training Information Program—appears to

have substantially strengthened the understanding and the commitment towards energy-efficient practices.

The data confirm this assumption:

- Over 77% of respondents consider these campaigns useful (Fig. 3).
- Nearly 88% report a medium and high attention to energy-related comfort at home.
- Close to 90% declare to monitor actively energy consumption to reduce waste.

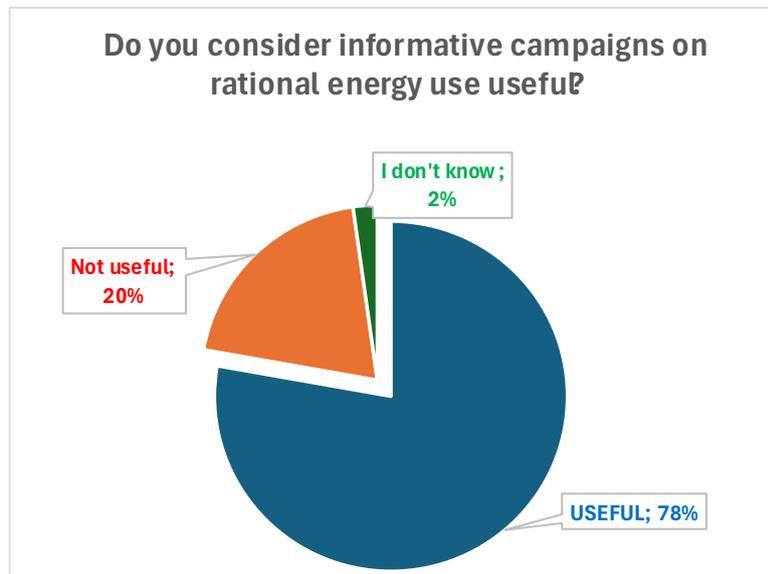


Fig. 3 – Perceived relevance of communication campaigns on energy efficiency

These indicators highlight a general improvement in sustainable behaviors and confirm the impact of structured strategic communication [5].

Digital Media and institutional channels

The survey also analyzed how people obtain information on energy efficiency. Alongside traditional media - such as newspapers, advertisements, and television - there is a remarkable rise of the use of institutional digital platforms and social media:

- Around 24.3% cited institutional campaigns as a key source.
- Approximately 22,6% mentioned official web portals.
- About 21,6% referred to social media networks.

This digital shift highlights the increasing importance of online tools with traditional media, broadening access to information, and fostering greater engagement with public policies on sustainability.

Communication effectiveness

The analysis indicates that increased public investment in education and communication has coincided with heightened awareness. More than 50% of respondents believe they are better informed today than five years ago. Over 75% consider information campaigns on rational energy use successful, suggesting a clear behavioral transformation accompanied by a deeper cultural change.

Applying classic communication models such as AIDA (Attention–Interest–Desire–Action) [6], the report interprets the population’s journey as starting from awareness and culminating

to tangible action. The campaigns captured public attention, stimulated curiosity, generated motivation, and ultimately affected behavior.

A more evolved model, AIDMA (which adds *Memory*) [7], offers a deeper framework for understanding this transformation. According to this perspective, the campaigns not only stimulated action but also boosted long-lasting awareness and memory retention. This is crucial for sustained behavioral change, ensuring that energy-efficient practices become habitual rather than temporary responses.

Notably, more than 40% of respondents in the last year reported increased attention to energy-saving behaviors—an indicator strongly associated with improved awareness and memory of institutional messages. Furthermore, 28,3 % attributed their increased attention directly to better institutional communication, emphasizing its transformative potential.

Public memory and Campaign recognition

Furthermore, significant finding relay to a *stimulated memory* of the “*Italia in Classe A*” campaign. Approximately 20% of respondents remembered interacting with one of the campaign media products, such as TV or radio spots, a dedicated show on the Italian Television La7, or multimedia platforms. While this may seem modest, it is a solid benchmark of *brand awareness*, especially for a public campaign addressing complex issues like the ones related to energy efficiency.

This 20% recall rate is particularly significant when interpreted through a branding lens: in five years, 40% of survey participants reported an increased willingness to invest in home improvements. This correlation between recall and behavior demonstrates the efficacy of the campaign strategy and its resonance in the public audience.

The final section of the report links the findings to theoretical frameworks in behavioral economics. Specifically, it highlights the alignment of the Program initiatives with the concept of *nudging* as defined by Thaler and Sunstein [8] according to which nudges are subtle interventions that encourage desirable behaviors without restricting freedom of choice, often relying on cognitive principles such as heuristics, framing, and social norms.

The integration of these techniques into the campaigns—through informative events, media products, urban labs, and educational tools—has fostered a stronger culture of energy responsibility. Rather than imposing regulations, the campaigns have gently guided citizens toward environmentally friendly behaviors, leveraging both emotional and rational appeals.

Conclusion: from awareness to cultural change

In a nutshell, the 2025 Demopolis survey underlines the effectiveness of ENEA’s communication and education initiatives. The progressive rise in public awareness, the widespread attention to energy-saving behaviors, and the increased recognition of institutional campaigns suggest a meaningful cultural shift.

The synergy between economic incentives, well-crafted public communication, and digital tools has successfully transformed abstract sustainability goals into tangible actions. Italian households appear increasingly informed, engaged, and empowered to take energy efficiency seriously—not only as a way to reduce energy bills but as a contribution to a broader environmental and social commitment.

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Towards sufficient holidays: Promoting closer destinations and travelling on the ground via an app-based artificial intelligence tool

Theme 5, sub-topic 5d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Air travel; Leisure travel; Challenge; Mobile app; Sufficiency.

Extended abstract

INTRODUCTION

Deeply rooted in air travel, holidays represent a huge generator of carbon emissions [1-2]. Due to their discretionary nature, far-away destinations could be replaced by closer destinations, connected by public transport. This is especially true for frequent flyers: do they really need air travel to satisfy the desire for discovering new places, cultures, and experiences? For the Swiss people, located at the very heart of Europe, destinations that can be reached at a fraction of carbon emissions are indeed available. The challenge is, however, how to make them appealing. In this conference contribution, we introduce a smartphone app aimed to tackle this challenge, targeting young frequent flyers aged 18-35 years old. The app features were informed by the behavioural Model of Action Phases (MAP) [3] and by learnings from workshops we performed with potential app users in the Swiss city of Lugano. The MAP theorises behaviour change as a process through four stages, suggesting that progress occurs through goal setting and shifts in personal and social norms, self-efficacy, and perceived behavioural control. If individuals start perceiving flying as problematic, they begin thinking to set a goal for change (pre-decision). Then, an increase in perceived behavioural control on alternatives to flying supports goal setting (pre-action), which then helps to put the new behaviour into practice (action), and to maintain it over time (post-action).

MATERIALS AND METHODS

The app was called Treeps, with a wordplay hinting at both travel and nature. It was co-designed by an inter-disciplinary research team including sociology, computer science, communication, and natural science experts. Based on previous experience in behaviour change apps in the mobility and energy domains [4-7] the research team suggested use of gamification, and identified three key features: i) feedback on carbon emissions of past holiday trips (acting on goal setting and personal norms), ii) suggestions for holiday destinations that can be reached by travelling on the ground and/or close to home destinations



that can substitute for short-break trips (acting on perceived behavioural control), and iii) possibilities for social interaction within the community of app users, to share experiences (acting on descriptive social norms) and ask for support on how to perform low-carbon holidays (acting on perceived behavioural control). Target frequent flyers using the Treeps app were also expected to be quite keen on technology [8-11]. We thus opted for providing those features via an artificial intelligence ChatBot tool. The ChatBot was thought to provide users with trip suggestions and to stimulate them to upload pictures and short descriptions of their trips, to be automatically posted on Instagram, which allows richer interactions, such as liking and commenting.

To get feedback on the ChatBot feature, we ran a workshop with 17-19 year-old high school students (4th December 2025, two one-and-a-half hour sessions, overall 80 participants). Participants were prompted to think of the following situations and to list positive and negative implications: “Artificial Intelligence offers you suggestions for holiday destinations” and “Artificial Intelligence asks you about your trips and helps you to share them on social media”. Participants’ answers, collected via the Wooclap digital tool, were inductively classified in categories, that informed the final design of the Treeps app.

RESULTS

The Treeps app is organised in four main sections. The home page shows gamified user statistics, reporting the points the user collected by interacting with the app and the Instagram page (Figure 1.a). Just below, the ChatBot, specifically called “TreepsBot”, feature is given salience: the sentence “Let’s talk about sustainable trips” invites to interact with the TreepsBot, by asking for suggestions on possible new trips, or talking about past holiday experiences (Figure 1.b).

Workshop findings indicate that features providing trip suggestions by the TreepsBot were well-received, as a way to quickly get ideas for holiday destinations. However, concerns existed about the risk to only get suggestions for well-known places. We thus opted for creating a dataset of novel and appealing “Treeps destinations”, and for training the TreepsBot to just pick ideas from there, suggesting them based on the users’ characteristics and needs. We built a dataset of 200 destinations that can be reached on the ground via public transport, starting from the Swiss city of Lugano. To populate it with novel and appealing destinations, we invited about 40 employees of the local university of applied sciences to share memorable experiences about train trips across Europe and close-to-home leisure destinations reachable by regional public transport. By relying on experiences by other people, we expected the Treeps set of low-carbon destinations to better match Treeps users’ interests and desires. The resulting list of destinations is made available in a dedicate Treeps section, called “Places”, which reports short and catchy destination descriptions (Figure 1.c), accompanied by a direct link on how to reach them by public transport (link to the route suggested by the Swiss Federal Railways route planner) and where to sleep (link to the Google Hotels webpage, filtering sustainability-certified accommodations).

The features aimed at providing TreepsBot support for sharing experiences on social media were instead negatively assessed by workshop participants, who felt they would preclude creativity and lack authenticity. We thus opted for limiting the TreepsBot role in experience sharing. The TreepsBot was trained to ask users to upload pictures of destinations they reached by sustainable mobility, to estimate the saved carbon emissions by public transport (compared to plane or car, for destinations closer than 200 kilometers), and to ask users to pick one of three motivational sentences providing injunctive social norm messages, randomly selected from a list of 20 injunctive messages developed by the research team.



Users could share any destination they visited-included those outside the Treeps set of places - provided they reached it by public transport or active mobility (cycling, walking). These elements are automatically built into a post, published at the bottom of the home page, in a dedicated app section (Figure 1.d), and in the Treeps Instagram page, which automatically considers all users as followers, if they are on Instagram.

Finally, Treeps uses a combination of push notifications, comments/liking on Instagram posts, and prizes to maintain interest over time, thus possibly increasing the behavioural effect. Every Tuesday, users receive a bespoke notification inviting to share experiences on previous weekend's trips, while on Thursday a notification invites to discover possible new destinations with the help of the TreepsBot and provides feedback on the user position in the point-based leaderboard, inviting to more interaction with Treeps, to climb the leaderboard.

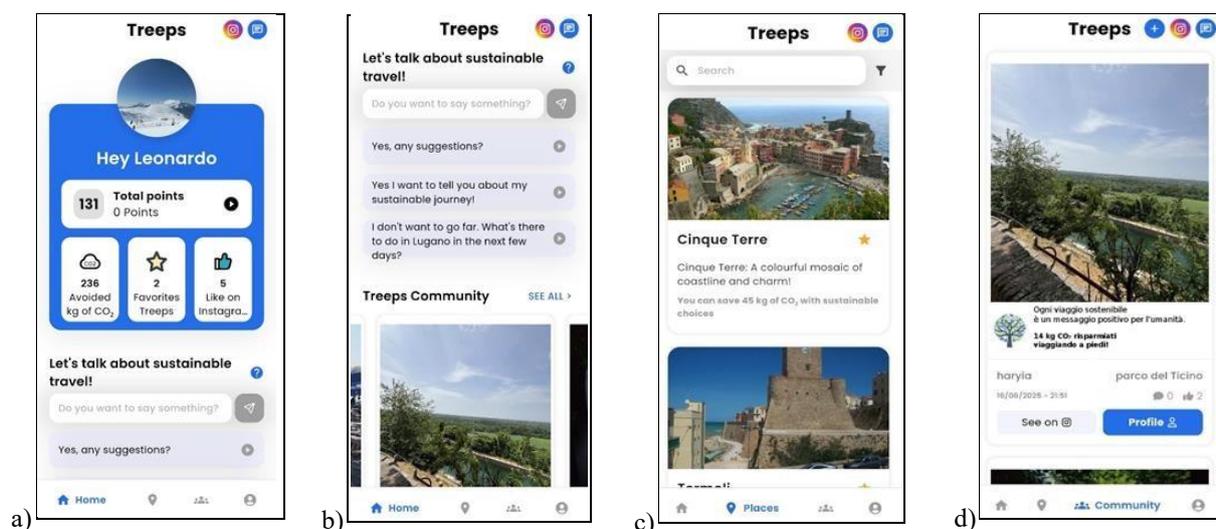


Figure 1. Screenshots of the Treeps app.

CONCLUSIONS

The Treeps app was fully available for iOS and Android since April 2025, and in May 2025 it was offered for three months to $n = 102$ individuals joining a randomised controlled trial (preregistered on AsPredicted platform, #220688). The treatment group was randomly assigned starting from a $N = 204$ sample of volunteers living or working around Lugano. Future research will thus report on the trial effects, allowing to thoroughly estimate the short- and long-term impact of Treeps use on holiday air travel, and to better understand the role of social norms and community-based processes in shaping sustainable leisure travel behaviour.

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“With or without you”: Resistance and support from high-level energy stakeholders regarding citizen participation in energy sufficiency strategies in France and the Netherland

Theme 1, sub-topic 1d) (12 font size)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Energy efficiency, Behaviour, Decarbonisation

Extended abstract:

The negative consequences of climate change are threatening human societies and will continue to increase in terms of intensity and frequency in the future [1]. Human consumption of energy based on fossil fuels, generating carbon emissions, is one of the main causes of climate change [2,3]. Thus, a radical shift in our energy governance model is required to phase out fossil fuel and shift to more sustainable and efficient energy use (energy efficiency strategy) and reconsider our overall energy consumption, shifting to a sufficiency energy strategy by reducing the energy demands and needs based on how much energy is needed in terms of minimum and maximum consumption [4,5,6,7].

Public participation in energy governance could help define and adopt more socially just efficiency and sufficiency measures [8,9,10]. Focusing on France and the Netherlands, some attempts to include the citizens at the highest level of energy and climate decision-making arose, including the climate assembly in France (2019-2020) and the energy citizen assembly (2023) or climate citizen assembly (2025) in the Netherlands. These attempts left debatable output regarding citizens' tangible influence on energy policies. In the French case specifically, if the citizens involved managed to reach a consensus and develop ambitious energy policy proposals, the latter failed to convince the rest of the population or the policy-makers to pass effective



laws [11]. At the local scale, EU schemes aim to encourage the development of local initiatives such as the energy communities (within the REPowerEU Plan⁶) leaving an emerging space for an increase of public participation in energy governance. In France, the slow trend of the decentralisation of the energy system correlated with a decrease in trust in the central government could contribute to increased energy citizenship development through citizen-led energy projects [12, 13]. In the Netherlands, the National Climate Agreement establishes a new local governance structure for the production of renewable energy strategies, namely regional energy strategies (RES). Those RES are locally defined areas which are required to develop plans where and how to produce renewable energy in their region, thereby providing sometimes more agency (still rather limited) to citizens for promoting local co-production of energy among residents [14]. However, limitations remain in the so-called citizen inclusion of citizens in local decision-making, as resistance from local governments towards higher citizen inclusion has already been underlined [15]. Moreover, these initiatives are all very nascent and pose a lot of challenges, leaving the question: how ready citizens are to take a more important role in energy governance processes from which they remain at best informed, if not fully excluded [16]. Previous qualitative work conducted with citizens in both French and Dutch contexts showed a strong interest from the general public to be more involved in energy governance [17]. However, it remains unclear how institutional stakeholders in energy governance are ready (or not) to increase the level of public participation in energy governance.

Our study aims to evaluate the existing energy stakeholders' narratives regarding breaks and enhancers for public participation in energy governance in France and the Netherlands. Building on Markantoni et al. [18], we divided the stakeholders involved in energy governance into three groups: public governance bodies (including public servants and elected representatives), interest groups (from the energy industry and business sector, but also civil society groups like environmental NGOs), and academic researchers and independent experts (specialists in energy governance and public participation). Between November 2024 and April 2025, we conducted interviews gathering the views of 60 of these energy stakeholders (37 in France and 23 in the Netherlands). To analyse the transcripts, we apply a mix of deductive coding based on an adaptation of the Participatory Capital Framework [17] and inductive coding building on participants' open statements to complete the list of inhibitors and enhancers for higher public participation in energy governance. To reinforce the validity of our results, we employed the Inter-Rater Reliability (IRR) method during the coding of the data by cross-checking the codes with different coders and checking the code book through blind coding sessions with external coders. Combining computing and thematic analyses [19], we unfold the narratives developed by participants, underlining the different group members' willingness to accept and facilitate (or not) changes towards more public participation in energy governance.

Based on the stakeholders' narratives and visions of the current and future energy governance structure(s), our results identify bottlenecks and facilitators to higher public participation in energy governance in France and the Netherlands. We also analyse the contrasts and similarities in narratives and viewpoints presented by participants across different interest groups. In both contexts, our key findings are that (a) some gatekeepers (elected representatives, high-level public servants and business and industry stakeholders) of the current energy governance are reluctant to see a higher participation of the public in energy governance, (b) the current institutional, economic, climate and geopolitical source of instability prevent any clear energy strategy to emerge (with or without citizen involvement) and (c) organisational factors in the

⁶ For more details see the European Commission official website consulted the 07/07/2025: <https://www.consilium.europa.eu/fr/policies/repowerEU/>



current energy governance reinforce inertia, therefore reducing the possibility of increasing citizen participation in energy governance.

Based on these findings, we expand the discussion on the current institutional mechanisms preventing or encouraging public participation in energy governance and identify the key policies and institutional changes required in current energy governance for citizens to shift from their role of energy consumers to being considered as active citizens with effective influence on energy matters. More general research on narratives on the future eco-social contract is valuable to draw the outline of general social and legal rules that could help reshape our current society in the context of interrelated climate and energy crises [see e.g. 20] We conclude by sharing our reflections on the need to evacuate the energy transition paradigm which seems to maintain the status quo in current energy trajectories, and instead rethinking our energy system from the establishment of a new energy social contract to encourage the emergence and implementation of ambitious energy sufficiency strategies that could reinforce social justice.

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Enabling socially just energy communities

Theme 2 Sub-topic a

Challenges and ownership by stakeholders

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Keywords: energy communities, gender, social inclusion, lifestyle changes

Extended Abstract:

Energy communities (EC) are organisations in which the members, who are traditionally outside the energy sector, share in the ownership, production, distribution and use of renewable energy at a local level [1], [2]. ECs have been gaining significantly in popularity, particularly in Europe. Indeed, the European Union's Clean Energy Package in 2018 officially acknowledged ECs as crucial players in steering the energy system towards a more decentralised use of renewable energy systems in which the role of citizens changes from passive consumers to engaged participants both contributing to and directly benefiting from the energy transition [1]. The primary goal of ECs is seen not as a mechanism to generate profit but to deliver environmental, local economic, or social benefits to the community in which they are embedded. It is also recognised that reaching carbon neutrality requires not only the adoption of renewable energy technology but also lifestyle changes which if to be widely adopted will need to be seen as fair and culturally relevant. However, evidence shows that lifestyle changes are gendered. For example, in a study in Norway and the UK, women were found to change their energy practices such as doing laundry when the sun was shining, whereas men looked at technical fixes [3]. Age can also be a determinant. In Germany older women were found to be more likely than younger women to change their behaviour patterns, for example, they cooked less to save energy [4]. These differentiations in behaviour linked to social characteristics point to the need for disaggregated energy use data. However, such official national level data is hard to find with the UK being one of the few countries to do so. An annual household survey collects data about people's housing circumstances (including energy efficiency), linked to a range of intersectionality dimensions within a household such as composition, ethnicity, age and employment status as well as whether they are tenants (private/social) or owner occupiers [5]. The survey respondent is required to provide answers to questions about all the individuals in the household.



The European Union's Member States are explicitly mandated to ensure that through their enabling frameworks for ECs "participation in renewable ECs is accessible to all consumers, including those in low-income or vulnerable households" (Article 22 RED). They are advocated as a means by which ordinary citizens can contribute to the energy transition. However, the evidence indicates that their membership tends to be rather limited in terms of their social diversity with demographics that can be summarised as mainly white, middleclass, middle aged and older men with a technical background [6], [7]. This is probably not surprising since research indicates that participation in 'desirable' energy activities and energy decision-making is influenced by social and economic factors, including gender, economic status, time availability and homeownership. For example, explanations for women's lack of engagement specifically mention time poverty due to care commitments, as well as a fear of insufficient technical knowledge to effectively participate with a preference for emphasis on environmental benefits, improved home comfort levels and household finance [8], [9]. While for men low income or unemployment inhibit volunteering [10] (Taniguchi, undated). A recent study of 71 ECs has shown that combating energy poverty tends to be the exception rather than the norm [11]. A narrow membership limits both the scope of energy communities contribution to promoting energy supply from dispersed sources as well as bringing into question whether energy communities can be socially just.

The paper is part of the output of the User TCP Research Programme Empowering All. It aims to support policy makers with recommendations for building a framework for enabling energy communities to promote just and inclusive energy transitions which promote behavioural changes that are not detrimental to wellbeing. For example, by providing financial support to enable low-income households to become members of ECs as has the municipality of Eklo, Belgium, buys shares on their behalf [11]. To identify households needing support, we recommend the UK's data collection method which provides a more comprehensive understanding of household energy use. The survey poses questions about all the individuals in the household to a household member who has been designated as the Household Reference Person rather than the standard practice of 'head of household' [5].

Research shows that many of the people responsible for working with end-users do not understand the complexities of the social dimensions of energy poverty and so those in need of advice or assistance are being overlooked [12]. In Austria, a course to train energy consultants on technical competence and know-how in energy-related matters, paid no attention to the social characteristics, such as gender, and age of potential clients who would be the intended beneficiary of advice about behavioural change in their homes [13].

The paper aims to provide guidance to citizens considering establishing energy communities, as well as existing communities, on the importance of social inclusion and how they can ensure that their membership reflects the social composition of the communities where they are embedded. To provide recommendations based on examples of good practice on how to overcome these challenges, we draw on the experiences of several existing EC in Europe using semi-structured interviews to identify what works and what does not work in creating inclusive ECs. Initial evidence shows that the timing of meetings at weekends and provision of childcare can increase women's participation. We provide a critical analysis of Horizon Europe project SCCALE 203050 Inclusivity Guide which was produced to overcome non-inclusivity in ECs [14].

Our methodology uses a mixed methods approach. A review of the literature provides an overview of the evidence of experiences in establishing and scaling-up energy communities, including the challenges of ensuring that their membership reflects the social composition of the communities where they are embedded. We use the energy justice theoretical framework to



explore how and the extent to which ECs fulfil their social role [11]. The framework helps identify three aspects of that role: (i) the extent to which procedures for membership of an EC influence the diversity of membership (procedural); (ii) distribution of outcomes in terms of benefits and services (distributional) and (iii) which sections of society and their needs are ignored or misrepresented (recognitional justice). The framework can also be used to support decision-making [15]. Energy justice considers the context, for example the social determinants of energy consumption which are gendered and vary across time and location [16]. We view the framework, through a gender lens [17] which gives a more nuanced understanding about how the energy transition may unevenly distribute benefits, costs and risks, thereby producing new inequalities or exacerbating existing ones. Although we use the term ‘gender’, we recognise that women and men are not two homogenous groups but that, within these groups, they are differentiated by a range of intersecting social characteristics such as age, ethnicity, socioeconomic status, sexual orientation and other social identities or positions which shape social experiences [18] or are affected by economic or political projects [19] which would include social inclusion or exclusion from ECs. Therefore, we aim to make a more detailed analysis of the social distribution of the energy transition by taking an intersectional approach that disaggregates data across different groups without prioritising one category of social difference.

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Global Patterns of Behavioural Adaptation to the Energy Crisis: Evidence from Eight European Countries

Theme 2, sub-topic 2d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy-saving behaviour, energy poverty, socio-economic vulnerability, inequalities

EXTENDED ABSTRACT

INTRODUCTION

The sharp rise in energy prices across Europe—particularly following the Russian invasion of Ukraine in early 2022—triggered a surge in household-level energy-saving measures [1]. While the broader energy crisis encompassed both supply instability and market volatility, the price shock was the most immediate factor affecting household behaviour. This study investigates the persistence of energy-saving behaviours adopted during the crisis and how this varied across household types, tenure, employment status, financial vulnerability, and national contexts.

The crisis stemmed from a sharp reduction in Russian gas imports, heightened demand post-COVID-19, and global market instability [2]. These factors caused unprecedented energy price spikes, exposing long-standing vulnerabilities in residential energy use and affordability [3]. Governments introduced emergency measures [4], but many households resorted to independent demand-reduction strategies [2], [5]. Although prices have dropped from 2022 peaks, they remain above pre-crisis levels in several countries [6], [7]. This context allows investigation into not just immediate responses but also the longer-term maintenance of such behaviours.

METHOD

We use data from an online survey (N = 14,254) in eight European countries: Belgium, Czechia, Estonia, Finland, Germany, Italy, Romania, and the UK. The survey captures self-reported behaviours during and after the crisis, alongside socio-economic, housing, and financial indicators. Two key behaviour indicators were assessed: (1) whether households adopted restrictive energy-saving actions (e.g. reducing heating/cooling, limiting appliance use) during the crisis, and (2) whether they continued at least one of these actions after prices stabilised.



Energy-saving behaviours were identified via a multiple-response item listing: reducing heating or AC, limiting energy-intensive appliances, upgrading to efficient appliances, using efficient bulbs, programmable thermostats, smart power strips/timers, using less water/fuel/energy, 'Other', or no actions. A follow-up question asked if households were still engaging in these behaviours after the crisis.

Key independent variables included household type (e.g. couples with/without children, single parents), housing tenure (owned outright, owned with mortgage, social rental, private rental, or living in a free residence), employment status, perceived income adequacy (on a 5-point scale from *finding it very difficult* to *living very comfortably*), and perceived financial burden related to energy costs (on a 5-point agreement scale from *strongly disagree* to *strongly agree* with the statement "My energy costs represent a major financial burden").

We employed descriptive statistics and multivariate models: logistic regression for the likelihood of adoption and continuation, and Poisson regression for number of actions. Categorical variables were dummy coded; analysis used complete cases. While correlational, the models offer insight into behavioural patterns and the socio-demographic conditions under which behaviours were adopted or maintained.

RESULTS AND DISCUSSION

Overall, 21.1% of households reported taking no action during the crisis, while 16.3% reported no continued actions afterward. Interestingly, 5,431 respondents (over one-third) reported new behaviours after the crisis that had not been listed previously—likely reflecting a misunderstanding of the follow-up question. To address this ambiguity, we categorised respondents into two distinct groups based on response consistency: those whose post-crisis behaviours were a subset of those reported during the crisis (labelled as consistent respondents, 62.4%), and those who reported at least one new behaviour after the crisis (expanded respondents, 29.9%). Descriptive statistics are presented separately for each group, while regression analyses are restricted to the consistent group to ensure interpretability and robustness of findings.

Figure 4 shows the most common actions: switching to LED bulbs (51.6% during; 55.4% after), reducing heating or cooling (40.1% to 42.7%), and using less water/fuel/energy (41% in both periods). While mean actions per household appeared slightly higher post-crisis (2.14 vs. 2.07), a paired-samples t-test among consistent respondents found a statistically significant decrease: $t(9186) = -47.75, p < .001$, Cohen's $d = -0.498$. Engagement varied by household and country characteristics. Single-parent households, those under greater financial burden, and those reporting low-income adequacy undertook more actions during and after the crisis. Respondents in Italy and Romania showed higher levels of activity, while Finland and Estonia reported fewer behaviours overall.



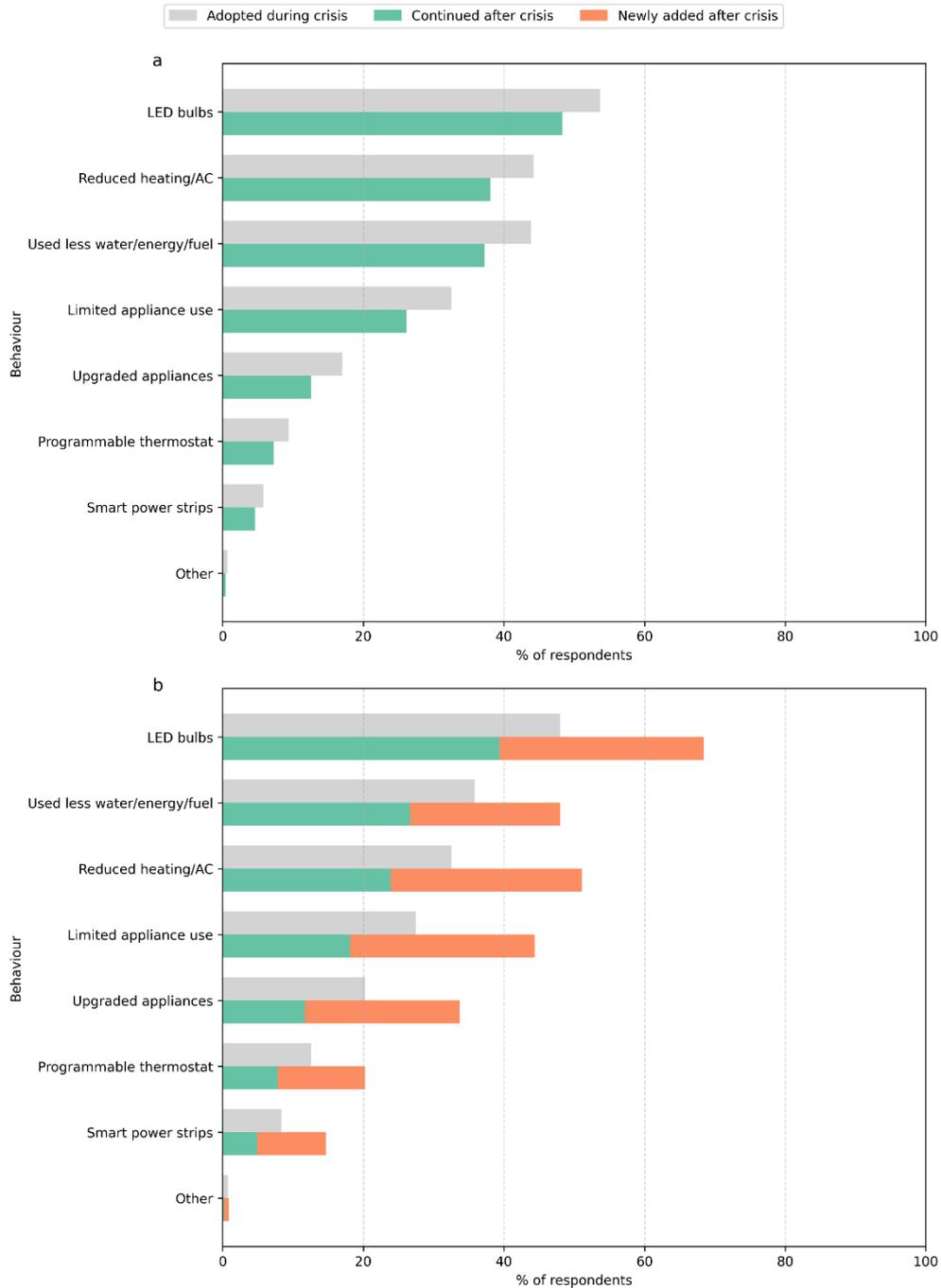


Figure 4 Energy-saving behaviours adopted during and after the 2021–2023 energy crisis, disaggregated by respondent group. a) Households with consistent responses, i.e. those whose post-crisis behaviours were a subset of or identical to those reported during the crisis. b) Households with expanded responses, i.e. those who reported adopting at least one new energy-saving behaviour after the crisis.

Cross-country analysis (Figure 5a) shows Italy and Romania with over 90% of consistent respondents continuing at least one behaviour. Finland reported the lowest engagement both during and after the crisis. Among expanded respondents (Figure 5b) Finland and Czech Republic had the highest rates of newly adopted actions post-crisis.

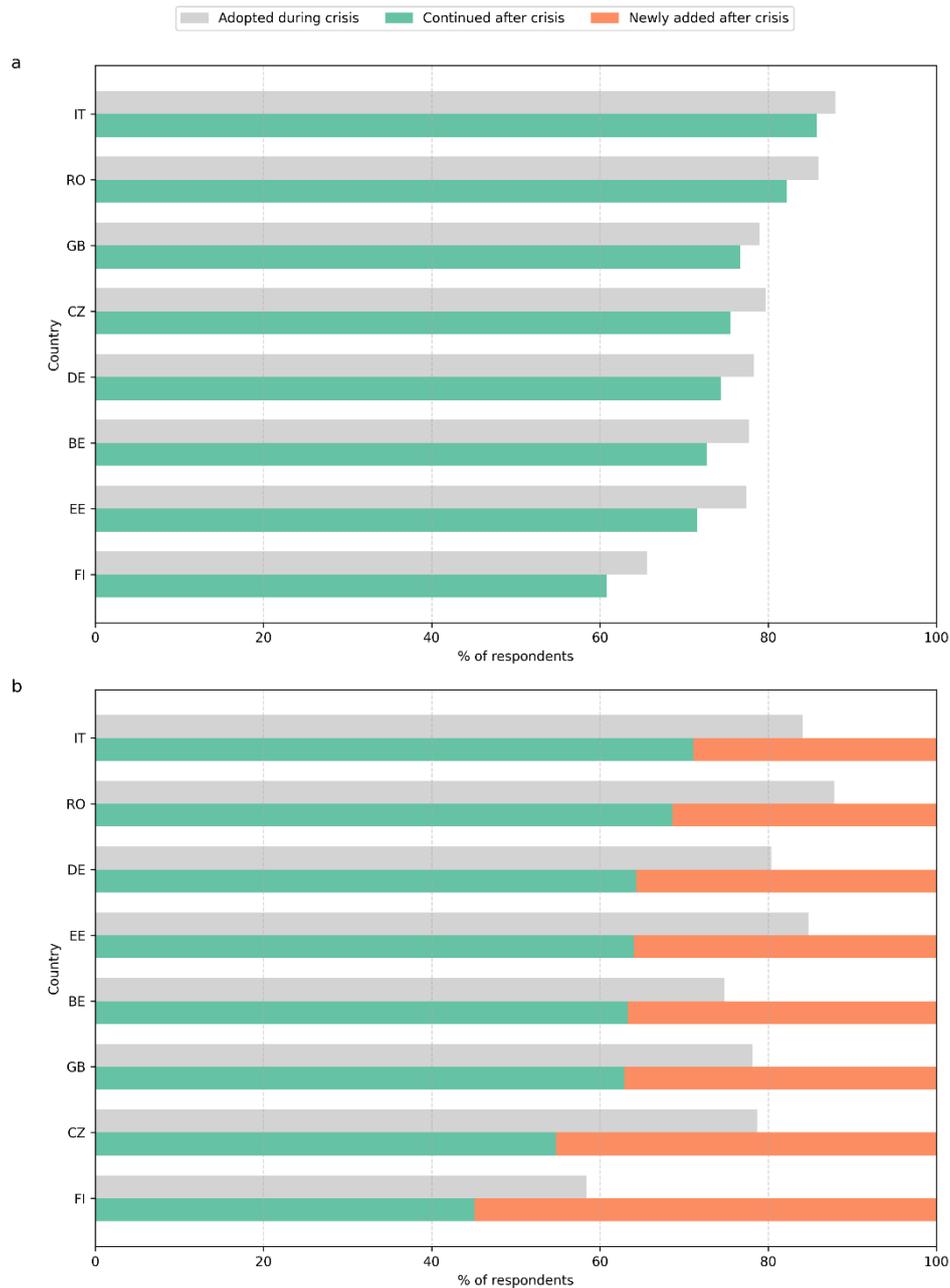


Figure 5 Changes in energy-saving behaviour during and after the 2021–2023 energy crisis by country and respondent group. a) Percentage of households in each country who reported adopting at least one energy-saving action during the crisis and continuing at least one of those actions after it, based on respondents with consistent responses across both questions. b) Among households whose responses expanded post-crisis, the percentage who continued previous actions and/or adopted new ones. Continued and newly added behaviours are shown as stacked bars. Percentages are calculated within each consistency group by country.

Regression analysis (Table 1) shows financial burden as the strongest predictor of both adoption and persistence, with a clear dose–response relationship [8]. Income adequacy also independently predicted both outcomes. Retired individuals, part-time workers, and single parents were more likely to adopt and maintain behaviours, whereas unemployed individuals were significantly less likely. Cross-country differences were again notable: Italy, Romania, and Czechia showed higher levels of behavioural change, while Finland and Estonia showed lower levels.

Table 1 Summary of regression models

Model type	Model outcome	N	Variance Explained
Logistic	Adoption during crisis (any action)	9187	Nagelkerke $R^2 = 0.137$ Accuracy = 67.6%
Logistic	Continuation after crisis (any action)	7762	Nagelkerke $R^2 = 0.078$ Accuracy = 64.3%
Logistic	Continuation of same actions only	6845	Nagelkerke $R^2 = 0.079$ Accuracy = 64.0%
Poisson	Number of actions during crisis	9187	Deviance explained: 14.9%
Poisson	Number of actions after crisis	7762	Deviance explained: 15.7%

These findings suggest that behavioural adaptation often reflected constrained circumstances rather than purely voluntary action. Financially burdened households were more likely to persist with restrictive measures, indicating both resilience and limited alternatives. While intent cannot be determined, the data raise important questions about the role of structural conditions in long-term behaviour change.

In the context of a just energy transition, these patterns suggest financially vulnerable groups may require targeted support. Relevant interventions include financial aid (e.g. energy allowances, social tariffs), infrastructure improvements (e.g. retrofits), and behavioural support (e.g. energy advice, default settings) [9]. Behavioural policies must also be sensitive to inequality and avoid assuming behavioural freedom where structural constraints exist [10].

Cross-country comparison highlights the importance of contextualising behavioural policies [11]. Countries with stronger safety nets or existing efficiency programmes may have alleviated the need for continued restrictive behaviours. In contrast, countries with weaker support structures, like Italy and Romania, saw both higher adoption and continuation—potentially reflecting fewer options during the crisis [12]. For instance, Finland—despite offering relatively generous general social protections—showed lower reported adoption and continuation of energy-saving behaviours, whereas countries like Italy and Romania, which experienced sharper price shocks and had fewer targeted relief schemes, exhibited both high adoption and high persistence. While it remains unclear whether continuation was driven by choice or necessity, these differences highlight the importance of national policy contexts in shaping behavioural trajectories [13].

These results call for coordinated EU-level strategies that acknowledge national disparities in vulnerability and policy capacity [14]. Energy-saving actions must be seen not just as environmental behaviours but also as signals of unmet needs [15].

CONCLUSIONS

This study offers cross-national evidence that many energy-saving behaviours during the energy crisis were shaped by financial pressure rather than environmental motivation.



Persistent behaviours—especially among vulnerable groups—often reflect necessity rather than proactive change.

Energy-saving actions should thus be recognised not only as mitigation strategies but as indicators of structural need. Country-specific patterns further underscore the influence of national contexts and the importance of tailored policy responses.

A fair and inclusive energy transition will require both EU-wide coordination and targeted national support. Future work should integrate self-reported behaviours with actual energy-use data and assess long-term impacts to inform equitable policy design.

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Sufficiency and collaborative foresight for a just and secure hydrogen transition: integrating social preferences into energy system modelling

Themes 2, 3 and 6, sub-topics 2c), 3a) and 6a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Hydrogen, Decarbonisation pathways, Energy system optimisation model, Discrete choice experiment, Participatory multi-criteria analysis

Extended abstract

CONTEXT AND MOTIVATION

Hydrogen has emerged as a potential “missing link” in low-carbon transitions, with EU and French strategies placing it at the core of future decarbonisation and energy system resilience. Yet its large-scale deployment faces significant barriers, including techno-economic constraints [1], industrial limitations, socio-environmental concerns [2], political challenges, and strategic vulnerabilities such as resource dependencies [3] and trade risks. Furthermore, the development of a global hydrogen market risks perpetuating patterns of ecological unequal exchange, with exporting regions disproportionately bearing water, land and energy burdens [4].

In this context, although sufficiency strategies⁷ [5] are occasionally cited as a way to reduce pressure on the hydrogen value chain [6], their potential to moderate demand and prioritise essential uses remains largely unexplored in energy modelling studies. A second major gap in the literature lies in the limited integration of social sciences into these models. In the case of hydrogen, recent studies call for participatory foresight exercises that engage citizens in shaping and assessing future transition pathways, moving beyond expert-driven methodologies to incorporate diverse societal preferences into long-term planning [7–9].

⁷ Sufficiency policies are defined by the IPCC as a set of measures and daily practices to avoid the demand for energy, materials, land, water, and other natural resources while delivering wellbeing for all within planetary boundaries.



This study explores how sufficiency strategies and social preferences can reshape hydrogen futures in France. Four long-term decarbonisation scenarios are modelled, combining varying policy ambitions and sufficiency assumptions. In a second step, the modelling is extended by integrating citizens' preferences, first to weight a multi-criteria evaluation of the four scenarios, then to inform the optimisation process and generate refined, socially aligned transition pathways.

METHODOLOGY

The proposed approach combines prospective energy system modelling with participatory multi-criteria analysis and stated preference methods. We use KiNESYS-IFPEN, a TIMES-based⁸ global optimisation model covering 29 regions, including France. The model minimises total system cost while meeting energy demand and respecting emissions targets. It integrates a broad portfolio of existing and emerging hydrogen technologies, allowing competition between supply routes and across end-use sectors. Its regional structure explicitly captures energy trade flows between world regions.

Four scenarios are defined (Table 1) to assess the impact of sufficiency measures on the French energy system and particularly on the hydrogen value chain.

Table 1. Scenario overview table

Scenario	Emissions reduction trajectory	Other energy and climate policies	Sufficiency strategies
S1 – Current policies	Moderate decarbonisation (AME)	PPE + EU binding objectives	None
S2 – Current policies + Sufficiency	Moderate decarbonisation (AME)	PPE + EU binding objectives	CLEVER
S3 – Net-zero	Net-zero by 2050 (SNBC)	PPE + EU binding objectives + SNBC objectives	None
S4 – Net-zero + Sufficiency	Net-zero by 2050 (SNBC)	PPE + EU binding objectives + SNBC objectives	CLEVER

Sufficiency measures are implemented across four major hydrogen end-use sectors: industry, heavy-duty road transport, aviation, and maritime. These assumptions are derived from the CLEVER scenario, a low energy demand scenario built using country-level bottom-up modelling [11].

- Scenarios are evaluated using a multi-criteria analysis based on six pillars:
- Economic costs reduction: Total energy system cost.
- Climate impact mitigation: Total CO₂ emissions of the energy system.
- Environmental justice: Composite index of procedural and distributive justice related to energy imports, a dimension rarely integrated into quantitative scenario assessment.
- Energy strategic autonomy: Dependence on imported energy commodities.
- Raw materials security: Reliance on critical raw materials and associated supply risks.
- Preservation of lifestyles: Variation in energy service demands.

⁸ For the full documentation of TIMES, see [10].



To integrate citizens' preferences, each criterion is weighted based on a Discrete Choice Experiment (DCE) conducted with a representative sample of French citizens. DCEs are stated preference methods in which individuals choose between sets of hypothetical policy options characterised by multiple attributes. In our case, the attributes correspond to the six evaluation pillars listed above (Table 2). The results allow us to determine the relative importance of each criterion in societal preferences, which are then used both to rank scenarios and, at a later stage, to inform the optimisation of the energy system model through a new composite objective function.

Table 2. Example of choices set for the Discrete Choice Experiment (DCE).

Criteria	Alternative A	Alternative B	Status Quo
Economic viability	+2% in total energy system costs	-4% in total energy system costs	No change
Climate mitigation	-18% in CO ₂ emissions	-7% in CO ₂ emissions	No change
Environmental justice	+10% improvement in justice index	+2% improvement in justice index	No change
Strategic autonomy	-10% in energy import dependence	-5% in energy import dependence	No change
Raw materials security	+5% in material security	-2% in material security	No change
Preservation of lifestyles	+5% in energy service levels (e.g. plane travel)	-30% in energy service levels	No change

MAIN RESULTS, CONCLUSIONS AND ASPIRATIONS

Preliminary modelling results suggest that hydrogen may play a necessary role in meeting French and EU energy and climate objectives across all decarbonisation pathways. However, the inclusion of sufficiency strategies significantly alters the scale and composition of hydrogen demand, particularly by reducing reliance on e-fuels in the aviation sector. This, in turn, mitigates the need for hydrogen imports and reduces pressure on domestic hydrogen infrastructure (Fig. 1).

In the *Current Policies* scenario (S1), net imports of energy commodities remain high, reaching around 650 TWh in 2050. This dependency is moderately reduced in the *Net-Zero* scenario (S3), by approximately 125 TWh. When sufficiency strategies are added (S4), imports fall more substantially, to below 300 TWh, mainly due to reduced oil product consumption (Fig. 2), a majority of which originates from countries in the Global South (Fig. 3). These shifts are reflected in the *energy strategic autonomy* criterion (Fig. 4), which scores highest in scenarios with sufficiency measures.

The multi-criteria analysis (Fig. 4) suggests that a net-zero trajectory incorporating sufficiency strategies (S4), offer a more balanced performance across several dimensions. S4 outperforms other scenarios in climate mitigation, environmental justice, and strategic autonomy, while maintaining acceptable trade-offs in economic cost and material security. However, such pathways entail significant shifts in energy service demands, requiring coordinated societal and policy changes to support transitions in mobility, consumption patterns, and industrial use.



Future work will focus on three major directions. First, we aim to refine the calculation of evaluation criteria, ensuring consistency and comparability across scenarios. Second, the upcoming Discrete Choice Experiment (DCE) will be conducted to empirically determine citizen preferences, enabling us to rank scenarios based on societal values. Third, beyond ranking, we will operationalise these preferences within a novel optimisation framework. By replacing the standard cost-minimisation objective of KiNESYS-IFPEN with a composite function informed by the DCE results, we will generate new, socially aligned transition pathways for the hydrogen sector in France.

This approach remains subject to limitations, notably in the selection and number of evaluation criteria, which must be constrained for feasibility within the DCE framework. Moreover, not all relevant dimensions of justice or environmental impact can be fully assessed within the boundaries of the model.

Figure 6. Evolution of hydrogen supply (positive values on the y-axis, MtH2) and demand (negative values on the y-axis, MtH2) in France across the four scenarios defined in Table 1. Note: hydrogen co-production and dedicated production for refineries are excluded.

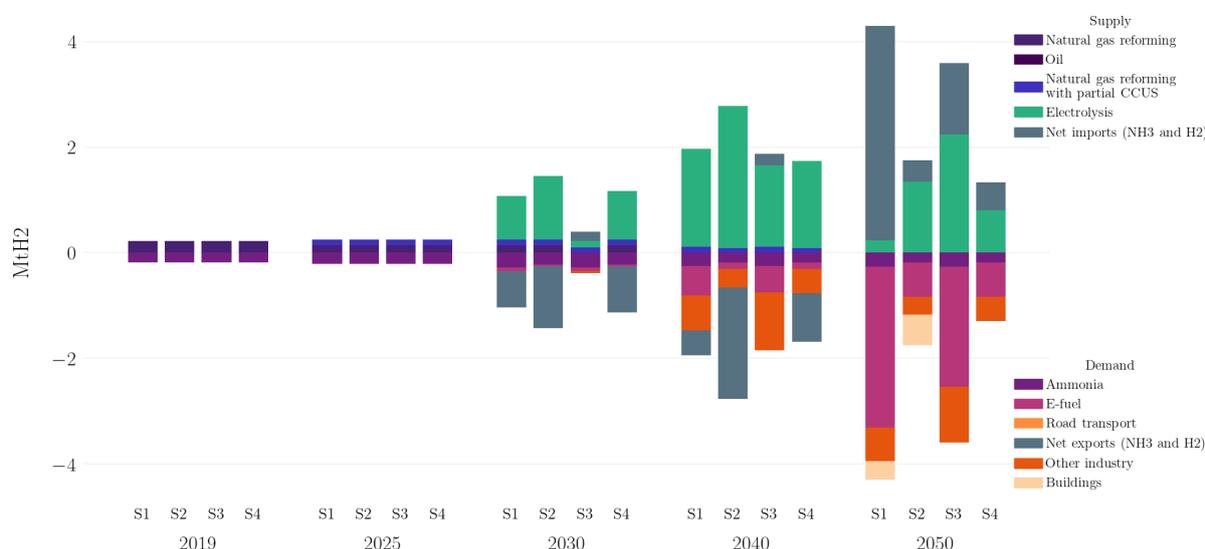


Figure 7. Comparison of energy product imports (TWh) in France in 2050 under scenarios S1, S3, and S4, disaggregated by energy carrier.

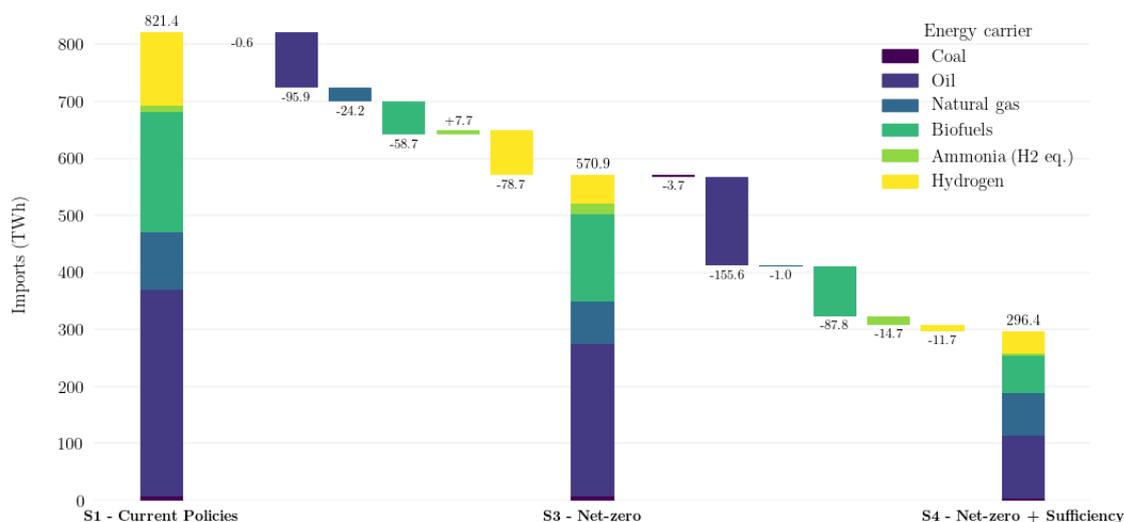


Figure 8. Comparison of energy product imports (TWh) in France in 2050 under scenarios S1, S3, and S4, disaggregated by exporting world region.

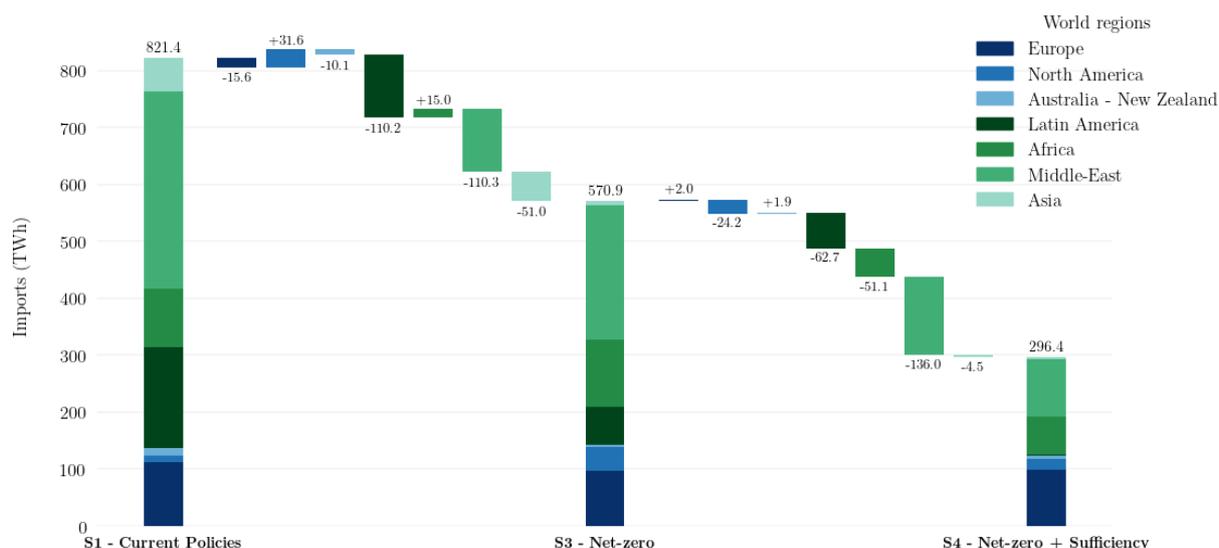
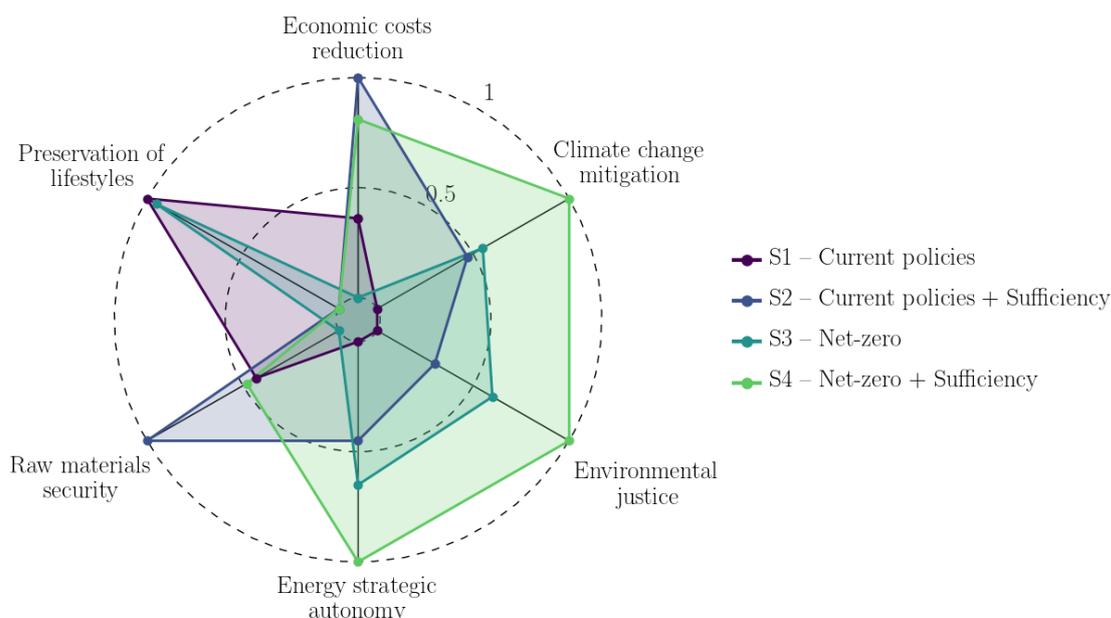


Figure 9. Multi-criteria performance of the four baseline scenarios presented in Table 1. Scores are normalised for each of the six criteria, ranging from 0 (lowest-performing scenario) to 1 (highest-performing scenario).



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Breaking Barriers: Rethinking Policy Instruments for Voluntary Climate-Friendly Behavioural Change

Theme 1, sub-topic 1d) (12 font size)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Evaluation, Behaviour, Ecological transition, Climate, Barriers

Extended abstract

There is a collective agreement on the necessity of combining different actions carried out by different actors at different levels to achieve carbon neutrality. Although the focus was initially on infrastructural and technological changes in agricultural, industrial or mobility systems, the recent years have seen an increased attention to individual lifestyles and behaviours. The International Panel on Climate change (IPCC) typically insisted in its 6th report [1] that combining technical and behavioural instruments in this area could result in a 40-70% reduction in greenhouse gas emissions (GHG) by 2050.

Policy instruments aimed at influencing individual or collective behaviours are certainly not new [2]. However, their use has soared in recent years on the wake of the development of social psychology, behavioural economics, and ‘nudge’ approaches in policy [3]. Examples now abound of their use to support the development of climate-friendly practices. In a 2019 study, Howlett & Rawat identified “five kinds of behavioural tools [...] most commonly used in relation to climate change policy: provision of information, use of social norms, goal setting, default rules, and framing” [4].

This communication draws on a study [5] commissioned by the French Agency for the Ecological Transition (ADEME), in which an interdisciplinary group of social science researchers and evaluators has been working on the identification of the types of policy instruments aimed at supporting voluntary behavioural change (VBC) most frequently deployed in France [7] and on their evaluation.

The study has raised three questions, the answers to which forming the basis of this communication:



- What does the literature on behavioural interventions tell about the potential impact of VBC instruments in the area of sustainable transitions?
- How far are VBC instruments deployed in real-life settings evaluated? In what ways?
- What do these evaluations tell about the real-life impact of VBC instruments in the area of sustainable transitions?

Different tools were used to answer these questions, including an interdisciplinary review of the literature, at the nexus of social psychology, behavioural economics, sociology, policy analysis and programme evaluation; and the identification and synthesis of existing evaluations of real-life VBC instruments in France and abroad in the area of sustainable transitions. Subsequent findings were then discussed with a community bringing together researchers and practitioners.

Preliminary evidence suggests that existing knowledge remains of limited use to evaluate the impact of VBC instruments in the area of sustainable transitions, for several reasons: 1) most available knowledge is based on experiments in controlled settings, in which real-life conditions associated with effectiveness are not tested [8][9]; 2) knowledge is mostly available in the area of social and health policies and it is only of limited validity in the ecological transition area [10]; 3) the literature is mostly concerned with individual barriers to change, despite the recognised multi-level nature of these barriers in the sustainability area, 4) most VBC instruments are used in combination with other instruments, or as part of broader sustainability policies, but the complementarity aspects are hardly discussed in the literature; 5) existing evaluations of real-life VBC remain limited in number and ambition and do not fill the above-mentioned knowledge gaps.

These limitations may raise concerns in terms of the relevance of using behavioural instruments for sustainability purposes, the potentially limited adequacy of the behaviour change techniques [11] being deployed, and ultimately the possibility to improve these instruments to trigger genuine behavioural changes.

In response to the above challenges, a new framework is being presented. It is designed with a view to help analyse VBC instruments in the sustainability area, and evaluate them. It draws on the heuristic value of the transtheoretical model [12][13] [12][13]; considers the variety of barriers to change in this area, and their combination; and the potential use of VBC instruments in combination with other instruments or as part of broader sustainability policies. The framework is tested on the five families of VBC instruments most frequently deployed in France, which have been identified in a first work of inventory also commissioned by the ADEME [6] : workshops, challenges, personalized support, digital tools, and community building. We anticipate that our study will provide actionable insights for improving the design, choice, implementation, and evaluation of VBC instruments.

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Flexibility for All? Unpacking Readiness and Equity in Demand Side Management

Theme 2, sub-topic 2b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Demand Side Management (DSM), Flexibility, Diversity, Social License to Automate (SLA)

Extended abstract

Demand Side Management (DSM) plays a key role in the energy transition by helping balance the volatility of decentralized, renewable energy. It allows households to benefit from cheaper, locally produced energy during times of surplus. However, energy flexibility—central to DSM—has a strong social dimension. Understanding how flexibility relates to diversity factors such as income, housing, or family status is essential to designing inclusive programs and avoiding the exclusion of vulnerable groups from affordable energy access. The concept of a social license, originally from the mining sector, highlights the importance of legitimacy, credibility, and trust (Boutilier & Thomson, 2011). Applied to automated DSM (Adams et al., 2021), it underscores that meaningful, ongoing public acceptance depends on recognising social practices, routines, habits, and users’ desire for agency—rather than treating flexibility as a mere commodity.

Assessing residential energy flexibility requires considering both appliance use and user behavior, as identical devices can show different potentials depending on how they're used (Afzalan & Jazizadeh, 2019). Flexibility depends on social, cultural, and economic factors—what Powells and Fell (2019) term “flexibility capital” as “the capacity to responsively change patterns of interaction with a system to support the operation of that system”. Wealthier households typically have more options, so a DSM policy or program that overlooks this matter risks reinforcing existing inequalities. Libertson (2022) adds that flexibility is also tied to social status and critiques demand-side technologies for assuming



that all users are rational and equal, an assumption that often disadvantages lower-income households.

To address the social dimension of DSM within its cultural and economic contexts and support a just and inclusive transition, the *Social License to Automate 2.0* task of IEA Users Technology Collaboration Programme developed a *flexibility readiness framework*. The framework builds on several supporting activities including a literature review on how diversity dimensions affect DSM participation (Henriksen et al., 2025), a diversity-focused analysis on energy saving actions of the Flash Eurobarometer 514 data (Eakins et al., 2025), energy profile data analyses to understand diversity-specific consumption differences (Garzon et al., 2023), and research into social dimensions of energy communities (Martin’s et al., 2024). The full Task report provides an overview on the complete results (Diamond et al., 2024).

Methodology. The framework was developed through a multi-stage, collaborative process, drawing on findings from other SLA2.0 activities. Based on a synthesis of existing theoretical perspectives, flexibility readiness was defined as “the readiness to modify one’s energy use in time, space, or intensity to accommodate specific needs regarding power consumption”—including shifting, relocating, or adjusting the intensity of use (adapted from Libertson, 2022). Diversity dimensions—such as gender, income, age, family status, and housing—were selected based on project research and prior findings (Henriksen et al., 2025). Expert workshops (5–7 participants) identified key flexibility factors per dimension, created expressions of low, medium, and high willingness to support tangible understanding, and mapped socio-demographic traits to these factors, forming the basis for the framework. This mapping informed the definition of three flexibility readiness profiles. The final framework and profiles were validated and refined in a concluding workshop.

Results. Based on insights from the literature and expert knowledge, three core dimensions of flexibility were defined, impacting the *flexibility readiness* of consumers:

- *Flexibility Capacity:* Involves the physical potential for flexibility, including prosumer technologies (e.g., solar panels), household loads (e.g., appliances), enabling technologies (e.g. home energy management systems), and temporal capacity (available time to engage in flexibility).
- *Flexibility Ability:* Considers the awareness, information accessibility, knowledge, skills, energy practices (when, where and what for energy is consumed) and flexibility of said practices. In this context, ability to control energy practices and ability to transform (ability to change conditions to improve flexibility) also play important roles.
- *Flexibility Willingness:* This refers to the user's motivation to engage in flexibility, influenced by perceived benefits (e.g. provided through incentivisation), technology affinity, and social norms.

Our research showed that these dimensions and factors show noticeable variation across social groups: Positively, men often exhibit higher technical flexibility capacity through greater access to enabling and prosumer technologies, while women tend to have higher temporal capacity. Households with young children show increased capacity linked to household loads. Homeownership and higher income boost flexibility capacity via access to advanced technologies and energy loads. Middle-aged individuals display enhanced flexibility ability due to their knowledge and control over energy use, with women showing strong awareness and practice-based flexibility. Men often dominate in skills and



transformative capacity, supported by financial means and decision-making power. Willingness to engage is higher among men, driven by technology affinity and financial incentives, whereas women are motivated more by environmental and social factors. Higher-income and medium-income households, as well as young, tech-affine individuals, also demonstrate strong willingness, supported by homeownership and access to incentives. Conversely, low-income households, tenants, and those with young children face barriers including limited access to prosumer and enabling technologies, reduced control, lack of information, and skill deficits that constrain flexibility. Older adults show lower willingness due to low digital literacy, while low-income groups often find limited benefits, reducing their motivation to participate.

Flexibility readiness can therefore be grouped into the following three levels:

- *High readiness*: tech-savvy, higher-income, homeowners with flexible schedules; men favour technology and finance incentives, women lean toward manual flexibility and social/environmental motives.
- *Medium readiness*: groups with potential but limited by access or challenging routines, including young people, households with children, and tenants.
- *Low readiness*: low-income and older households facing financial, informational, and routine barriers, especially older women and those affected by language issues.

These profiles show that *flexibility readiness* is shaped by intersecting factors such as income, age, gender, and housing status, shifting household positions up or down the readiness scale.

Conclusion. The *flexibility readiness framework* can offer valuable insights into how households can adapt energy use to support system needs. However, focusing solely on individual flexibility—especially when tied to technological resources—risks reinforcing inequalities and overlooking the broader imperative of reducing overall energy demand. This is where the concepts of sufficiency and sobriety are crucial: DSM should not only aim to shift consumption in time, but also reduce it to ecologically sustainable levels (Guillard, 2021; Thomas et al., 2019). Without this, DSM programs risk privileging high-consumption households with the means to automate, rather than encouraging restrained, conscious energy practices.

Embedding DSM in community contexts can strengthen both flexibility and sufficiency with shared goals like optimizing local renewable energy, autonomy, and energy solidarity fostering more inclusive engagement. Framing flexibility as part of a collective effort to reduce dependence on the grid encourages more conscious and cooperative consumption practices, moving beyond individual performance toward broader ecological responsibility. *Flexibility readiness* should therefore also assess how practices align with sufficiency and social values—not just technical responsiveness—to ensure DSM contributes meaningfully to climate goals and systemic change.

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Trade-offs in Sustainable Food Consumption

Insights from a choice-based conjoint experiment on eco-attributes in apple purchase decisions

“Academic contribution”

“Policy/practice contribution”

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Keywords: Consumer Behavior, Sustainable Food Consumption, Sufficiency, Choice-Based Conjoint Analysis, Trade-Offs, Eco-Attributes

Extended abstract

In the face of climate change and ambitious ecological objectives, sufficiency is increasingly gaining traction as a necessary complement to efficiency and substitution in sustainable transformation processes. Food producers and retailers are also coming under rising pressure to meet established sustainability goals and to conserve resources across their entire supply chains. The production and distribution of fruits and vegetables, in particular, contribute substantially to ecological burdens: long-distance transport spanning thousands of kilometers, combined with energy-intensive storage—such as refrigerated shipping across oceans—are significant CO₂ drivers[1]. At the same time, conventional farming practices often involve extensive monocultures with high pesticide use, which accelerate biodiversity loss [2]. Besides that, single-use packaging is a crucial environmental factor. Plastic packaging is still essential in the food industry due to its hygienic properties, protective function, storage stability, and low cost[3]. However, it accounts for more than one-third of global plastic consumption and is a major contributor to pollution.[4] Its short lifespan and careless disposal often cause serious ecological harm, ranging from the massive accumulation of plastic waste to contamination of ecosystems.[4]

Although consumers show increasing interest in sustainable products and environmental issues[5], many food manufacturers and retailers hesitate to adopt sufficiency-oriented or resource-saving practices due to fear of additional costs and adverse market reactions. Understanding consumers' trade-offs in favor of sustainability is essential to developing a more effective and sufficient transformation[6]. This is particularly true in food purchasing, where decisions often involve complex trade-offs between ecological ideals, price sensitivity, convenience, and other product attributes[7]. Knowing how individuals evaluate and prioritize these factors is vital for designing products, assortments, and marketing approaches that support sustainable consumption.



Fresh produce like apples provides an ideal context for analyzing such decision-making processes. Apples are among the most frequently purchased food items; consumers are very familiar with them, and they come in many forms that clearly convey environmental signals, such as packaging type, origin, or production type (e.g., organic certification). Despite the growing availability of sustainable alternatives, we have limited knowledge of which ecological features consumers prioritize and how far they are willing to go to make sufficiency-oriented choices, even if it means sacrificing comfort or paying higher prices[8].

To address this gap, our study investigates which product characteristics and ecological attributes influence consumer preferences when buying apples, and which compromises they are willing to make for more sustainable options. Part of the survey was a choice-based conjoint (CBC) experiment, in which participants were repeatedly presented with sets of four apple product profiles that systematically varied across five attributes. Participants were asked to select the product they would most likely purchase for each set. In a second step (dual-response format), they were additionally given the option to reject all presented products by selecting a “none” option. The apple profiles varied systematically along five central product attributes:

- Origin (From the Region, Germany, Italy, New Zealand)
- Packaging (unpackaged, paper, bioplastic, conventional plastic)
- Point of sale (supermarket, discounter, farmers’ market, organic store)
- Certification (none, EU organic, Bioland)
- Price

For origin, we selected four levels representing a range of environmental implications associated with transport and seasonality: apples from the region, Germany, Italy (as an example of intra-European import), and New Zealand (as a long-distance overseas import). For packaging, we included unpackaged, paper, bioplastic, and conventional plastic options. These alternatives were chosen based on current market availability and guided by the packaging classification matrix by Burgstaller et al.[9], which categorizes materials according to their raw material source (fossil-based vs. renewable) and biodegradability. The point of sale included supermarkets, discounters, organic food stores, and farmers’ markets—reflecting the most common food retail formats in Germany, which differ in terms of accessibility, price level, and perceived sustainability. For certification, we distinguished between no certification (conventional), the EU organic label, and Bioland, one of Germany’s most recognized and stricter organic certifications[10]. Finally, price levels were defined in alignment with actual retail prices for apples in Germany and varied systematically to allow for an estimation of price sensitivity across the different product profiles. Figure 1 shows an example of a conjoint choice set.



Which of the apples shown here would you buy?

			
From New Zealand	From Germany	From Italy	From the Region
Unpacked	Bioplastic Packaging	Plastic Packaging	Paper packaging
Point of Sale: Supermarket	Point of Sale: organic store	Point of Sale: farmers' market	Point of Sale: Discounter
			
1.39 €	2.49 €	3.50 €	2.39 €
Select	Select	Select	Select

Would you really buy the selected product?

Yes No

Figure 1: Example of conjoint choice set.

A quantitative online survey was conducted with 948 German consumers. Part-worth utilities were estimated using a hierarchical Bayes approach to analyze the CBC data. Based on these estimates, we assessed the relative importance of each product attribute, analyzed combinations of features, and compared them to provide nuanced insights into how consumers rank trade-offs. Results show that origin had the greatest influence on choice behavior, followed by point of sale, packaging, and price. Organic certification played a minimal role. Apples from the region, German apples, and unpackaged apples received the highest evaluations. On the other hand, plastic-packaged apples and imports from New Zealand were firmly rejected.

Examining utility combinations reveals how consumers balance ecological signals with other factors. For example, unpackaged apples with a high price were rated more favorably than low-priced apples in plastic packaging. Likewise, conventionally grown but unpackaged apples were preferred over Bioland-certified apples in paper packaging. These findings indicate that consumers are willing to make trade-offs and perceive sustainability as added value. They are guided by a sufficiency logic that prioritizes simplicity, visibility, and ecological coherence over abstract certification or reduced cost.

In conclusion, sustainable food choices reflect a complex interplay of perceptions, practical considerations, and the visibility of ecological benefits. Our choice-based conjoint experiment shows that sufficiency-oriented preferences are measurably present in many consumers' everyday decisions, particularly when ecological attributes, such as regional origin or plastic-free packaging, are available, clearly communicated, and easily understood. The results bear

several practical implications. First, price was less important than expected, suggesting that sustainable improvements do not always require financial compensation to gain consumer acceptance. Second, the consistently high utility values for regional and unpackaged products indicate a demand for simpler, low-impact options. This supports the idea that reducing product variety, limiting long-distance imports, and eliminating unnecessary or overpacked products could serve environmental goals while aligning with consumer preferences. The full results will be presented for the first time at the BEHAVE 2025 in Paris.

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Exposing ‘energy injustice gaps’: the case of young adults in Paris.

Theme 2, sub-topic 2b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy vulnerability, Energy justice, Housing market, Institutions

Extended abstract

1. INTRODUCTION

Young adults living in large cities often inhabit energy-inefficient housing and struggle to afford energy services, placing them at risk of energy poverty (EP). However, this issue is frequently overlooked in both in EP measurement and public policy. On the one hand the problem is widespread and is therefore often considered as a situation usually faced by younger people [1]. On the other hand, young adults supposedly face a lower risk of severe health effects are supposed to be lower than for older people and they often do not recognise themselves as energy poor [2].

Our research examines the energy poverty difficulties faced by young people living in Paris. While young households are not often identified as energy poor, we demonstrate that they encounter unique vulnerabilities in their energy usage. Adopting an energy justice perspective, we investigate the extent to which injustices in the functioning of housing markets and institutions cause energy vulnerability among young adults. Specifically, we show how housing inequalities, limited access to certain rights and a lack of recognition of their specific needs result in energy injustices that can severely impact the daily lives of young adults.

We first show that energy vulnerability issues experienced by young adults may require a distinct approach compared to other population groups and develop the concepts of energy vulnerability and energy injustice in relation to this group (2). We then examine the role of housing markets and of institutions in producing the energy injustices faced by this group (3). We finally discuss the energy injustice “gaps” faced by young adults as an urban issue (4).

2. ENERGY VULNERABILITY OF YOUNG ADULTS: A PROBLEM IN NEED OF A SPECIFIC APPROACH?

Vulnerability is usually analysed through three dimensions [3]: exposure, sensitivity and capacity of response. Energy vulnerability (EV), which can be viewed as the risk of falling into energy poverty, involves several dimensions. In terms of exposure, EV may relate to high indoor temperatures in summer, and low temperatures in winter. In terms of sensitivity, EV



may be related to certain threats, such as the economic risks faced by certain households with low incomes. In terms of capacity of response, EV raises questions such as how certain types of households can deal with high energy bills, with income variations, and with inadequate housing conditions and a lack of choice regarding heating equipment and thermal insulation and fewer opportunities to benefit from certain assistance schemes.

Conversely, the concept of energy injustice (EI) relates to aspects that create differences that perceived as unfair [4]. EI can be analysed along three dimensions stabilised in the literature [5]: distributive, procedural and recognition justice.

Young adults share some common characteristics with regard to EV factors. The transition to adulthood involves learning to live independently [6]. Practically speaking, this means finding one's own place, managing a budget, paying bills, and receiving less support from one's parents. This learning process also applies to developing new practices, habits and understandings, and applied to energy use, it can influence future lifestyles.

However, young adults are not a homogeneous group [7], suggesting that different forms of EV may exist, depending on the group considered: students (who may be local or international), employed young adults, and young adults who are neither in education, employment, nor training (NEET). These groups differ in terms of income and autonomy, both financial and in terms of the material support they receive from relatives. These groups also differ in terms of their schedules and how they use urban amenities. Finally, these groups can differ in terms of social ties [8], resulting not only in different material circumstances, but also in different levels of social support, such as that provided by parents. These differences may result in specific energy injustices. For example, energy assistance schemes are often inaccessible to students. The way in which different groups interact with institutions can vary, as can the recognition of their specific needs.

3. HOUSING MARKETS AND INSTITUTIONS AS “PRODUCERS” OF ENERGY INJUSTICE

Based on an analysis of the academic and grey literature, as well as semi-structured interviews with stakeholders involved in research and policy implementation, we have identified two main “producers” of EI.

On the one hand, the local housing market [9] has specific impacts on young adults, through tensions on the segment of small flats, a significant proportion of substandard housing, financialisation of the housing market for students and the development of AirBnB, which has reduced the supply of affordable housing. Young adults often rent dwellings on the top floors which are equipped with inefficient electric heating.

On the other hand, young adults are dependent on formal and informal institutions that can exacerbate their energy vulnerability. For example, access to assistance schemes is usually designed for families. Furthermore, there appears to be an informal norm according to which it is acceptable to live in poor housing conditions while young.

4. ENERGY INJUSTICE GAPS FACED BY YOUNG ADULTS AS AN URBAN ISSUE

At city level, we identify three types of EI gaps.

The distributional EI gap is driven by both housing inequality within Paris, which can result in unequal energy burdens, and the need to use additional, often electric, heaters. It is also driven by differences in access to energy assistance schemes, with young households mostly



not benefitting from the “Chèque énergie”. Cold or excessively warm homes can impact the ability to study at home, potentially impacting academic achievement.

The procedural EI gap relates to knowledge of where assistance information is available and how to access it. There may also be procedural inequalities relating to the possibility given to residents to express their needs in collective residences, and to receive help with simple repairs. Finally, the timing and spatial availability of some mechanisms is not adapted to the needs and constraints of young adults.

The recognition EI gap may be related to informal norms such as the widespread belief that young adults do not require high levels of thermal comfort. In terms of formal rules, we have identified a gap that disadvantages foreign students. This group might require specific advice, to help them navigate the French administrative system. In terms of time and place, the specific needs of students who require warm spaces in which to study during the winter period are also not recognised.

5. CONCLUSION

Although young adults are often absent from statistical analyses and policy approaches relating to energy poverty, our work suggests that the poor access to thermal comfort and to affordable energy is a problem for many young adults in Paris. Analysing their difficulties through the lens of energy vulnerability is a promising approach, as it focuses not only on actual energy poverty, but also on this group’s exposure to the risk of becoming energy poor, either temporarily or permanently. Our discussions with stakeholders on the various factors contributing to energy vulnerability, their correlates and the injustices that may affect young adults contribute to the general research agenda on energy justice [10; 4].

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Public Acceptance of Building Decarbonization Measures - A Systematic Literature Review

Theme 3, sub-topic 3b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Demand Flexibility, Demand Response, Social Acceptance, Public Acceptance, User Perspectives, Energy Policy

Extended abstract

Introduction and Motivation:

Buildings account for about 40% of the EU’s total energy use and nearly a third of its greenhouse gas emissions [1]. Decarbonising this sector is therefore essential for meeting Europe’s climate goals. Achieving this requires more than technical upgrades — improved energy efficiency, lower heating loads, and greater demand-side flexibility are all needed [2]. Stronger building performance cuts emissions, lowers costs, and reduces fossil fuel dependence [3]. Making buildings more flexible also helps balance supply and demand as variable renewables expand.

However, technical and infrastructural solutions alone are not sufficient. Real-world success depends on the willingness of people to accept, adopt, and adapt to these measures in their daily lives. Policies promoting retrofits, smart thermostats, EV chargers, or heat pumps inevitably require participation from building owners, tenants, and households. Without widespread public support, even the best-designed interventions risk delays, limited uptake, or outright rejection [4]. Fostering acceptance is therefore not an optional add-on but a core condition for meaningful decarbonisation. Understanding people’s preferences, motivations, and concerns enables policymakers to craft measures that are not only technically sound but also perceived as fair, practical, and beneficial [5]. Strong public acceptance can amplify the effectiveness of technological solutions by encouraging complementary behavioural changes, such as shifting energy use in response to real-time pricing or actively participating in demand-response programs [6]. Conversely, poorly designed policies that ignore social acceptance risk backlash, resistance, and missed climate targets.

While many studies assess technical and economic impacts, fewer explore how people perceive these measures. Existing research often focuses narrowly — on retrofits [7] or pricing [8] — without connecting findings across contexts. Factors like cost, trust, fairness, and responsibility all shape support. To make decarbonisation socially viable, fragmented evidence must be brought together to guide better policies and future research.

Research Questions & Objectives:

This study aims to lay the groundwork for future research on how to foster public acceptance of policies and interventions designed to improve the energy efficiency and flexibility of buildings. By synthesising what is already known, the project seeks to clarify which factors shape public support or resistance and how these insights can inform policy design and implementation.

The central question is: *What factors influence public acceptance of decarbonisation measures, and how can these insights guide more effective policies?*

To answer this, the project conducts a comprehensive review of studies on public acceptance in the context of building decarbonisation. This synthesis identifies common drivers and barriers, highlights research gaps, and offers practical guidance to design studies and policies that are socially robust and impactful.

Method:

This study uses a systematic literature review to map and synthesise current knowledge on public acceptance of building decarbonisation measures. Only peer-reviewed articles published in English since 2015 in OECD countries are included, focusing on concrete actions like energy efficiency upgrades, renewable integration, smart heating or cooling, direct load control, smart charging, or dynamic pricing. Searches were conducted in Scopus, Web of Science, GreenFILE, and ProQuest using combined thematic and methodological terms related to acceptance, attitudes, and user perceptions in residential contexts. Standard screening steps removed duplicates and excluded purely conceptual papers to maintain a robust empirical base. Key data — such as intervention type, acceptance drivers, and study methods — were coded to identify patterns and gaps.

Results and Key Findings:

To provide a basic overview of the review, Figure 1 shows how the final 548 studies are categorised into thematic areas, highlighting the spread across energy efficiency measures, demand flexibility and pricing, renewable energy technology and storage, smart home technologies, heating and cooling, and related sub-categories.



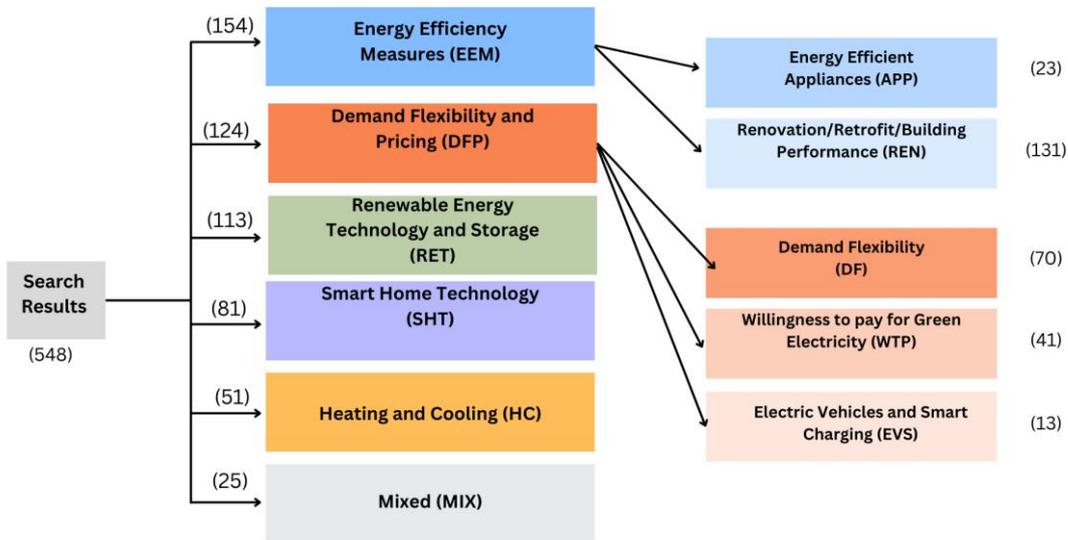


Figure 1: Categorisation of the reviewed studies by intervention type and thematic focus

Figure 2 presents the geographic distribution of the reviewed studies, showing a strong focus on Europe and North America, with additional contributions from Asia, Oceania, and other OECD regions.

Geographic Distribution

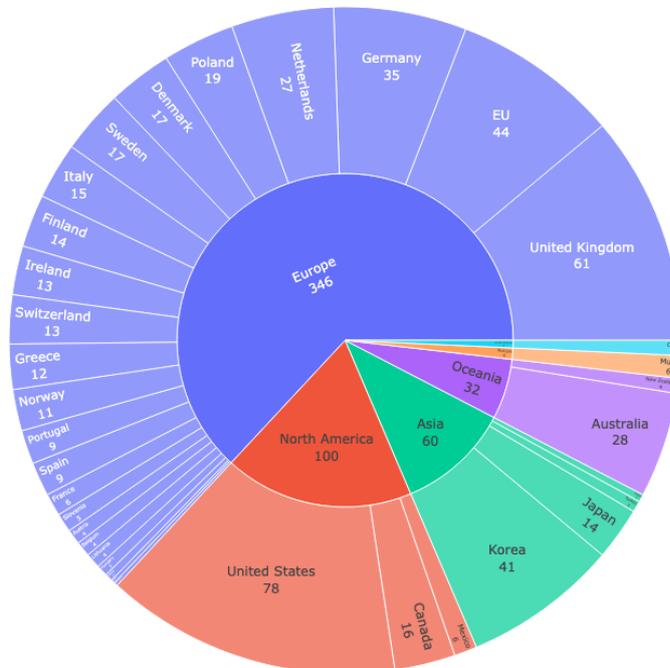


Figure 2: Geographic distribution of the reviewed studies

Across studies on building renovation and retrofits, homeowners and tenants generally show strong interest in improving energy performance. Surveys often find that over half intend to upgrade insulation, windows, or heating, and in some regions nearly half have done so in recent years. However, actual uptake lags behind intentions due to costs, trust issues, and perceived hassle. Those who do complete retrofits report high satisfaction, suggesting clear benefits like comfort and lower bills help close this gap. For heating and cooling technologies, financial incentives and trusted advice appear crucial. Environmental concern alone rarely drives adoption. Clear information on costs, savings, and performance can shift hesitant households toward investment. Satisfaction with upgrades is generally high, with comfort gains cited as a main reason for support.

For energy-efficient appliances, many consumers see the value but choices are shaped mainly by upfront costs and convenience. Labels alone have limited effect unless paired with incentives or clear savings. Social norms and information help, but adoption remains low among lower-income households without targeted support. Some studies find only 5–6% of low-income households benefit from appliance assistance, despite widespread willingness if costs are reduced.

For demand flexibility, people’s willingness to join demand-response programs depends on trust, fairness, and clear savings. Many are open to flexible tariffs or direct load control if they keep override options and see real benefits. In some trials, over half chose flexibility contracts when savings were clear, but many expect bill cuts of 10–15% to participate. Different segments exist: some households are open to experimenting, while others are highly loss-averse and want guarantees. Similarly, willingness to pay extra for green electricity is shaped by perceived fairness, trust, and clear environmental benefits. Most consumers prefer solar and wind over biomass and are willing to pay about 5% more if they believe the supply is credible and the impact clear. People with stronger environmental or altruistic values are especially likely to support paying more.

Finally, for smart home technologies and electric vehicles, convenience is the top priority. While energy efficiency is valued, users adopt smart thermostats, Home Energy Management Systems, and smart EV charging primarily for practical comfort and control. Trust in automation, the ability to override settings, and clear evidence of cost savings are essential. Many households remain unaware of these technologies or discount future savings, highlighting the need for awareness-raising and clear, user-friendly solutions.

Taken together, these findings show that public acceptance is shaped by a mix of perceived fairness, trust, convenience, control, and visible benefits. Decarbonisation measures that align with people’s daily routines, address upfront cost barriers, and offer clear and credible rewards are far more likely to gain broad support.

Conclusions and Recommendations:

This review confirms that strong public support for building decarbonisation depends on measures being fair, affordable, and convenient. To close the gap between intention and action, policies should combine clear incentives with trusted information, easy-to-use technologies, and safeguards that protect comfort and user control. Programmes should lower upfront costs through targeted subsidies, bundled retrofits, or all-inclusive service models for heat pumps and smart appliances. Demand response schemes should include override options and clear compensation to build trust.



Researchers should explore how financing models like on-bill payment, leasing, or pay-as-you-save can help spread costs. More applied work is also needed on practical ways to protect comfort and make new systems easy and reliable for diverse households. Clear communication and local advice networks can help ensure people feel confident and empowered to adopt these solutions.

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Policy Impacts on Heating System Adoption in Switzerland: Integrating individual behaviour into an agent-based model

Theme 1, sub-topic 1d) and 6a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Residential heating decarbonization, Policy effectiveness, Behavioural factors, Agent-based model (ABM)

Extended abstract

Residential heating accounts for 44 % of household energy consumption in Switzerland and over 15% of national greenhouse gas (GHG) emissions [3]. Switzerland should decrease emissions from buildings by 82 % by the year 2030 and achieve a net-zero emissions building stock by 2050 (relative to the year 1990) [19]. Electrification of heating systems, particularly through heat pumps adoption, offers a one reasonable solution to reduce residential CO₂ emissions, with benefits increasing as power grids decarbonize [15].

To accelerate heat pumps adoption, the Swiss government has implemented a range of supportive measures. As part of the Climate and Innovation Act, an annual budget of CHF 200 million is allocated for ten years to support homeowners replacing fossil-based heating systems or improving insulation [9]. Furthermore, Switzerland imposes a carbon tax of CHF 120 per tonne, with two-thirds of the revenue redistributed to citizens and businesses, benefiting those who consume less fossil fuels [7]. While heat pump adoption is increasing—reaching 21.3% of residential buildings in 2023, up from 17% in 2021—fossil fuel systems still dominate, accounting for 54.4% of residential heating in 2023 [4]. Which raises concerns about the effectiveness of existing policies.

The effectiveness of existing policy instruments on sustainable technology adoption has been extensively explored using various energy models, which serve as an effective tool for climate policy planning [21]. In Switzerland, recent studies have applied various modelling approaches—including system dynamics, S-curve fitting, and agent-based models (ABMs)—to examine the adoption of heat pumps in the residential sector. While some studies [20] find current policies sufficient to meet the decarbonization targets, others [5, 18, 22, 23] suggest additional policies may be required. Which raises the question of whether additional policy support is required to accelerate the decarbonization of residential heating.

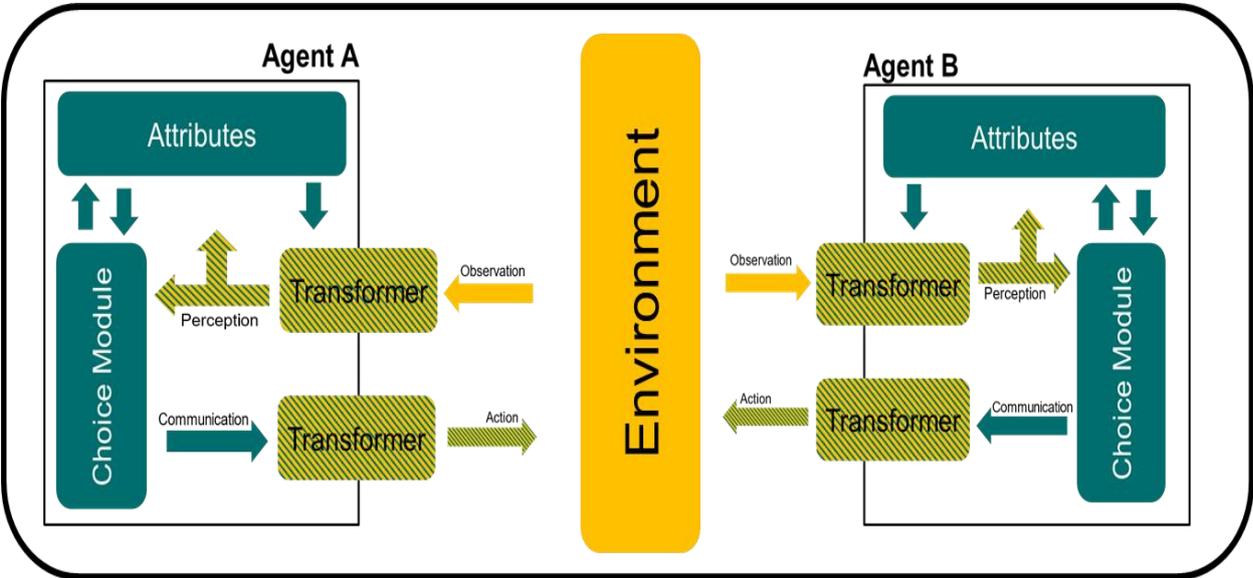
Many models focus on financial and technical factors influencing energy efficient technology adoption, while behavioral factors remain largely overlooked, which may undermine the



effectiveness of existing policies and slow adoption. A growing body of research indicates that human decision-making often deviates from full rational models due to cognitive biases such as present bias and limited attention. Instead of engaging in a thorough evaluation of costs and benefits [14, 16, 17] Individuals often rely on mental shortcuts to simplify complex decisions [6,8]. While these shortcuts can ease decision-making, they also introduce systematic biases that distort perceptions of technology attributes often leading to an overestimation of costs and an underestimation of potential benefits, ultimately hindering adoption of energy-efficient technologies [13].

Against this background, this study aims to evaluate the effectiveness of various policy instruments in promoting heat pump adoption, while explicitly accounting for behavioral factors that influence household decision-making. To do that, we adapt an existing consumer choice framework (See Figure 1)—originally designed as part of the Sweet Cosi project to capture individual behavior into energy system models [1].

Figure 1: consumer choice framework



The framework illustrates how several agents interact with each other in the environment that characterizes the information and technologies available together with the general state of the world (e.g., weather conditions, energy prices). Each agent is characterized by a set of attributes and can take decisions in the choice module. To take decisions, agents need information that are observed in the environment. However, this information is transformed leading to perceived information. Observed and perceived information might be different due to two major reasons: First, information that is in principle observable might not be available to an agent. E.g., agents might only be able to observe information in their close neighbourhood but not in more distant locations. Second, agents might have misperceptions, e.g., agents might observe environmental footprints but only partially pay attention to these footprints or wrongly judge their magnitude. The perceived information is processed in the choice module, which evaluates the different decision dimensions (e.g., financial, environmental, etc.) and combines them into a final choice. Once agents make a decision, they communicate it back to the environment.

This consumer choice framework is applied to integrate three key behavioural factors (environmental preferences, attention to environmental impacts, and present value bias) into an agent-based model that simulates the adoption of heating systems in Switzerland. In this model, households are represented as agents who make annual decisions about whether to retain their existing gas heating system or switch to a heat pump. Each decision is guided by a scoring function that evaluates available alternatives based on two key dimensions: monetary cost and environmental cost. These individual scores are then aggregated into a single overall score for each option, reflecting the agent's specific priorities. The agent subsequently selects the heating system associated with the lowest aggregated score, thereby minimizing their perceived total cost.

The behavioral factors are quantified using three multiple price lists experiments integrated into the 2025 wave of the Swiss Household Energy Demand Survey (SHEDS) [10]. First, environmental preferences experiment which aims to capture respondents' willingness to pay (WTP) for carbon mitigation, reflecting the value they place on reducing emissions [11]. Second, attention to environmental impacts experiment which aims to capture the extent to which such attention influences actual decision-making, recognizing that individuals may not fully consider environmental impacts in their decision making [12]. Third, present value bias experiment which aims to capture the tendency to undervalue future energy cost savings compared to immediate investment costs [2].

After data collection, we will run the following policy scenarios, we apply our model to analyze the impact of public policies on the adoption of heat pumps in Switzerland. These policies include classical economic instruments such as carbon taxes on fossil fuels and subsidies on investment costs of heat pumps but also information policies to correct misperceptions, and the combination of the two. Our approach allows us to examine the impact of policies when behavioural factors are accounted for. To understand their empirical relevance, we compare the model outcomes for the scenarios with and without behavioural factors. Our approach therefore provides conclusion at two different levels. First, we contribute by informing the public debate on appropriate policy measures to decarbonize residential heating in Switzerland with an empirically founded model that accounts for individuals' behaviour. Second, by comparing model outcomes with and without behavioural factors, we draw conclusions on the empirical importance of behavioural factors for numerical modelling of heating adoption behaviour and its impacts on public policy support.

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Healthy Home: Promoting Energy retrofitting for Older Adults' Well-being and improving climate resilience

Theme 2, sub-topic c)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Retrofitting, Energy efficiency, Behaviour, Decarbonisation; Elderly

Extended abstract

“Healthy Home” is a public awareness initiative designed to upgrade the Italian existing building stock, with a particular focus on the health and well-being of elderly citizens. The action is coordinated by ENEA (the Italian National Agency for New Technologies, Energy and Sustainable Economic Development), in partnership with ADA (Association for the Rights of the Elderly and Pensioners), which operates in the metropolitan area of Naples. The initiative supports the implementation of the revised Energy Performance of Buildings Directive (EPBD) within Italy's Integrated National Energy and Climate Plan (INECP) [1].

As part of the national program “*Italia in Classe A*”, led by ENEA on behalf of the Ministry of Environment and Energy Security, *Healthy Home* aims to encourage public debate around the importance of living in sustainable, healthy environments. The initiative seeks to increase the renovation rate among households, especially those most vulnerable to energy poverty and health risks, by focusing on the intersection between energy efficiency, indoor comfort, and quality of life for people over 65.[2]

Elderly citizens were deliberately chosen as the main target audience, as they often face barriers to home renovations due to anxiety, fear of change, and a lack of familiarity with new technologies. [4]

The project followed a multi-stage approach, combining technical information with participatory activities. It opened with an informative workshop that brought together over 100 participants, including institutional representatives, energy experts, healthcare professionals, and local stakeholders. The event aimed to identify practical strategies to support elderly citizens during the retrofitting process and promote healthier lifestyles and more sustainable energy habits. [5]

In the second phase, a focus group using the “World Café” methodology was organized with elderly participants to explore four central themes: (1) resistance to renovation due to the



inconvenience it causes; (2) financial constraints and cost concerns; (3) personal safety during construction; and (4) perceived benefits such as improved indoor comfort, health, and energy savings. [6] This format encouraged open, structured dialogue and revealed widespread uncertainty and hesitation among older citizens, often rooted in prior negative experiences or lack of clear information. [7]

The third stage involved general practitioners, who were asked to assess the health implications of inadequate indoor environments for older people. [8] Their findings highlighted several critical factors such as poor ventilation, presence of mold, disruptive noise, vibrations, and social isolation — all of which contribute to elevated risks of respiratory illness, stress, and psychological disorders. [9] These results reinforced the project's core message: energy renovation is not just a technical upgrade, but a form of preventive healthcare for the aging population. [10] [11]

To further assess attitudes and housing conditions, a structured questionnaire was administered to a sample of 100 individuals aged between 70 and 88 years. Participants were recruited through general practitioners, caregivers, ADA association volunteers, and an online survey platform. Many respondents were homeowners, with 52.8% residing in apartment buildings and 47.2% in other types of dwellings such as single-family homes or duplexes. Most respondents reported spending substantial time at home, underlining the importance of ensuring a safe and comfortable living environment.

The responses revealed three main areas of concern regarding retrofitting projects: health impacts (e.g., dust, noise, respiratory discomfort), safety issues (e.g., accessibility during construction, fear of scaffolding or strangers), and exclusion from decision-making processes.[12] Poor communication with contractors and lack of progress updates also contributed to stress and resistance. Notably, only 33% of participants had already installed energy-saving technologies, and most interventions in apartment buildings were focused on common spaces, with no installations of EV charging infrastructure.[13]

While the project gathered valuable qualitative insights, the current lack of quantitative impact indicators limits a full evaluation of its effectiveness. Future monitoring phases will aim to quantify behavioral changes, such as the number of participants who initiated renovations, consulted professionals, or accessed available incentives after engaging with the project. Collecting these metrics will be crucial to assess real-world outcomes and inform policy recommendations.[14]

Many respondents indicated an interest in future renovations, especially those encouraged by financial incentives. Alongside a growing awareness of sustainability, a clear demand emerged for safety-related technologies such as smart alarms and emergency response systems, indicating that personal security is a key motivation for investing in home improvements.[15]

One notable gap emerged in terms of access to information. A striking 54% of the sample reported never having participated in any awareness or training program related to energy renovation. While some had received advice from doctors or professionals such as architects and social workers, a significant portion had received no support whatsoever. Moreover, the project identified a substantial digital divide among older adults.[16] Although part of the sample responded online, many participants faced challenges in using digital tools to access renovation information, submit applications, or understand incentive schemes. This finding suggests the urgent need for dedicated digital literacy programs tailored to seniors, enabling them to navigate energy services, apply for benefits, and make informed decisions.[17]



In the fourth phase, energy technicians and experts addressed the practical issues faced during renovation projects: noise, dust, service interruptions, and mobility barriers. [18] They proposed a set of mitigation strategies, including detailed planning of construction timelines, the use of low-impact technologies and sustainable materials, and a commitment to transparent and empathetic communication with residents. These recommendations are crucial to creating trust and reducing psychological resistance among elderly homeowners.[19]

The project concluded with a public dissemination event attended by about 100 people, including institutional representatives, healthcare professionals, architects, social experts, and elderly citizens. The event was an opportunity to present project outcomes, share best practices, and promote sustainable habits that improve well-being while contributing to climate goals.[20]

Although piloted in Naples, *Healthy Home* provides a highly adaptable model that can be scaled to other regions.[21] To ensure broader impact and institutional continuity, the project emphasizes the need for stronger partnerships with stakeholders in the field of public health, pension, institutions and the National Association of Italian Municipalities (ANCI). These alliances will be key to expanding outreach, integrating energy-health policy frameworks, and building long-term support systems tailored to the elderly population.[22]

The final phase of the awareness campaign will focus on three pillars: (1) providing accessible, up-to-date information on financial incentives; (2) offering expert consultation on both low-cost and advanced retrofit measures; and (3) promoting capacity building to help elderly citizens manage their energy behavior in an autonomous and informed way.[23]

In conclusion, *Healthy Home* stands as an innovative and inclusive model that links energy policy, social welfare, and healthcare. By addressing practical barriers, digital inequalities, and psychological concerns, the project demonstrates how energy renovation can be redefined as a tool for dignity, comfort, and well-being in later life — and as a scalable solution for sustainable aging in Europe.[24]

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Quantitative representation of lifestyles: a systematic literature review

Theme 1, sub-topic 1a)

Theme 5, sub-topic 1a)

Theme 6, sub-topic 1b)

- “Academic contribution”
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Keywords: Lifestyle, Demand-side, Behaviour, Lifestyle Indicators, Sufficiency, Social Practices

Extended abstract

For decades, climate change mitigation research prioritized energy supply-side and technological options. Within demand-side strategies, efficiency measures historically received more attention [1]. Yet, this focus has evolved since the IPCC (International Panel on Climate Change) Sixth Assessment Report (AR), which broadened the scope to include more systemic dimensions. Increasingly, research highlight the role of socio-cultural factors and infrastructure design [2], as well as lifestyle choices [3],[4], sufficiency-based solutions and [5], well-being approaches [6]. This reflects a growing recognition that transformative change involves not only technical adjustments but also shifts in values, and provisioning systems.



While Energy System Models (ESM) and Integrated Assessment Models (IAMs) are widely used to inform and guide decision-makers on energy and mitigation policies, their focus remains largely techno-economic. Despite recent efforts to improve demand-side modelling, these models often poorly integrate sufficiency, societal and lifestyle aspects. When such aspects are included, the emphasis is typically on technology adoption and diffusion rates with cost-minimisation framework. Behavioural choices are assumed to be rational and modelled through the maximisation of utility functions that represent actors' preferences, potentially overlooking major determinants and drivers [7],[8].

Despite progress in integrating demand-side dynamics into mitigation and energy modelling, a significant gap remains in how lifestyles and what shape them are represented, particularly the challenge of translating qualitative aspects into quantitative indicators. This includes identifying robust indicators to coherently assess the impact of lifestyle changes on energy demand [9].

While improving the efficiency of devices has a measurable and direct impact on final energy demand, lifestyle changes influence energy use more indirectly, by altering demand for end-use energy services upstream in the energy chain. Several scenario-based approaches have begun to address this complexity by emphasizing energy services and their associated input hypothesis, including the Low Energy Demand (LED) [10],[11] and CLEVER scenarios [12]. In pursuit of well-being for all within planetary boundaries, recent research even proposes going one step further and explicitly linking energy services to the fulfilment of human needs [13].

To address this methodological gap, this work conducts a systematic literature review of the quantitative representation of lifestyles, particularly in relation to energy demand and climate mitigation. By focusing on the following research questions:

- What quantitative indicators are used to represent lifestyles on the demand side?
- In what context, geographic regions, and types of studies are these indicators used?

To answer these questions, a lifestyle definition is first needed. In this paper, we adopt the framing proposed by Agnew, Pettifor et Wilson, who describe lifestyle as “a unifying meta-concept comprised of three common integrating elements: behaviors, cognitions and context”, [3]. Lifestyles are considered as “an amalgam of patterned or habitual behaviors, purposeful actions and aspirational self-concepts, responding to and shaped by a mosaic of physical, socio-economic and cultural stings”. In this perspective, behaviours are the observable component of lifestyles and are then at the core of the quantified representation of lifestyles. By focusing on lifestyles rather than behaviours, this review ensures that behavioural “patterns” are analysed in relation to cognitive processes and contextual conditions: recognizing that behaviours are shaped by, and embedded within, broader environments rather than existing as purely individual choices.

Some studies with scopes close to this review have already been performed. For example, Andreou et al. (2022) conducted a systematic review on the key lifestyle changes in current mitigation pathways, analysing the modelling approaches and scenarios assumptions underpinning them [14]. However, their focus was limited to IAMs and ESMs, and on residential and transport sectors. Moreover, their analysis emphasized indicators used to assess the impacts of lifestyle changes, rather than those used to explicitly represent lifestyle patterns themselves.

In addition, Sugiyama et al. (2024) developed a classification of variables within IPCC AR6 scenario database, organizing them across categories (primary energy, emissions, final



energy, energy service). However, their approach remained broad in scope while highly anchored to a highly specific dataset [15]. Similarly, Wiese et al. (2024) developed a typology of twelve service-level indicators to facilitate scenario comparison in sufficiency-oriented pathways [16]. While valuable, their review was constrained to pre-established “shared” indicators and only adopted a singular “sufficiency” framing, narrowing its conceptual breadth.

To conduct this systematic review, the search query was structured around four main components: 1) lifestyle, 2) indicator, 3) demand-side and 4) excluding factors. Each component is composed of several keywords or expressions relevant to its theme. The central component – lifestyle – is composed of direct references (e.g; lifestyle) and related concepts such as sufficiency, practice theory, social practices, low energy demand and various sectoral policy associated with “behaviour”. These were selected because they contextualise behaviour, practices and consumption as embedded in material and social contexts shaped by infrastructures, institutions, policy frameworks. Thus, aligning with the adopted lifestyle definition. This perspective moves beyond seeing behaviours as isolated or purely individual emphasizing their relational and systemic nature. To be included in the initial pool, articles had to mention at least one keyword from each of the first three components in their title, abstract or keywords and none from the excluding factors component. Using this approach, 7275 articles were retrieved from the Web of Science and Scopus databases and subsequently screened independently by two researchers, followed by a conciliation process to harmonize evaluations and build shared prior knowledge.

During this screening phase, articles were assessed based on their titles and abstracts using three main inclusion criteria:

1. Conceptual integration of lifestyle, either directly or indirectly through related frameworks such as social practices, sufficiency, low energy demand framework or other approaches that view behaviour as embedded in their social and material contexts.
2. Focus on demand-side of individuals and households, including aspects such as needs, wants, desires, energy services, final energy, useful energy, food, goods and everyday services.
3. Quantitative treatment of lifestyle, with inclusion of indicators, metrics, quantitative variables or parameters enabling the representation and analysis of behavioural aspects.

Following this initial screening process, additional relevant articles were added based on expert consultation and the lead researcher review, some of which originated from the grey literature, thereby broadening the scope and representativeness of the final corpus considered for screening.

Once the relevant articles were selected, quantitative indicators representing the lifestyles of individuals and households on the demand-side were extracted from them. At this stage, both articles and indicators were systematically categorised to enable deeper analysis. For each article, in addition to basic bibliographic information, topical focus (lifestyle, sufficiency, degrowth...), domain focus (housing, mobility, food, cross-sectoral...), methodological approach (survey, statistical analysis, modelling, scenario...) or also heterogeneity level (from “unique average agent” to very disaggregated types of households) were also recorded. Indicators were further categorised according to their associated sector, sub-sector and end-use (heating, appliance, diet, mode of transportation...) but also according to their unit structure (central unit, scale, time relation) and their type (stock, flux, index, share,



intensity...). This structured categorisation supported comparative assessment and synthesis across diverse studies, enabling the identification of emerging patterns, gaps, and potential for more integrated representations of lifestyle in energy modelling.

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Smart systems and household energy behaviour: A systematic literature review using the motivation, opportunity, & ability framework

Theme 1, sub-topic a) / sub-topic d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: household energy consumption, smart systems, motivation, opportunity, ability

Extended Abstract

Smart systems are increasingly promoted as tools to support and facilitate the acceleration of the energy transition. Researchers though, suggest to be mindful of the social implications of smart systems [1]. Smart systems can be extremely helpful for tracking consumption, or employing interventions for reducing energy consumption or changing when to consume energy [2]. Yet, challenges in using those systems may negate system benefits [3], leading to their suboptimal or improper use. The current study reviews existing research on smart systems and household energy behaviour. We distinguish between overall reduction in energy consumption and load shifting. Load (or peak) shifting, means shifting your energy consumption from peak to off-peak hours. It is an important goal for many countries. More often the electricity net has to deal with net congestion - when electricity demand exceeds the grid's capacity, potentially leading to shutdowns.

First, we assess whether smart systems can stimulate changes in household energy consumption or can evoke load shifting. Next, we analyse the literature using the motivation, opportunity and ability (MOA) framework. The framework posits that behaviour change requires individuals to be motivated and recognize personal benefits in changing, have the opportunity to act, and be able to do so [4, 5]. Successful behaviour change hinges upon that all three components have been met. This study aims to assess how effectively smart systems address the three MOA components, to shed more light on the role of smart systems in accelerating the energy transition. The ultimate goal of this review is to provide an overview with specific guidelines for policy and practice on how to successfully employ smart systems in the energy transition.

A systematic literature review was carried out to study the empirical evidence on how smart systems have affected household energy behaviour. The selection of literature followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines [6]. We included articles from peer-reviewed, English language, journals, published from January 2015 to February 2025, who had performed empirical research on how a smart system technology had impacted energy (including electricity, gas, water) consumption. Studies had to report a measure of behaviour change to be included in the review. Studies that reported simulations on existing data, or focused on measures of perception (e.g., intention to reduce



energy consumption) were excluded. Finally, we only included studies that examined household behaviour (e.g., no workplace energy behaviour). A total of 122 articles was selected for review.

Most of the studies reviewed report positive effects of smart systems. Households tend to either lower their energy consumption, or shift their energy consumption after a smart system has been installed [e.g., 7 - 10]. Smart systems thus appear helpful in shifting energy consumption to off-peak hours. However, the results are not all positive though. There are various instances where the introduction of a smart system initially reduced energy consumption, but was later followed by overconsumption. This signifies the danger of rebound effects. Finally, we also see that there are cases where smart systems do not change behaviour at all. One study for instance, using a mixed-methods design, shows that although smart systems enable households to manage their energy consumption more effectively, people are not always willing to do so [11].

The extent to which smart systems help to *motivate* people to adjust their behaviour differs. There are instances where a smart system induces environmental awareness that encourages households to live more sustainable [12]. The system helps users become aware that their actions have consequences, which in the case of the climate crisis are rather dire. An adjustment of behaviour then serves someone's self-interest, as it may help to negate those negative consequences. Yet, smart systems also can quickly lose its appeal when the novelty wears off [13]. People may feel less challenged by the target behaviour and be less motivated. Finally, privacy concerns may also negatively affect motivation [14]. In that case, a change in behaviour is not necessarily considered to serve someone's self-interest, rather the interest of commercial parties.

From a technological perspective, smart systems provide the *opportunity* to support behaviour change. However, examining opportunities through a social lens produces mixed results. There is evidence that people feel that smart systems give them access to control their own consumption [10]. The smart system is then acknowledged as a mechanism that enables someone that change their energy consumption. Yet, research also suggests that the opportunities provided by smart systems are so abundant that people do not know where to start and hence not start at all [15]. Thus, a smart system may not always offer the opportunity for behaviour change.

The *ability* to manage a smart system is an important third factor. While smart systems offer a lot of information and insights into household energy consumption, users must understand what this information entails and how to act on it. Smart systems that combined with interventions such as information prompts with energy saving tips are promising in helping users manage and apply the information effectively [16].

A change in behaviour is unlikely when there are no obvious benefits for change [5]. In the case of household energy behaviour, immediate benefits are often monetary. For instance, people may shift their consumption to off-peak hours when electricity is cheaper. However, this systematic literature review finds that such incentives alone are insufficient to sustain behaviour change. In studies where smart systems neither reduced energy consumption nor led to load shifting, there was a lack of motivation, ability, or opportunity - either individually or in combination. We propose that smart systems can indeed accelerate the energy transition. But only if researchers, policy makers and practitioners work together to ensure that households understand the information provided by smart systems, are aware of the available assistance options of systems in changing energy behaviour, and that in the end, households experience the benefits themselves.



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Economics of sufficiency: A mixed methods study on sufficiency-oriented strategies in business

New business models for transition, sub-topic 4a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Decarbonisation, Business, Industries, Sufficiency Economy

Extended abstract

1. INTRODUCTION

Sustainability crises such as climate change and resource scarcity threaten not only social well-being, but also the economic sector. While green growth is heralded as a solution by some, it does not seem successful in stopping the continuous transgression of planetary boundaries [1]. Rather, a new paradigm seems to be needed that goes beyond efficiency and consistency to include sufficiency [2] and contributes to the decarbonisation of the economy. In such a “sufficiency economy”, business practices ensure the well-being of all humans while operating within planetary boundaries by reducing production and consumption volumes [3]. Sufficiency-oriented business models encourage consumers to reduce their consumption by managing demand through consumer engagement and education or by offering long-lasting products and life-extending services [4]. In addition, they anchor sufficiency in all operational processes of the company, for example through operations-focused strategies such as aligning the production of the business with actual consumer demand or avoiding launches of unnecessary new products, as well as governance-related strategies, including limited profit expectations and growth targets [5].

Reorienting and designing business models that support sufficiency can be beneficial for the individual company as well as for society and the environment. From a company’s strategic perspective, a sufficiency orientation can improve its market position and reduce the



reputational risk associated with unsustainable practices [6]. Downsizing production saves resources, energy and money and can promote the local economy. In addition, sufficiency-promoting business practices can help consumers to adopt sustainable consumption patterns and avoid overconsumption [7] which in turn can strengthen customer loyalty and help to attract new customers [8].

While companies are becoming increasingly aware of the potential benefits associated with resource savings, the uptake of sufficiency practices is still low. Current business practices supporting sufficiency can be observed mainly in small companies and niche areas of the economy. In addition, previous research on sufficiency in businesses has mainly used qualitative research designs and case studies, so that quantitative assessments of the adoption of sufficiency strategies in companies and the implications of their implementation are lacking. Therefore, this research addresses existing research gaps regarding the uptake of sufficiency-oriented strategies, enablers and advantages associated with the adoption of sufficiency strategies, as well as scaling activities.

2. METHOD

This contribution employs an exploratory sequential mixed methods design. In a qualitative phase, expert interviews with companies with a high orientation towards sufficiency were conducted between October and December 2024 to explore existing sufficiency strategies and understand the prerequisites for their implementation. The semi-structured interview guide consisted of a set of guiding questions allowing for open-ended responses. The interviews (N=13) were coded using MAXQDA analysis software and analysed using the qualitative content analysis method.

The quantitative phase then built on the qualitative findings and explored the extent to which the qualitative findings could be replicated in a larger, more diverse sample of companies from Germany, Austria and Switzerland (N=304) with a focus on sustainability, but not explicitly on sufficiency. Study participants of the company survey were selected through systematic and convenience sampling. The online questionnaire was made available to participants via an online platform. The survey was accessible between the end of December 2024 and the end of February 2025. The invitations to the survey were sent by email or shared in newsletters and professional networks, followed by a reminder two weeks later. The data analysis is descriptive in nature, i.e. it focusses on percentages, means and standard deviations. The mixed methods study has been approved by an ethics committee and was pre-registered with an open science platform (<https://osf.io/txjsa/>).

3. SELECTED RESULTS

The following section presents preliminary results on the implementation rates of internal and external sufficiency-oriented strategies among companies that participated in the mixed methods study, complemented by direct quotes from interviewees that illustrate the reasoning behind their adoption.

The quantitative results of the survey with regard to the adoption of internal sufficiency strategies (see Figure 2) highlight that the most commonly implemented internal strategies are a sufficiency-oriented culture, the reduction of resource consumption and the adjustment of production volumes along needs. One interviewee stated that “the production volume [is oriented] toward [actual] needs. This year, for instance, we haven’t produced anything”.

The results indicate that companies focus on implementing management-driven and operational strategies that are often more directly controllable and in line with the organisation's existing sustainability practises. In contrast, strategies that challenge basic financial principles, such as limiting profits, restricting shareholder returns or avoiding innovation cycles, are much less frequently implemented.



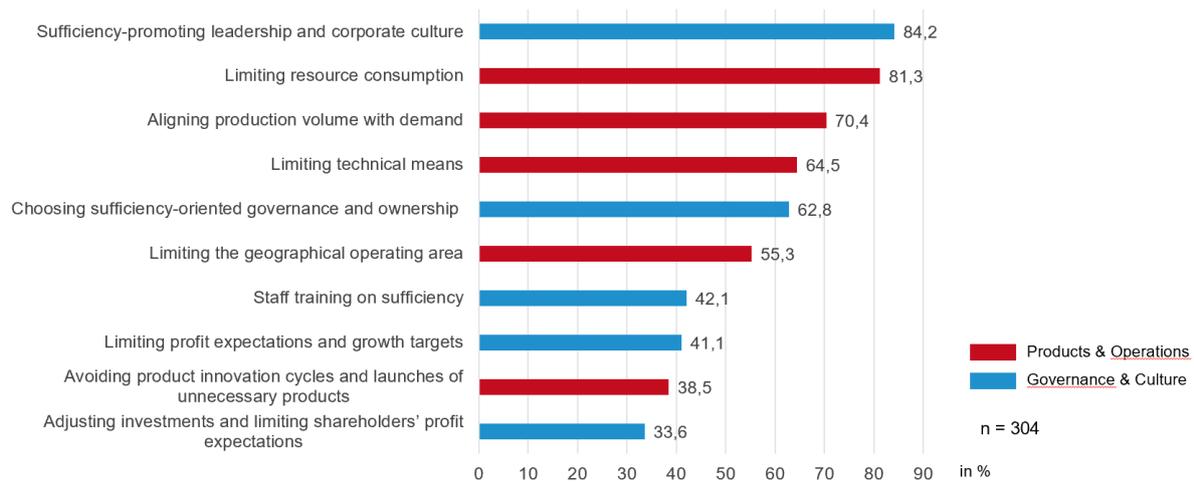


Figure 1: Uptake of internal sufficiency-oriented strategies

Among the external sufficiency-oriented strategies that address customers and other stakeholders, the most frequently implemented strategies are lobbying and activism for sufficiency-supporting structures, raising awareness of consumption needs and questioning consumption for instance through communication campaigns and adapting sales and marketing (see Figure 2). One interviewee stated that bringing attention to sufficiency “was the basic idea of the company, the purpose itself was actually to raise awareness [...] for our environment and our resources and our consumption”.

The results suggest that companies are more inclined to implement information and advocacy-oriented strategies, probably because these approaches are low-barrier and less resource-intensive and can improve reputation and brand positioning. In contrast, practical and structural changes such as the expansion of the business model to include repair services, extended warranties or inclusive financing are less likely to be implemented. Another explanation for the low prevalence of strategies that complement the product offerings of manufacturers and providers, e.g. through repair services, is the high number of service companies in the sample of the quantitative survey.

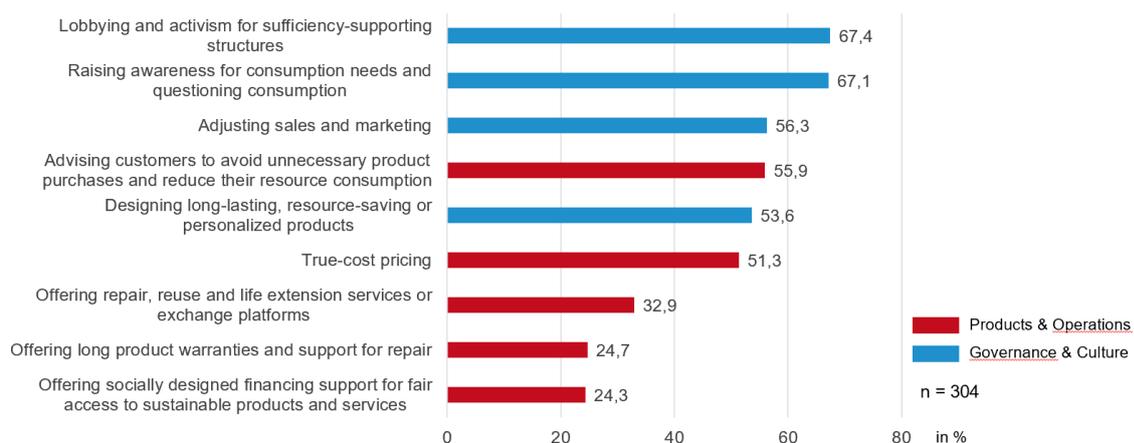


Figure 2: Uptake of external sufficiency-oriented strategies

Please note that the remaining results of the study, e.g., enablers and advantages that facilitate the implementation and scaling activities to support the mainstreaming of sufficiency-oriented strategies, are not included in this extended summary (for reasons of

word count) but will be presented at the conference.

4. PRELIMINARY CONCLUSION

While this study revealed numerous sufficiency-oriented strategies in practice, there are differences in how widely they are adopted. The relatively low implementation rates of financial and structural strategies imply that while sufficiency is being integrated into activities and operations, far-reaching systemic changes remain limited. The fact that 'soft' strategies are the most popular suggests a gap between informational or educational sufficiency practices and those that require structural and systemic change and therefore remain underdeveloped in practise. This emphasises the need for supportive policy frameworks or incentive structures to facilitate wider adoption of sufficiency strategies at a strategic level.

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From Interest to Action: Using Behavioural Science as a Cost-Effective Tool for Policy

Topic 1, sub-topic 1a), 1c), 1d), 1e)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Behavioural science, heat pumps, home retrofits, communications, cost effectiveness, public policy

Extended abstract

Background & objective.

Canada’s residential sector must accelerate adoption of energy-efficient technologies to meet federal energy-saving targets of 17 PJ by 2030. Traditional financial incentives alone have struggled to convert interest into decisive action. We therefore tested whether low-cost, behaviourally informed e-mail campaigns can (i) raise immediate interest in retrofits and (ii) generate transferable insights that improve the uptake of other retrofits—specifically home air sealing. Our goal is to demonstrate that strategic communications can be a scalable, cost-effective policy lever that complements, and sometimes outperforms, capital incentives.

In a partnership with Toronto Hydro, we previously ran two field experiments ($N = 150,000$ households) to explore how communications can boost retrofit adoption. Each household received one marketing e-mail whose subject line and body content described heat pump co-benefits using Function, Social Norm, Environmental, Air Quality, Financial, or Combined framings. Open- and click-through rates were measured with email analytics. Conversion to installation was inferred over 12 months using electricity consumption data. The results showed that the different framings varied considerably in their effectiveness, with the Function condition outperforming others (e.g., Combined framing) by several times in click rates and inferred heat pump installation rates. This study was conducted as part of the Program of Applied Research on Climate Action, a partnership between the Privy Council Office, Natural Resources Canada, and Environment and Climate Change Canada.

Methods.



Applying learnings from the heat pump study, we co-designed an “ultra-lean” e-mail series using pre-consented email addresses from the Canada Greener Homes Grant program from Natural Resources Canada. The series ($N \approx 120,000$, 5 waves) retains the best-performing framings from the previous study. Each cohort is compared to a control group based on the nature of the experiment.

In Wave 1, preliminary analytics show an open rate of 69.3% and click-through rate of 45.2% overall. Emails were sent to only those grant recipients that had not already completed an air-sealing retrofit. Using an intention-to-action ratio based on previous findings, we estimate that around 13% of people who opened the email would complete an air-sealing retrofit. For Wave 2, we are measuring whether providing useful information in a series of communications will increase click-through rates compared to a one-shot communication. The final results of this study, including estimated cost per PJ saved, will be presented at the conference.

Discussion.

Three design insights have emerged:

1. **Brevity with clarity.** In the heat pump study, keeping messages under ~200 words quadrupled clicks relative to longer but similarly framed content.
2. **Framing specificity.** Co-benefit framings that worked for heat pumps did not work as well for air-sealing despite higher, overall click-through rates.
3. **Reciprocity through providing useful information.** Early results indicate that providing valuable advice and insights ahead of asking for participation may increase click through rates. Full results are forthcoming.

Policy relevance & scalability.

Using behaviourally informed communications in the absence of incentive-based programs can yield similar PJ savings at a fraction of the cost.

Conclusions & recommendations.

Behaviourally optimised e-mails can translate homeowner interest into retrofit decisions at a much lower cost than direct incentives. We recommend:

- Embedding continuous testing inside government outreach,
- Preferring more concise content focusing on co-benefits, and
- Leveraging reciprocity cues when financial levers are modest.

Overall, these findings demonstrate how behavioural science can be applied to boost interest and adoption of retrofits, and increase policy effectiveness.



Is There a Sufficiency Effect? Energy Poverty as a Mirror in the French Context

Theme 2, sub-topic 2b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Precarity, Behaviour, Energy Crisis, Micro econometrics

Extended abstract

Context

Since the outbreak of the 2022 energy crisis triggered by Russia's invasion of Ukraine and the resulting spike in energy prices, France has implemented a wide range of measures to curb domestic demand and protect households from the inflation in energy prices. Among these measures, the “*Plan de sobriété énergétique*”, launched in October 2022, which was widely promoted as a national effort to encourage more energy-efficient and responsible behaviours. According to official assessments, the plan was a success: the French Transmission System Operator (RTE) reported a 9% decline in electricity consumption during the winter of 2022-2023 (weather-adjusted), with the Ministry for the Ecological Transition attributing part of this reduction to "*more sufficient behavior*." [1]

Yet this interpretation raises substantial conceptual and empirical challenges. For sufficiency to be meaningful, it must not be conflated with short-term behavioural responses to price fluctuations or crisis signals. Actions such as turning down thermostats, switching off lights, or limiting heating may appear as sufficiency practices; however, when driven by economic constraints or fear of scarcity, they fail to capture the essence of what sufficiency truly entails. Sufficiency, as defined in the IPCC's Sixth Assessment Report, is "*a set of policy measures and daily practices that avoid the demand for energy and resources while delivering well-being for all within planetary boundaries*." [2] Sufficiency is an equity-based theory of distributive justice [3] and more importantly, an organizing principle [4] that enables societies to flourish without overshooting planetary boundaries. As an institutional and political framework, sufficiency relies on long-term structural changes such as land use management, urban planning, infrastructure, housing, that provide people to enough of essential services for a good life.



In this respect, our paper is also anchored in the broader literature on energy poverty [5], particularly the work around affordability of energy and less around access to energy [6]. From this standpoint, we distinguish sufficiency from constrained consumption: reducing energy use due to unaffordable prices signals deprivation, not sufficiency. Sufficiency implies a voluntary and long-term reduction in demand that preserves well-being—such as through renovation or modal shift without rebound. This distinction shapes both our method and analysis.

This paper seeks to reframe the post-Ukrainian crisis narratives in France by providing a micro-econometric reassessment of household energy use since 2022. Our objective is to distinguish between sufficiency and energy poverty and to identify which groups, if any, exhibited patterns consistent with long-term sufficiency practices. Specifically, we study the extent to which the 2022 energy crisis triggered a structural shift in electricity consumption among French households, and how much of the observed decline in consumption can be attributed to short-term, price-driven behavioural adjustments?

Methodology

To address these issues, we combine two complementary empirical strategies, each operating at distinct scales and leveraging different datasets. First, we estimate short-run price elasticities using high-frequency household-level electricity consumption data from ENEDIS. The dataset includes 30-minute smart meter readings, disaggregated by tariff type (base vs. peak/off-peak) and contracted power level (e.g., 3 kVA, 6 kVA, 9 kVA, etc.). This level of granularity allows us to analyse behavioural responses to price variation across diverse technical configurations and consumption profiles. We match these consumption data with regulated retail tariff indices (TRV) and apply weather corrections using Heating Degree Days (HDD), calculated from ENEDIS meteorological observations. After applying the time series for climatic and calendar effects, we estimate regional and contract-specific elasticities over the 2022–2024 period.

Results

Results indicate significant variations in price elasticity across tariff structures and contracted power level. Households with lower subscribed power, particularly under peak/off-peak arrangements, show greater responsiveness to price signals. This pattern suggests that more constrained users, either financially or technically, tend to adjust their consumption to price variations. Conversely, households with higher subscribed power under base contracts exhibit weaker responsiveness, indicating limited behavioural change despite rising prices. These disparities underscore the unequal capacity of households to manage their electricity consumption, shaped not only by price dynamics, but by infrastructural, contractual, and socio-economic constraints. It suggests that a part of what has been referred to as sufficiency may in fact correspond to energy poverty.

Second, we conduct a socio-spatial analysis using annual electricity consumption data at the Ilots Regroupés pour l'Information Statistique (IRIS) level, over the 2019 to 2024 period. Although these data lack contract and power-specific information, they can be matched with granular socio-demographic indicators from the French statistics office (INSEE) including income deciles at the IRIS scale. This approach enables us to explore how electricity consumption trends have evolved across the income distribution, and to assess whether these observed patterns signal structural shifts or expose differentiated vulnerabilities among geographic and social groups. Results based on IRIS-level electricity consumption between 2022 and 2024 reveal a clear downward trend, though unevenly distributed across income groups. The most significant reductions are observed in the least advantaged IRIS zones, whereas households in the wealthiest deciles (9 and 10) show either no reduction or a slight increase in their electricity use during the same period. Importantly, as prices stabilized in 2024,



we observe a partial rebound in electricity consumption among upper-income groups, challenging the official hypothesis of a lasting behavioral shift. In contrast, electricity use among the lowest-income groups remains persistently lower, reflecting again energy poverty rather than sufficiency.

By combining elasticity analysis with a socio-territorial lens, we provide a comprehensive understanding of post-Ukrainian crisis household electricity behaviour in France. The high-frequency smart meter data reveal how households responded to price signals in real time, while the IRIS-level data shed light on broader, longer-term distributional dynamics across geographic and income strata.

Discussion

Together, these findings call into question the interpretation of the 2022–2023 electricity demand reduction as a structural shift toward sufficiency. Instead, the evidence suggests a dual pattern: constrained energy use among vulnerable households and temporary restraint among higher-income groups, with limited signs of systemic transformation. Our contribution is twofold. Conceptually, we clarify the meaning of sufficiency within the context of energy transitions. Sufficiency cannot be inferred from aggregate reductions in demand alone; rather, it must be recognized as socially equitable. Empirically, we provide robust evidence that the post-Ukrainian crisis decline in electricity consumption in France was largely driven by energy prices, rather than a widespread shift toward sufficiency practices.

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Sufficiency and Universal Basic Needs in Low-Carbon Transitions: What Structural Changes and Macroeconomic Impacts?

Theme 6, sub-topic 6a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, Universal Basic Needs, Low-Carbon Pathways, Macroeconomic Modeling, Multisectoral CGE modelling, Mobility, Housing, Accessibility, Mitigation, Equity.

Extended abstract

Context

Since the publication of the IPCC Working Group III report in 2022, the concept of sufficiency has gained renewed attention in both policy and academic debates [1]. Sufficiency defines a corridor bounded below by the imperative to ensure that everyone has enough for a good life, and above by the need to avoid overshooting planetary boundaries [2]. It is therefore not a marginal lifestyle adjustment, but a systemic approach to shaping societal flourishing within ecological limits [3]. This corridor-based understanding makes sufficiency applicable across scales, from macroeconomic pathways to sectoral policies in buildings, mobility, and beyond. However, existing modelling frameworks remain poorly suited to capture the structural contribution of sufficiency to addressing the economic and socio-ecological challenges of the 21st century [4]. Most conventional models tend to focus on technological efficiency, rather than on the underlying conditions that shape demand. In contrast, sufficiency is rooted in justice-based theory: it is a governance principle aimed at avoiding unnecessary resource use while ensuring that everyone’s essential needs are met. In this paper, we ask a fundamental question: What investments and structural transformations are required to guarantee universal access to basic needs through low carbon means, and what are the macroeconomic implications of such a transition? Addressing this question requires embedding sufficiency principles into macroeconomic modelling.

Methodology



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We first identify sufficiency policies in the mobility and housing sectors. To do so, we use ChatSufficiency [5], an AI-powered online database developed by the World Sufficiency Lab, designed to support researchers and policymakers in navigating the growing body of literature. The tool enables users to extract and categorize policy measures that align with the principles of the sufficiency corridor; ensuring well-being for all while staying within ecological limits. The policies identified through ChatSufficiency reflect a fundamental shift: from optimizing consumption to redefining what is necessary and fair in a warming planet, based on the principle of “enough.” In the mobility sector, for instance, we identify 46 policies [6] focused not on increasing cycling rates per se, but on creating structural conditions that allow people to meet their basic needs through local, low-carbon accessibility. These include investments in spatial planning, proximity-based services, and infrastructure that reduce the need for motorized travel. In the housing sector, sufficiency policies emphasize access to adequate and affordable dwellings, renovation of existing buildings, and regulation of underuse and vacancy rather than simply expanding the housing stock.

Once the sufficiency-related policies and measures had been identified, the next step was to embed them within a macroeconomic modelling framework in order to assess their potential macroeconomic impacts. To this end, we used the global version of the ThreeME model (Macroeconomic Multi-sectoral Model for the Evaluation of Environmental and Energy Policies) [7], an open-source, energy-economy-environment Computable General Equilibrium (CGE) model. ThreeME was specifically designed to evaluate the short- and long-term effects of environmental and energy policies on key macroeconomic and sectoral indicators. Its sectoral disaggregation allows for a detailed analysis of structural shifts, such as changes in employment, investment, energy use, and trade balances, across different branches of the economy. Additionally, its detailed treatment of energy flows made it well-suited to investigate how economic agents adapted their energy-related behaviors under different policy conditions.

In the version we used, the model represents the global economy, with an explicit distinction between major world regions, including the Global North and the Global South. Having such a regional disaggregation enables us to explore equity and justice issues across regions, particularly the persistent asymmetries in capacities, responsibilities, and development needs. This dimension is crucial in the context of the UNFCCC negotiations and the principle of Common But Differentiated Responsibilities (CBDR). It allows us to assess how sufficiency-based policies may translate differently across regions, and to explore whether low-carbon transitions can be aligned with development objectives in the Global South while ensuring a fair distribution of effort and resources globally. This framing is essential not only from an ethical standpoint but also for ensuring political feasibility and legitimacy in the global governance of climate transitions.

For this article, we developed a set of scenarios to compare different decarbonization pathways. Alongside a baseline scenario without specific climate policies, except existing ones, we included a techno-efficiency scenario relying solely on technological and energy efficiency improvements to reach climate neutrality by the end of the century. In contrast, the scenario we focus on in this paper is a sufficiency-based transition scenario, which integrates the policy measures identified through ChatSufficiency. This scenario aimed to explore the structural and macroeconomic implications of prioritizing demand-side transformations and access-based sufficiency measures as a pathway to deep decarbonization.

To implement this scenario, we propose to enrich the structure of the model by integrating new variables that reflect the principles of sufficiency, specifically, an accessibility and affordability index (that we call sufficiency index) for mobility and a sufficiency index for housing. These indices capture whether people can reach essential services via low-carbon means, and whether



their housing conditions meet essential standards in terms of surface area, affordability, and energy services.

Rather than assuming fixed modal shares or behavioural shifts, we start from a normative objective: by 2050, 100% of the population should have guaranteed access to essential services related to housing and mobility via low-carbon modes. We then quantify investment needs and structural transformations required, such as changes in urban form, infrastructure design, or housing policies, and how these affect key macroeconomic indicators including GDP, employment, sectoral dynamics, trade balances, public finance, and GHG emissions.

Results:

This work is currently in progress: we are in the phase of implementing the three scenarios within the model, in particular translating sufficiency policies and measures into the ThreeME macroeconomic framework. At this stage, we are not yet in a position to provide quantified results. These will be produced in the coming months, and the simulation outcomes will be available in time for the December conference, where they can be presented and discussed.

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Willingness to share energy data

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: energy data, willingness to share, risk-benefit perception, behavioural energy research

Extended abstract

The European Green Deal aims for climate neutrality by 2050 by transforming the energy system towards decarbonisation, decentralisation, and digitalisation. Smart technologies and digital energy services play a pivotal role in enabling demand-side flexibility, which is essential for integrating renewable energy sources and stabilising the grid [1]. However, these services rely on the availability of household-level energy data, i.e., data generated and collected by smart energy products such as smart meters or other sensors and devices, creating new value for customers [2,3]. Hence, the willingness to share energy data is a critical behavioural factor for the successful implementation of a digitalised and flexible energy system. Although users recognise benefits of smart technologies such as cost, time and energy savings, comfort or an decrease of effort there is growing public concern about data privacy, surveillance, and the potential misuse of personal information [4,5].

Existing research on willingness to share energy data shows that individuals are generally more open to data disclosure when they can perceive tangible, individual-level benefits. For example, a representative study by [6] in the UK found that a majority of respondents were willing to share half-hourly smart meter data when it enabled e.g. personalised tariff information. These findings indicate that instrumental motives—such as cost savings or service improvement—play a key role in shaping attitudes towards energy data sharing. While such studies offer valuable insights, they primarily provide descriptive evidence and rarely engage with explanatory models that account for underlying psychological or social mechanisms. In contrast, studies such as those by Kim, which examine data sharing in general in the field of IoT, can provide a more comprehensive picture by drawing on theories such as the privacy calculus framework [7]. This approach conceptualizes individual decisions as a trade-off between perceived benefits and perceived privacy risks and has been shown to predict intentions to disclose personal information in digital contexts.



In the energy domain, however, there remains a lack of empirical studies that systematically apply such frameworks, especially with a focus on multidimensional benefit perceptions. Only, Tschersich et al. [8] explored willingness to share data under different benefit constellations: benefits for self, for others, or for both. As Vigurs et al. [9] highlight, existing research focuses predominantly on privacy concerns, with limited attention to the perceived benefits of data sharing.

The study addresses two core research questions:

1. What is the role of different types of perceived benefits in shaping individuals' willingness to share energy data?
2. How does the willingness to share energy data vary depending on the type of third party receiving the data?

The research model of this study draws on the conceptual framework proposed by **Bearth and Siegrist** [10], who applied the risk-benefit approach (which is connected to Social Exchange Theory and Economic Exchange Theory) to the case of sharing medical and genetic data. They argue that risk and benefit perceptions are **predictive variables** for the willingness to share data (WTS), whereas trust in data recipients is central to forming a sharing decision.

By transferring and adapting this framework to the domain of **energy data**, the current study extends existing research in two key ways: First, it expands the benefit dimension beyond individual utility by incorporating **four types of perceived value** (efficiency, innovation, transparency, collective impact) as conceptualized by Jetzek et al. [11]. Second, it systematically examines the role of **trust in energy data recipients** (e.g., municipalities, energy providers, citizen organizations) as a contextual factor in the risk-benefit evaluation. This integrated model is particularly relevant in the context of the energy transition, where citizens' willingness to share energy data is not only a question of personal utility but also a **precondition for collective action and system-level transformation**.

The study is based on a quota-representative online survey of Austrian households (n = 1198), conducted in 2022 by the fieldwork institute Norstat. A standardized questionnaire was used to assess participants' willingness to share different types of energy data, their perceptions of benefits and risks, and their level of trust in various data recipients.

- Willingness to share (WTS) was measured across four data types (e.g., smart meter data, data of PV production, data on electricity consumption of dishwasher and washing machine) on a 7-point scale (1 = not likely at all, 7 = very likely).
- Risk perception was operationalized via five items adapted from [10], capturing privacy and security concerns.
- Benefit perception was measured using four constructs aligned with the Jetzek et al. [11] framework. 5 dimensions of generated value through sharing of data were conceptualized: 1.) value through data-driven efficiency, 2.) value through data-driven transparency of own energy behaviour and 3.) to the collective energy behaviour, 4.) value through data-driven innovation and 5.) value through data-driven impact on the society (i.e., the transition of the energy system).
- Trust perception was measured with three items per recipient type (public institution, energy supplier, community association), adapted from [10].



Additionally, the survey captured respondents' digital affinity (based on an adapted version of the Media and Technology Usage Scale by Rosen et al. [12]), ownership of smart energy products, and socio-demographic characteristics. All multi-item scales used 7-point Likert response formats, and reliability analyses (Cronbach's α) were conducted to ensure internal consistency.

Although the data analysis is currently in progress, first results show respondents' willingness to share energy data is rather moderate, with similar mean values for the public institution ($M = 4.62$) and an association ($M = 4.61$), and slightly higher for an energy supplier ($M = 4.74$). As for the trust for electricity data usage for the right purpose, the respondents reported that it is slightly higher than the average for the public institution ($M = 4.71$) and the energy supplier ($M = 4.70$), and considerably higher for the association ($M = 5.35$). Respondents associate a moderate risk with sharing electricity data, with the lowest risk concerned with the energy supplier ($M = 4.61$), and slightly higher risks affiliated with an association ($M = 4.71$) and a public institution ($M = 4.77$).

The five dimensions developed were summarized into two constructs based on a factor analysis, i.e. individual benefits through exploitation (1, 2 and 3) on the one hand and collective benefits through exploration (4 and 5) on the other. Concerning exploitation benefits, they are more associated with the energy supplier ($M = 5.20$) compared to the public institution ($M = 5.07$) and association ($M = 5.08$). Similarly, in terms of exploration benefits, the energy supplier provides greater perceived advantages ($M = 4.95$) compared to the public institution ($M = 4.86$) and association ($M = 4.88$).

Ultimately, enabling households to actively contribute to the energy system through data sharing is not just a technical or legal challenge – it is a behavioural and communicative one. This study helps identify where interventions, trust-building strategies, and targeted communication are needed to unlock the full potential of smart, participatory energy systems. Thus, this paper contributes to Track 1a of BEHAVE 2025 by combining behavioural science, information systems theory, and energy research to better understand the social practices and decision-making processes that underpin energy data sharing.

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Quantifying Demand-Side Flexibility and its limiting factors: A Modelling Approach

Theme 1, sub-topic c) and d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Flexibility potential, Demand-side flexibility, Heat Pumps, Electric Vehicles, Policy impact

Extended abstract

The increasing integration of renewable energy sources into energy systems necessitates enhanced demand-side flexibility to balance variable generation and maintain system stability. This study presents a model to quantify a country’s flexibility potential based on the total stock of installed components and their average flexibility per unit, while systematically accounting for limiting factors such as financial, regulatory, and behavioural constraints. This enables realistic estimations crucial for system planning and effective flexibility program design. Additionally, the study analyses policy measures that can address these limiting factors to accelerate flexibility deployment.

For this, flexibility is defined as the ability of a component, or pool of components, to deviate from their operational profile, where the operational profile serves as the baseline representing the planned or typical operation of the device under normal conditions. The flexibility potential is therefore assumed as the maximum possible deviation from an average component’s baseline operation by increasing or decreasing its consumption or production without compromising its primary function or user comfort beyond acceptable limits. This ensures that flexibility is understood not as an abstract potential but as a measurable deviation from a defined operational plan, providing a practical and comparable basis for quantifying demand-side flexibility across devices and contexts. A decrease in demand is referred to as positive flexibility, while an increase in demand is referred to as negative flexibility.

The model is applicable to any flexible component. This study illustrates its use for heat pumps and electric vehicles (EVs):

- **Heat pumps** are key flexible loads in electrified heating, with flexibility potential strongly dependent on outdoor temperature, which affects both heat demand and the Coefficient of Performance (COP). While technical flexibility further varies with activation duration and environmental conditions, this study focuses on social, regulatory, and behavioural factors influencing uptake. “Therefore, based on pre-studies, we simplify the technical potential as the maximum activation over a four-hour period at 0°C, a temperature at which a balanced upward and downward flexibility potential is possible (heating demand exists, but not to the extent that the heat pump



must operate continuously).

- Assessing the flexibility potential of **electric vehicles (EVs)** requires understanding both the total number of EVs and, crucially, the stock of home charging stations, as these offer flexibility potential, contrary to most public fast-charging infrastructure, where users prioritize rapid, full charging over flexible operation. Flexibility potential is further closely linked to user mobility patterns and the availability of private parking, which enables home charging and potential PV integration. Regional differences are significant: urban areas like Vienna show low private parking rates, while rural regions in Austria exhibit high rates, affecting the scalability and spatial distribution of EV flexibility potential.

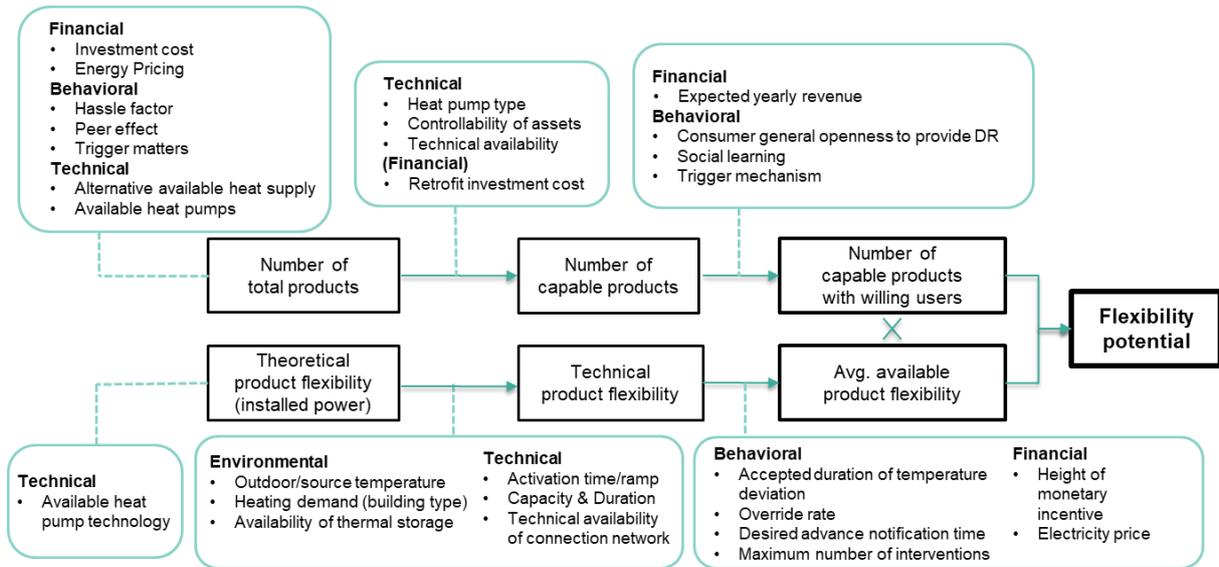


Figure 10 Structure of the developed model as applied to heat pumps, illustrating the calculation of realistic flexibility potential from the total stock of installed units and the theoretical heat pump flexibility per asset.

Figure 10 shows the model structure applied to heat pumps. The same model can be analogously applied to electric vehicles, with the distinction that, in this case, EVs and charging stations need to be considered separately. Starting from the total number of installed assets and an average flexibility potential per unit, the model sequentially applies various limiting factors to derive the realistic flexibility potential:

- Starting from the total stock of assets, the upper path in the figure reduces this number by technical and financial constraints, resulting in a subset capable of providing flexibility. This is further narrowed by the proportion of users willing to actively participate and enroll in flexibility programs.
- Separately, on the lower path, the theoretical maximum flexibility of an average heat pump is limited by technical and environmental factors to reflect what is technically feasible, before further reductions due to behavioural and financial factors yield the realistically deliverable flexibility per unit.

This structured approach ensures that flexibility estimations reflect not only technical but also real-world social and behavioural constraints, providing a practical foundation for system planners and policymakers.

The model has been applied to Austria using market studies to determine the number of installed units and international literature to quantify further influencing factors. While nearly all components should be technically smart grid ready [1] by 2030 due to regulatory requirements, behavioural factors significantly limit usable flexibility. Especially the step from technically capable to actively participating components varies widely depending on user willingness, with survey data indicating an openness to participate between 30% [2] and 84% [3]. The participation of asset owners in demand response (DR) programs and flexibility services is shaped by behavioural openness to external control, financial incentives and perceived economic benefits, as well as by social learning within communities. For electric vehicles, beyond participation in DR programs, actual flexibility additionally depends on whether vehicles are plugged in while parked, while for heat pumps, user interventions such as thermostat overrides ([4],[5]) may further limit the average available flexibility potential. An estimation of the positive and negative flexibility potential for Austria has been conducted under both optimistic and conservative assumptions until 2030, providing a quantified range of flexibility contributions under varying adoption and participation scenarios, as shown in Figure 11. In the conservative scenario for 2030, a positive potential of 135 MW is calculated to be available for positive, and 108 MW for negative flexibility services, assuming an outdoor temperature of 0°C. In the optimistic scenario, these values increase significantly to 650 MW for positive flexibility and 520 MW for negative flexibility. As previously mentioned, the major differences between the scenarios primarily result from user-related factors.

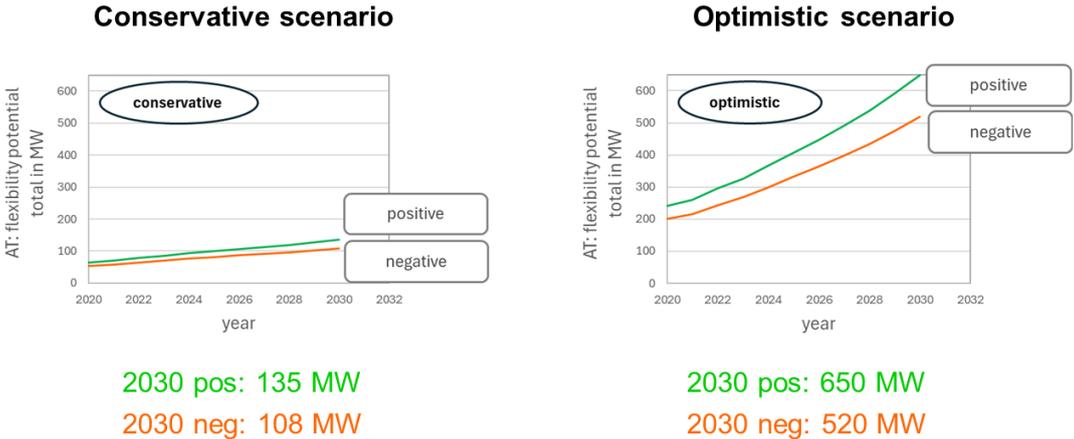


Figure 11 Estimation of positive and negative flexibility potential of heat pumps for Austria under both optimistic and conservative assumptions until 2030.

Further, different policy measures were evaluated to accelerate the deployment of flexible technologies in the energy sector was further developed, categorizing instruments by how they can drive technology adoption and flexibility provision. While regulatory and financial measures such as fossil fuel bans or targeted subsidies create market pull and reduce entry barriers, measures addressing user willingness and informed participation are particularly crucial for unlocking flexibility potential in distributed assets.

Key policy measures therefor include:

- **Public awareness campaigns and capacity-building programs** [6] that foster voluntary participation, enabling users to actively contribute to flexibility and decarbonization goals.
- **Training programs for installers and sellers** [7] of heat pumps and EV chargers, enhancing trust while ensuring the flexibility narrative reaches end users effectively.
- **Certification schemes** [8] for “flexible-ready” products and installers, providing



transparency and further enabling different stakeholders to incorporate flexibility as a reliable option.

- **Legal requirements for device interoperability** ([9],[10]), ensuring technical compatibility across manufacturers and systems, which reduces transaction costs and user frustration—two major barriers to voluntary flexibility participation.

Future research could benefit from quantifying the impact of specific policy measures on flexibility potential to better understand how financial, regulatory, and behavioural levers translate into measurable participation and activation rates. Additionally, the approach can be extended to other flexible components and applied across different countries to validate and further refine the model.

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From Plans to Paralysis: What Holds Back Energy Efficient Renovation in Social Housing?

- “Academic contribution”
- “Policy/practice contribution”

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EXTENDED ABSTRACT

1. INTRODUCTION

The decarbonization of the residential building stock is central to meeting the European Union’s climate neutrality goals [1]. On a national level, the Netherlands introduced the National Climate Agreement (“Klimaatakkoord”), which sets ambitious targets for the building sector to reduce GHG emissions [2]. Especially Dutch social housing associations (HAs) are expected to contribute to the national goal of CO₂-neutral housing stock by 2050, by transforming their existing housing stock with poor energy labels such as E, F, and G to at least energy label D [3], [4].

Dutch HAs, which manage a large share of low-income social housing in Europe, are increasingly engaging in energy-efficient renovation (EER) to reduce energy consumption and improve living conditions [5]. However, while insulation and passive measures are widely implemented, the integration of regenerative technologies, such as district heating networks, heat pumps, or renewable electricity systems, remains limited [6]. The rooftop organization Aedes recently adjusted its sectoral goals from a minimum of energy label B to energy label D, suggesting that significant barrier remain [4], [7]. These challenges include the realization of organizational transformations and large-scale retrofit complexity [3]. Other practical barriers that Dutch HAs encounter are asset heterogeneity, limited option of financing and investment or internal capacity of professionals [8]. Further decisive “hidden barriers” are suspected.

Dutch HAs operate in a complex institutional context. Their decision-making is shaped by regulatory frameworks, stakeholder interactions, and market uncertainties [8]. Identifying and understanding barriers within this context is critical to accelerating EER. . The aim of this study is to investigate and understand the barriers that HAs encounter, using Transaction Cost Theory (TCT) and Behavioral Insights (BI) as complementary lenses.

2. THEORETICAL FRAMEWORK

TCT has been applied in energy research to uncover “hidden barriers” in project planning and implementation [9], [10], [11]. TCT focuses on the costs associated with due diligence, coordination, negotiation, monitoring, and enforcement, especially under uncertainty and asset specificity. TC-categories identified in energy related research are due diligence cost, search for information cost, negotiation cost; approval and certification cost, monitoring and verification cost, trading cost; and enforcement cost [9-11]. Notably, Williamson [12] integrates Simon’s



concept of bounded rationality into TCT to account for limited decision-making capacity. In “*The Mechanism of Governance*,” Williamson [13] further emphasizes that behavioural assumptions are central to understanding transaction costs in complex environment as part of TC-research.

Alongside TCT, BI provide a cognitive lens on decision-making. This perspective emphasizes how psychological limitations and heuristics shape organizational behavior. Key concepts include bounded rationality [14], status quo bias [15]; loss aversion, and present bias [16]. These behavioral traits contribute to organizational inertia, slow decision-making, and risk aversion, especially when innovations deviate from well-established practices [17].

In recent years, BI has become increasingly pivotal in shaping the design, implementation, and evaluation of energy policies, as highlighted by Mundaca et al. [18] and the OECD [19]. This is especially relevant for the energy-efficiency context, where complex decision-making environments are influenced by cognitive biases and limited information processing [20]. Behavioural barriers are now widely recognized as shaping how decisions are made and sustained within organizations [21]. Reports from the European Environment Agency emphasize that phenomena such as bounded rationality, status quo bias, and loss aversion not only affect individual but also institutional behaviour. Consequently, even when financial and technical conditions are favourable, these psychological constraints can limit the willingness to adopt more ambitious renovation strategies. Integrating TCT and BI offers a multidimensional understanding of the structural and behavioral mechanisms that constrain EER in the social housing sector.

3. METHODOLOGY

This study adopts a multiple case study design involving eight Dutch HAs that have executed EER projects. The empirical data was collected between January 2023 and July 2024 and includes semi-structured interviews with decision-makers, as well as document analysis of renovation plans, strategy documents, and internal reports. The interviewees consisted of key decision makers such as technical managers, project leaders, asset managers, and sustainability coordinators. Interview durations ranged between 50 and 90 minutes and addressed topics such as renovation planning, regulatory compliance, technology adoption, tenant engagement, and risk assessment.

Data analysis was guided by a deductive coding scheme derived from TCT and BI. Codes included transaction cost categories such as due diligence cost, negotiation cost, and monitoring cost, as well as behavioral patterns such as choice overload, loss aversion, and status quo bias.

4. EXPECTED RESULTS

Preliminary findings from the case studies indicate that Dutch HAs approach EER with considerable caution, often favouring low-risk, and default solutions such as insulation. Despite the growing policy pressure towards higher energy labels, decision-making processes within HAs are characterized by both transactional inefficiencies and behavioral constraints.

From a TC perspective, several stages in the EER process are perceived as excessively complex, costly, and uncertain. The need to individually assess each building’s energy potential and technical feasibility contributes to high due diligence costs, particularly in portfolios that contain heterogeneous building types. Moreover, the necessity to coordinate with external actors, including municipalities and contractors, further increases negotiation and coordination costs. Once projects enter the implementation phase, HAs must invest considerable resources into monitoring and enforcing contractor performance, aligning renovation schedules with tenant needs, and resolving unexpected disruptions, which significantly increases enforcement



costs. In addition, behavioural traits play a crucial role in shaping EER-projects. HAs display strong status quo bias, which leads them to default to familiar measures even when more innovative approaches may offer long-term benefits. Decision-makers often express a reluctance to adopt new technologies due to fear of tenant dissatisfaction, uncertainty over energy savings, or reputational risks should projects underperform. The complexity of renovation options, compliance frameworks, and regulations, further contributes to decision paralysis and cognitive overload. As a result, even when financial and regulatory conditions are relatively supportive, associations tend to delay or minimize interventions that require more extensive planning, cross-departmental coordination, or technical innovation.

These transaction cost and behavioral barriers often reinforce one another. For example, asset heterogeneity not only increases the technical and administrative complexity of planning renovations but also amplifies the psychological burden of making the “right” choice. This results in a higher tendency to delay decisions or settle for incremental, low-risk interventions.

5. CONCLUSION & OUTLOOK

This study reveals that EER in Dutch HAs is hindered not only by external constraints but also by internal decision-making dynamics. Transaction cost barriers, such as high due diligence and coordination costs, combine with behavioural bottlenecks, such as loss aversion and decision inertia, to discourage HAs from adopting more ambitious renovation strategies leading to decision paralysis. In sum, the decision-making processes of HAs reflect a complex interplay between structural transaction costs and behavioral barriers.

Looking ahead, this research contributes to the fields of behavioural public administration, organizational decision-making, and transaction cost economics in energy transitions. The findings underscore the need for integrating behavioural insights into policy design, such as using nudges, simplified compliance schemes, or default options, can empower HAs to make bolder decisions aligned with climate neutrality goals.

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Mapping Unintended Consequences in Energy Transition: Beyond Good Intentions and Towards Just Outcomes

Theme 2, sub-topic 2b), 2c), 2d)

- “Academic contribution”
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Keywords: Unintended Consequences (UIC), Energy justice, Just transition, Energy transition, Policy design, Hard-to-reach energy users

Extended abstract

1. Introduction

The energy transition is widely seen as a defining moral and political challenge of our time. It is not only about technologies and targets, but about responsibility, action, and justice – about doing the right thing, and doing it in time. Even so, what happens when the “right thing” turns out to be more complex and complicated than expected? When measures aimed at addressing inequality end up reinforcing it instead? Or when policies intended to support a just energy transition reproduce the very disparities they were meant to redress?

Scholars have long warned against reducing the energy transition to a technical issue alone. Instead, energy systems are best understood as socio-technical configurations shaped by political, economic, and cultural forces, and deeply embedded in everyday infrastructures such as transport, housing, and food systems [1,2,3,4].

Critiquing initiatives driven by good intentions may appear unhelpful in times when action and commitment are urgently needed. However, by attending to what does not go as planned, we gain insights into how energy transitions unfold – not only as technical transformations, but as social, institutional and political processes. While sustainable energy policies are typically designed with ambitious environmental and social goals, they do not always lead to the intended outcomes. These unintended consequences (UICs) can range from increased emissions to social inequities or technical problems. Examples such as social exclusion and distorted incentives



point to the importance of anticipating the broader, sometimes unintended, consequences of energy policies and programmes [5,6].

2. Analytical Framework

In this paper, unintended consequences refer to unforeseen negative effects of seemingly positive interventions – such as financial incentives or informational campaigns on energy efficiency, behaviour change, and demand-side measures – particularly when they disadvantage vulnerable and marginalised communities.

To explore this, we draw on the typology proposed by Suckling et al. [7], which categorises UICs along two axes: whether they are knowable in advance, and whether they are avoidable. This produces four ideal types: ***Knowable and avoidable***: foreseeable effects for which **preventive action or adjustment would have been possible, but was not taken or prioritised**. ***Knowable but unavoidable***: consequences that are recognised in advance but cannot be prevented due to political, economic, or institutional constraints. ***Unknowable but avoidable***: unanticipated outcomes that could potentially have been avoided through broader perspectives, participatory processes, or more adaptive governance. ***Unknowable and unavoidable***: genuinely unforeseeable effects **emerging from complex and dynamic socio-technical interactions**.

Rather than reducing complex dynamics to a simple matrix, the typology serves as an analytical tool for reflecting on the complexity of unintended consequences – and on the kinds of knowledge, processes, and institutional conditions required to address them.

3. Methodology

This study draws on a combination of methods: an international policy review, a literature study on unintended effects in the energy sector, and a survey with 72 experts from 16 countries. In addition, 18 interviews were conducted with individuals involved in programme design, evaluation, or policy development in the energy domain.

In a second phase, the analysis was deepened through case studies from participating countries. The cases were selected to reflect thematic variation in energy policy, including pricing mechanisms, building retrofits, electrification, mobility, communication strategies, and justice-oriented frameworks. The six empirical cases presented in this paper were chosen from this broader material to illustrate different types of unintended consequences across diverse national and institutional contexts. We interviewed individuals responsible for programme design, implementation and/or evaluation, and complemented this material with documentation from reports, websites, and other relevant sources.

4. Empirical Cases

The paper presents six empirical cases from Sweden, New Zealand, and the United States. These were selected to reflect variation in geography, policy type, and institutional conditions. Each case is analysed in terms of its policy goals, implementation outcomes, and position in the typological framework.

In New Zealand, the phaseout of the Low Fixed Charge tariff, intended to increase fairness and remove cross-subsidies, led to higher electricity costs for many low-use, low-income



households – a group already recognised as vulnerable. Meanwhile, the Warmer Kiwi Homes programme has delivered clear energy and health benefits but has also raised concerns about installation quality and a potential rebound in energy use. In the U.S., Vermont Gas’ programme promoting heat pump water heaters encountered unanticipated system-level responses that limited the expected load-shifting benefits, as customer responses were not aligned with the intended **behavioural** incentives. The Justice40 initiative – aiming to ensure that 40 percent of federal climate and energy investments benefit disadvantaged communities – illustrates how ambitious equity goals can be constrained by institutional and implementation challenges. In Sweden, the national rollout of EV infrastructure has progressed rapidly but has so far primarily benefited urban areas, exacerbating geographical disparities in access and use. Finally, an energy communication campaign in Malmö, Sweden, intended to promote behaviour change, struggled to reach its target groups due to mismatches in assumptions about everyday life, practices, and the diversity of local communities.

The analysis was conducted within the framework of the Hard-to-Reach (HTR) Energy Users Task of the Users TCP by the International Energy Agency (IEA). The HTR Task is an international collaboration that aims to identify hidden energy users and explore ways to better engage them in support of a just energy transition [8].

The cases were selected to represent variation in geographical setting, type of policy or programme and type of UIC. For each, we analysed the intended logic, the consequences observed in implementation, and how these mapped onto the typological framework. These examples are analysed through the lens of *unintended consequences* (UICs) – outcomes that are not aligned with the original goals of a policy or programme. Drawing on Suckling et al.'s typology, the cases are situated along two axes: whether the consequence was knowable or not in advance, and whether it was avoidable. The resulting framework enables reflection not only on what went wrong, but also on how knowledge, institutional arrangements, and governance capacity shape both outcomes and the ability to respond.

5. Concluding Reflection

These cases illustrate how well-intentioned interventions can interact with social, technical, and organisational contexts in ways that lead to outcomes misaligned with original goals. Drawing on Suckling et al.'s typology, the analysis enables reflection not only on what went wrong, but also on the types of knowledge, institutional arrangements, and governance capacities required to avoid or manage unintended consequences.

By framing UICs as part of how transitions unfold, rather than as failures, we argue for more inclusive, adaptive and reflexive approaches – particularly when aiming to engage marginalised and vulnerable communities in ways that support a more just energy transition.

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Systemic discrimination and housing (in)equality: A mix-method analysis in four European countries

“Academic contribution”

“Policy/practice contribution”

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EXTENDED ABSTRACT

SCOPE AND OBJECTIVE

This paper focuses on the role of systemic discrimination (in various forms) as a vulnerability factor in causing and/or exacerbating a lack of quality housing as a manifestation of housing inequality. Housing inequalities can manifest in various distinct ways, including but not limited to housing deprivation, lack of quality housing or lack of access to and/or affordability of energy, health and transportation services [1, 2]. We define housing inequality as lack of inclusive access to affordable and acceptable quality housing that is defined through meeting basic human needs in the context of ongoing sustainability challenges. Importantly, this definition does not suggest uniform housing conditions for all but emphasises ensuring that all individuals should have affordable and acceptable access to available housing (*inclusivity concept*) that supports their well-being (*quality housing concept*). While housing inequality extends beyond the physical structure of dwellings to the wider built environment, including the quality of the surrounding neighbourhood, access to services and infrastructures, this paper focuses on quality housing of *peoples' residential dwellings*.

Research on the role of systemic discrimination in housing, and particularly neighbourhood inequalities, is already well established, particular with a focus on racialised and ethnic discrimination in contexts such as the USA and UK [3, 4]. Similarly, effects and perceptions of being or having low-income residents is a focus of existing literature. However, less attention has been paid to how *subjective experiences of discrimination* - whether based on race, gender, age, or income - shape perceptions of housing quality [5]. This paper addresses that gap by



exploring the following research question: How do experiences of systemic discrimination relate to people's subjective perceptions of living in adequate, quality housing?

METHODOLOGY

We apply a mixed-method approach that integrates insights from a quantitative-qualitative literature review, qualitative stakeholder interviews and focus groups, as well as data from a quantitative online survey conducted as part of the EU Horizon-funded HouseInc project (ID# 101132513) [6]. Specifically, we draw on empirical insights from four case studies conducted as part of the project: an urban neighbourhood in Southwest Germany, a semi-urban region in northern Italy, two cities in the Moravian-Silesian in the Czech Republic, and a rural informal settlement in Southwest Romania. These case studies combine secondary sources with primary data collected through 51 stakeholder interviews and six focus groups. The aim is to investigate housing inequalities and their effects on particularly vulnerable communities. The data was qualitatively coded using MaxQDA. Findings from these qualitative, exploratory case studies inform the analysis and interpretation of quantitative survey data gathered across several European countries, including the four case study countries (with about 2500 participants). All data was collected between November 2024 and April 2025. For the quantitative analysis of this paper, we focus on low-income households as one dimension of vulnerability, defined as respondents reporting incomes below the national median in each country, to analyse how experienced discrimination in the housing sector predicts dwelling problems demonstrating low housing quality.

CASE STUDY FINDINGS

Findings from the case studies highlight how systemic discrimination drives spatial, social, and economic exclusion within the housing sector. In this paper, we identify and examine key mechanisms behind these dynamics, including geographic barriers, limited access to public transportation, and historical path dependencies, that (re)produce exclusionary policies. Moreover, we explore how these factors intersect with the socio-demographic characteristics of vulnerable populations, such as ethnic minorities, individuals with migration backgrounds, and lower- to middle-class residents defined by limited economic and social capital. These qualitative insights inform and contextualize the analysis and interpretation of the quantitative survey data, particularly in the contextualisation of observed country-specific variations.

SURVEY: DESCRIPTIVE STATISTICS

We begin by presenting some descriptive statistics of the predictors and the dependent variable in our analysis of the four European countries. Regarding the predictors, i.e., the experienced discrimination in the housing sector, we find that low-income households most commonly report discrimination based on their income (reported by 27-33% of respondents, depending on country, see Figure 1). Other experiences of discrimination in the housing sector across the four countries are related to age (reported by 12-22%), family status (reported by 8-20%), and education (reported by 7-20%).



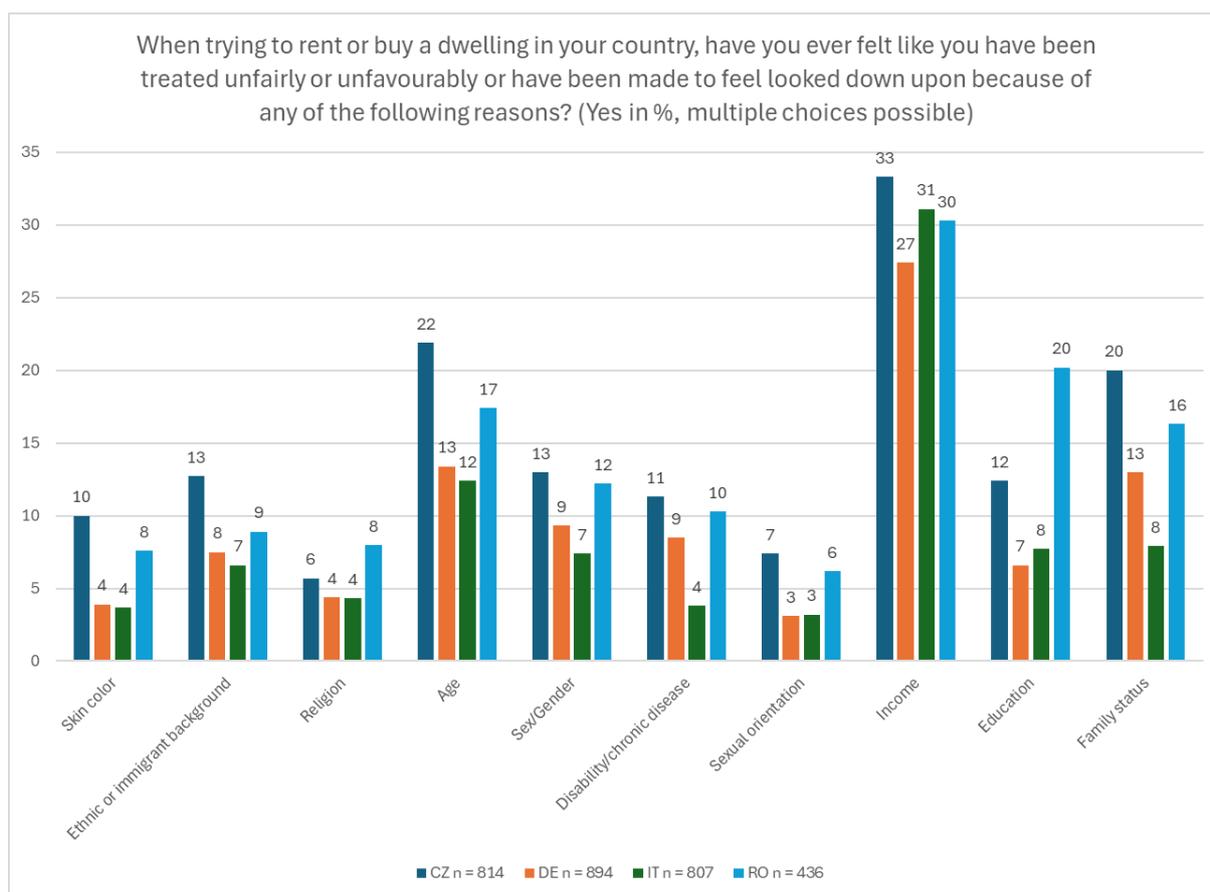


Figure 1: Reported experienced discrimination for four EU countries

Interestingly, the levels of experienced discrimination vary between countries: Italian respondents reported the lowest overall rates of discrimination across most categories, yet income-based discrimination was the second highest among them. Respondents in the Czech Republic reported the highest levels of discrimination across nearly all categories, while in Romania, the highest shares of discrimination were reported in relation to religion and education. These findings point to clear country-specific patterns in housing-related discrimination. Moreover, respondents were able to report multiple reasons for discrimination: In Czech Republic most respondents reported at least one form of experienced discrimination, followed by Romania, then Germany and lastly Italy.

Regarding the dependent variable, i.e. dwelling problems demonstrating low housing quality, the descriptive statistics show that low-income households are mostly affected by mould on windows or in the bathroom (reported by 6-13% of respondents; see Figure 2). Here, we also find country-specific variations, indicating fewer dwelling problems in Germany than in the other three countries with the highest overall rate of dwelling problems in Romania, closely followed by Italy. Hence, country-specific differences in housing quality are visible in the results.

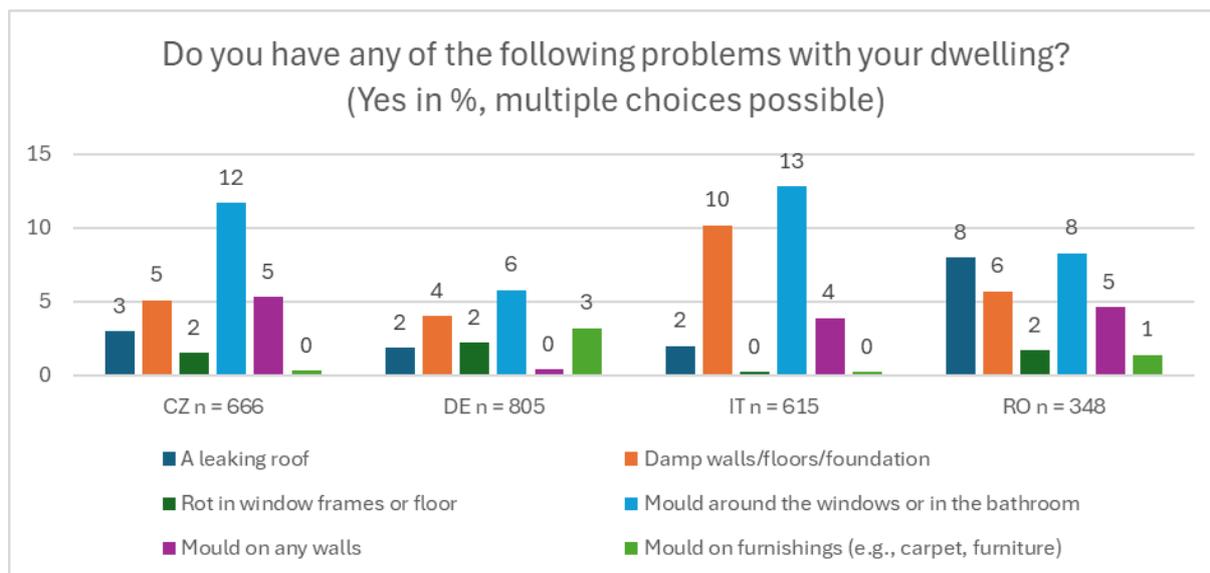


Figure 2: Reported experience with dwelling problems for four EU countries

SURVEY: MULTIVARIATE ANALYSES

To examine being discriminated due to various reasons in the housing sector and its impact on housing quality (operationalized by having any one of several dwelling problems), we conducted logistic regressions – one for each country. The results are presented in Table 1.

Discrimination due to...	CZ n = 814	DE n = 894	IT n = 807	RO n = 436
...skin color	OR = 0.49 p = .075	OR = 0.49 p = .154	OR = 1.11 p = .846	OR = 0.99 p = .986
...ethnic or immigrant background	OR = 0.91 p = .774	OR = 0.60 p = .143	OR = 1.14 p = .735	OR = 1.12 p = .810
...religion	OR = 0.70 p = .436	OR = 0.82 p = .649	OR = 0.47 p = .118	OR = 2.31 p = .155
...age	OR = 0.80 p = .307	OR = 0.56 p = .028	OR = 0.85 p = .569	OR = 0.27 p = .001
...sex/gender	OR = 0.92 p = .760	OR = 1.24 p = .503	OR = 0.90 p = .766	OR = 1.40 p = .440
...disability/chronic disease	OR = 0.88 p = .643	OR = 0.74 p = .319	OR = 1.29 p = .558	OR = 0.21 p = .001
...sexual orientation	OR = 0.68 p = .307	OR = 1.54 p = .415	OR = 0.83 p = .716	OR = 1.32 p = .606
...income	OR = 0.56 p = .002	OR = 0.76 p = .173	OR = 0.58 p = .003	OR = 0.86 p = .598
...education	OR = 1.20 p = .500	OR = 0.75 p = .430	OR = 1.14 p = .685	OR = 1.33 p = .450
...family status	OR = 0.99 p = .950	OR = 0.73 p = .213	OR = 1.01 p = .987	OR = 1.07 p = .854
Effect size Nagelkerke R ²	.088	.073	.032	.101



Table 1: Results of country-specific logistic regressions of the discrimination predictors (independent variables) on housing quality operationalized by having one or several of the above-presented dwelling problems (dependent variable).

Across countries, the results show that discrimination due to income and age are factors that are related to worse house quality. However, the effects are small indicating that other factors also impact why people live in good or bad housing. We will analyse the data in further detail including covariates in the regression. Moreover, using further dependent variables to operationalize housing quality may help to answer the research question more extensively.

CONCLUSION

We analysed how experienced discrimination in the housing sector predicts low housing quality for vulnerable social groups. Unsurprisingly, the quantitative survey results indicate that low-income respondents primarily report discrimination in the housing sector based on their income. Relatively high levels of perceived discrimination are also reported in relation to age, education, and family status. Discrimination in the housing sector due to income and age are related to bad housing quality. These findings align with, and the country-specific differences are interpreted through the lens of the qualitative case studies. This paper thus contributes to the literature on systemic discrimination by triangulating insights from multiple methods and data sources to uncover types of patterns of housing-related discrimination and to inform targeted policy recommendations.

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Do I Wanna Know? Predicting Information-Seeking and Avoidance Behaviour in the Context of Sustainable Fuels

Themes and sub-topics 2c) and 3b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Alternative Fuels, Information Seeking and Avoidance, Structural Equation Modelling, Informed Decision-Making and Public Participation

Extended abstract

INTRODUCTION

Achieving carbon neutrality requires the replacement of fossil fuels in all sectors, including aviation, heavy-duty transport, and chemical feedstocks. Alongside electrification, renewable alternative fuels are increasingly recognized as a bridge technology to decarbonize hard-to-electrify sectors. One viable alternative fuel solution are *solar fuels* produced through artificial photosynthesis. This process mimics nature by using solely solar energy, water, and existing CO₂ to generate high-energy hydrocarbons [1], [2].

In addition to the techno-economic development of sustainable energy innovations, current research emphasises the importance of public understanding about how these technologies work, their potential benefits and risks. This enables individuals to make informed decisions about adopting and using them, rather than relying on potentially false assumptions [3], [4]. However, awareness and knowledge about sustainable fuel solutions is rather low in the public, which can lead to increased risk perceptions, false beliefs, low acceptance, and a lack of adoption intentions [5].

This line of reasoning presupposes that the public is willing and motivated to actively engage in information-seeking and processing behaviours. However, current research shows that individuals may deliberately engage in information avoidance, defined as the intentional decision to delay or avoid (risk) related information. While some scholars define information avoidance as the opposite end of information seeking, others describe it as a distinct construct with different predictors [6]. The Risk Information Seeking and Processing (RISP) model by Griffin et al. [7], [8] integrates a variety of predictors of risk information-seeking, avoidance and processing behaviour. According to RISP, individuals seek and systematically process information when perceived information insufficiency hinders their ability to deal with a risk. However, a critical shortcoming of the RISP is its missing conceptual definition of information avoidance. Although heuristic routes are acknowledged, avoidance behaviour remains theoretically underspecified. This has been identified as a key reason for the model’s limited explanatory power, especially when applied to emerging or unfamiliar risks, such as those associated with novel energy technologies [9].



Thus, to examine the predictors of information seeking and information avoidance in the context of alternative fuels, this study investigates the following research questions:

- **RQ1:** Do individual attitudes, perceived benefits and risks of solar fuels, and information-related factors predict (a) information seeking and (b) information avoidance?
- **RQ2:** Which of these factors are the most significant predictors of (a) information seeking and (b) information avoidance?
- **RQ3:** Are information seeking and information avoidance regarding alternative fuels empirically distinct constructs, each associated with different predictor variables?

Building on theoretical insights from existing frameworks, e.g., [7], [10], [11], the following research model was proposed.

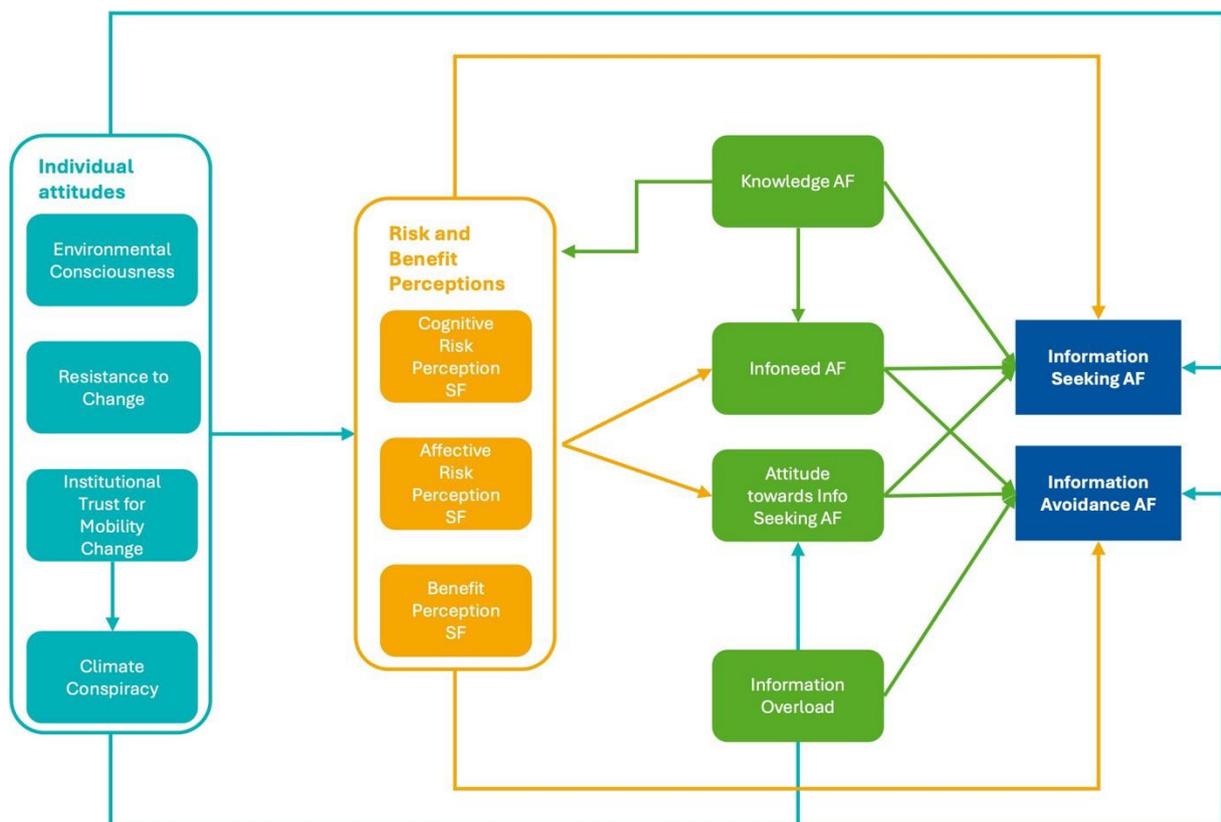


Figure 1: Research model of information seeking and information avoidance in the context of alternative fuels

(SF = Solar Fuels, AF = Alternative Fuels)

METHODOLOGY

We conducted a quantitative online survey using Qualtrics software (Version February 2025; © Qualtrics, Provo, UT). After a thematic introduction and informed consent, the questionnaire comprised blocks on sociodemographics, alternative fuel information attitudes and behaviour, solar fuel evaluation, and attitudinal factors. All constructs were measured with established validated scales or self-developed items based on qualitative pre-studies, using six-point Likert scales (1 = *strongly disagree*, 6 = *totally agree*). The survey was conducted in Germany in February 2025 by a market research agency to ensure representativeness in terms of gender, age, federal state, education and area of living. After data cleaning, the final sample consisted of $N = 518$ participants. To analyse the attitudes and



perceptions that determine informationseeking or avoidance behaviour regarding alternative fuels Partial Least Squares Structural Equation Modelling (PLS-SEM, SmartPLS Version 4.1.1.2) was employed. This variancebased method was chosen for its suitability for complex models with multiple constructs. Following the guideline by Hair et al. [12], we evaluated and optimized measurement and structural model quality (Table 1), confirming item reliability, internal consistency, construct reliability, convergent validity, and discriminant validity.

RESULTS

The final model (Figure 2) resulted from the stepwise exclusion of items with loadings below .60 and structural paths not meeting quality criteria. Participants reported moderate information-seeking ($M = 3.20$, $SD = 1.33$) and lowered levels of information avoidance ($M = 2.57$, $SD = 1.25$) behaviour. In contrast, their information need was slightly elevated ($M = 3.83$, $SD = 1.32$), and attitudes toward information seeking were generally positive ($M = 4.06$, $SD = 1.26$). Self-reported knowledge of alternative fuel technologies was rather low ($M = 2.53$, $SD = 1.09$). Regarding solar fuels specifically, risk perceptions on both the affective ($M = 2.74$, $SD = 1.23$) and cognitive ($M = 2.97$, $SD = 1.00$) dimensions were lowered, while perceived benefits were rated relatively high ($M = 4.16$, $SD = 1.05$).

Table 1. Quality measurement results for PLS model factors (NOI: Number of items; AVE: Average variance extracted, CR: Composite reliability, CRA: Cronbach's alpha), range of construct factor loadings, and descriptive statistics (Min, Max, M : Mean, SD : Standard deviation)

Construct	NOI	AVE	CR	CRA	Factor Loadings Range	Min	Max	M	SD
Environmental Consciousness	4	.689	.870	.849	.740-.880	1	6	4.07	1.18
Resistance to Change	3	.643	.783	.732	.734-.838	1	6	3.13	1.03
Institutional Trust for Mobility Change	6	.654	.907	.894	.759-.878	1	6	3.22	1.06
Climate Conspiracy	3	.716	.829	.804	.828-.861	1	6	2.95	1.36
Cognitive Risk Perception Solar Fuels	3	.626	.784	.707	.629-.887	1	6	2.97	1.00
Affective Risk Perception Solar Fuels	4	.838	.937	.935	.902-.925	1	6	2.74	1.23
Benefit Perception Solar Fuels	4	.727	.877	.874	.827-.879	1	6	4.16	1.05
Knowledge Alternative Fuels	6	.805	.957	.952	.860-.923	1	6	2.53	1.09
Information Need Alternative Fuels	6	.799	.951	.949	.877-.928	1	6	3.83	1.32
Attitude towards Information Seeking Alternative Fuels	7	.772	.954	.950	.820-.916	1	6	4.06	1.26
Information Overload	3	.774	.929	.858	.803-.919	1	6	3.25	1.22
Information Seeking Alternative Fuels	3	.914	.954	.953	.952-.958	1	6	3.20	1.33
Information Avoidance Alternative Fuels	3	.730	.818	.815	.825-.874	1	6	2.57	1.25

Overall, the model supported our theoretical assumptions, indicating that individual attitudinal factors influenced risk and benefit perceptions, which in turn were associated with information need and attitudes toward information seeking—both acting as predictors of informationseeking and avoidance behaviours. Additionally, certain exogenous attitudinal constructs (e.g., climate conspiracy beliefs) and intervening variables (e.g., perceived benefits) demonstrated direct effects on information-related behaviours.

The model explained 61.5% of the variance in information seeking. The strongest predictors were information need ($\beta = .469$, $p < .001$), attitude toward information seeking ($\beta = .313$, $p < .001$), and knowledge of alternative fuels ($\beta = .178$, $p < .001$). Notably, knowledge and information seeking were positively related, suggesting that participants with greater knowledge were more likely to engage in further information seeking, potentially reinforcing their knowledge base. In contrast, the explained variance in information avoidance was significantly lower, accounting for 37%. Information need ($\beta = -.312$, $p < .001$) and attitude toward information seeking ($\beta = -.148$, $p < .01$) emerged as the strongest negative predictors, along with perceived benefits ($\beta = -.163$, $p < .001$). Climate conspiracy ($\beta = .146$, $p < .001$) and information overload ($\beta = .114$, $p < .01$) were positively related to avoidance.



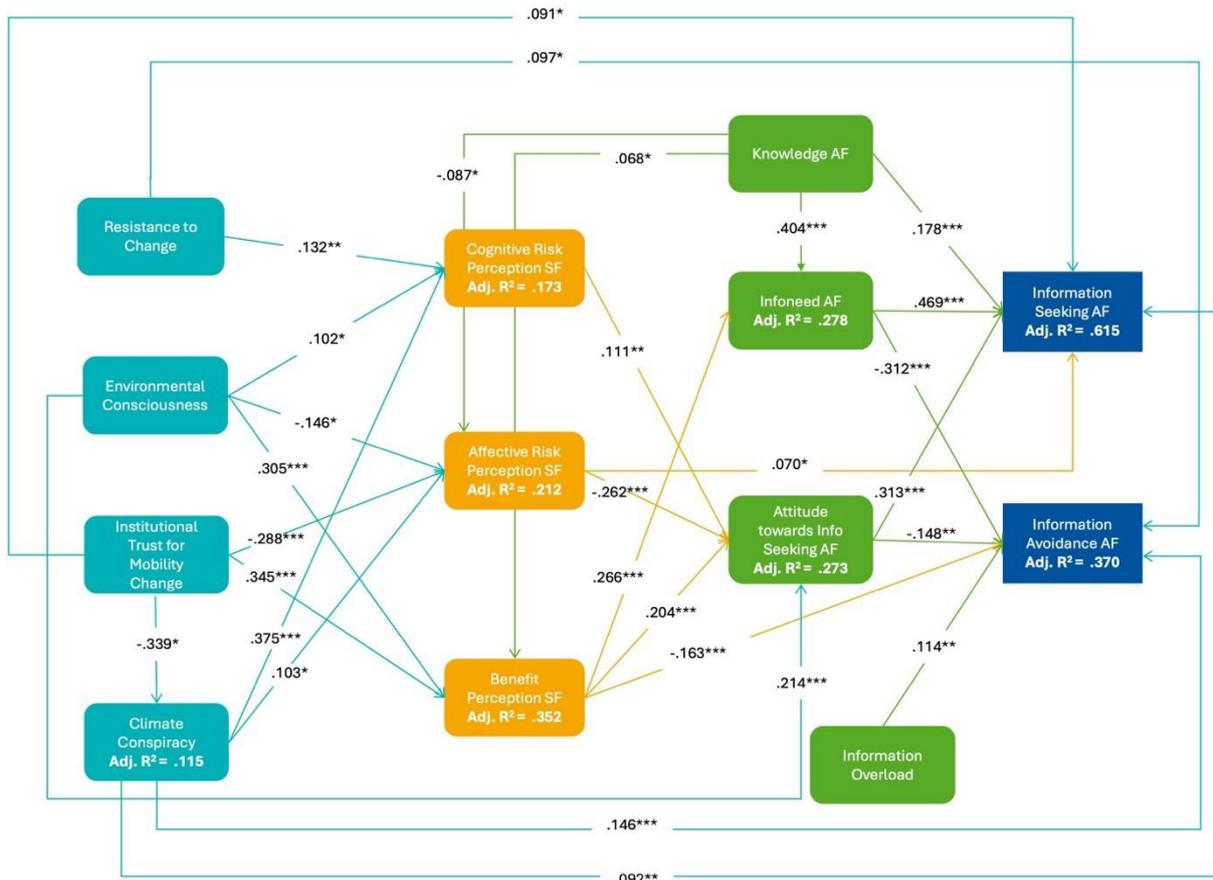


Figure 2: Structural path model with path coefficients (from bootstrapping with $n = 5000$ subsamples) for alternative fuel information-seeking and avoidance behaviour (* = $p < .05$; ** = $p < .01$, *** = $p < .001$)

DISCUSSION

Understanding the psychological drivers of information-seeking and avoidance behaviour is essential for shaping effective communication strategies in the context of the mobility transition. Our findings indicate that information seeking and avoidance represent two distinct constructs. While some predictors were related to both constructs, their effects differed in direction and magnitude, explaining considerably less variance in information avoidance. Nonetheless, our model explained a higher proportion of the variance in information seeking (61.5%) and information avoidance (37%), than reported in the meta-analysis by Yang et al. [9] (median seeking = 0.52, median avoidance = 0.10). This suggests that novel predictors, such as benefit perceptions and climate conspiracy beliefs, offer important explanatory value, even within the context of a relatively unfamiliar technology. These findings indicate the need for conceptually disentangling information avoidance from seeking, which is underspecified in traditional frameworks like the RISP. The results emphasise the importance of individual attitudinal factors, which, despite having few direct links to the target constructs, exerted a substantial influence through risk and benefit perceptions. Further, our findings support the idea that individuals may feel overwhelmed by information overload, leading to avoidance behaviours [10]. Enhancing media literacy [6] could empower individuals to seek and process information about societally relevant topics. Finally, this research underscores the importance of understanding predictors of information-seeking and avoidance behaviours to enhance public engagement in the energy transition and enable informed decision-making about support and acceptance. Future studies should

characterize information avoiders to identify their constraints and assess when they might be willing to engage in discussions on societal issues like sustainable energy transformation.

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Willing-to-share what? Data sharing and energy efficiency behavior – empirical evidence based on the privacy calculus model

Theme 3, sub-topic 3b)

Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Data sharing, Energy technology, Energy savings, Digitalization

Extended abstract

1. Introduction

Problem Statement. Data-driven tools, products and services have massive technical potential to reduce energy consumption [1]. Smart metering and energy management systems are prominent examples, but the digitalization of the energy sector goes beyond single technologies – it is a system shift [2]. Sharing data with energy suppliers becomes a stepping stone to unlocking potentials for energy efficiency, energy savings, and demand response. For private households, the willingness-to-share data is therefore a pre-condition to both adoption decisions and usage behavior with regard to energy-saving technologies [3][4]. However, the link between data sharing and energy-related behavior has only recently garnered attention – much remains unclear.

Scope and Objective. This submission examines end consumers’ willingness to share data in the context of digital tools that support energy-saving behavior. Starting from theory, we develop hypotheses regarding data sharing in the context of energy-saving tools. Exploiting survey data from Germany, we then study empirically which factors explain the willingness-to-share data with energy suppliers and how data sharing connects with the intention to use energy-saving technologies.

2. Methodology

Theoretical foundation. Based on a review of the applicable literature on data sharing in general,



the privacy calculus model [5] is chosen as the conceptual framework. Further reviewing the literature on digital tools for energy-saving behavior in particular, this model is extending to formulate five hypotheses specific to the willingness-to-share energy data from digital tools. Figure 1 shows the hypotheses and the mechanism of transmission from willingness-to-share to intention-to-use digital tools.

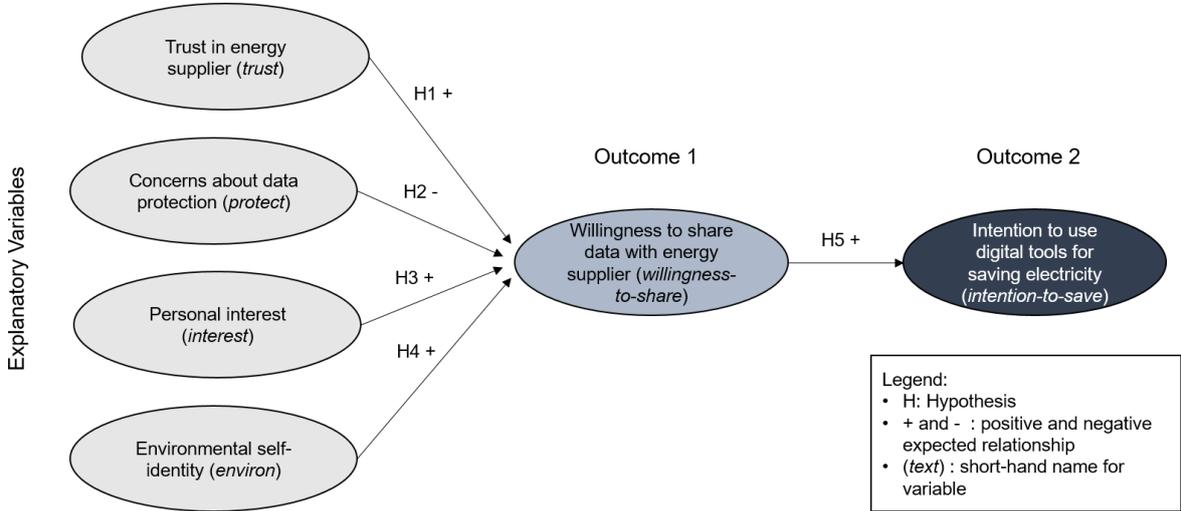


Figure 12: Hypotheses regarding the willingness to share data

Data. The empirical work draws on a representative survey among households in Germany in 2024. After data cleaning and plausibility checks, the sample comprises 1,240 observations. Each variable is represented by multiple items. Control variables include (a) socio-demographics, (b) household technology (e.g. solar panels, electric vehicles), and (c) technology affinity. The survey contains questions on willingness-to-share broken down by market actors (e.g. local supplier or international company), and by purpose for data processing (e.g. individual benefits, or collective welfare).

Analysis. Multiple linear regression is used to test the hypotheses. The four explanatory variables are tested for two outcome variables: willingness-to-share and intention-to-use (see Table 1). Specifications use Huber-White standard errors and a 95% level of confidence. Control vectors are used in robustness tests.

Table 2: Descriptive statistics for regression analysis

Variable	Mean	SD	Min	Max	Encoding
willingness-to-share	3.344	1.038	1	5	5: high willingness
intention-to-save	3.239	1.094	1	5	5: high intention
trust	3.375	0.926	1	5	5: high trust level
protect	3.006	1.109	1	5	5: highly concerned
interest	3.243	1.040	1	5	5: strong interest
environ	3.614	0.963	1	5	5: strong environmental identity

Notes: Statistics are based on full sample of 1240 participants. Short-hand names for variables are spelled out in Figure 1. Control variables omitted from table.

Additionally, descriptive means estimation and t-tests are conducted to better understand the heterogeneity and the mechanism behind the behavioral choices: (a) whether willingness-to-share differs across market actors and (b) whether the stated purpose for data processing matters.

3. Results

Regression results. Figure 2 shows the results graphically, with bar heights representing coefficients. In Panel (a), the outcome is the willingness-to-share data with the energy supplier. All coefficients have the expected signs and are statistically significant. Higher trust in the energy supplier is associated with a 0.42 unit increase in willingness-to-share data. The result is economically meaningful: relative to the mean outcome 3.34, this indicates a 13 % increase. Concerns about data protection are negatively associated: a 1-unit increase in concerns corresponds to a 0.17-unit decrease in willingness-to-share (5% of mean). The coefficients for personal interest and environmental identity are positive, but smaller than for trust.

In Panel (b), the outcome is the intention to use digital technologies, i.e. the reduced-form relationship between intention and the predictors (cf. Fig. 1). While the three positive relationships are in line with Panel (a), there are two differences. First, concerns about data protection are not a significant predictor of intention-to-use. Second, the magnitudes diverge: personal interest has the largest relative effect on intention-to-use, whereas environmental attitude and trust in energy supplier are now on par. For reference, the coefficient on personal interest of 0.38 correspond to a 12% increase evaluated at the mean outcome of 3.24.

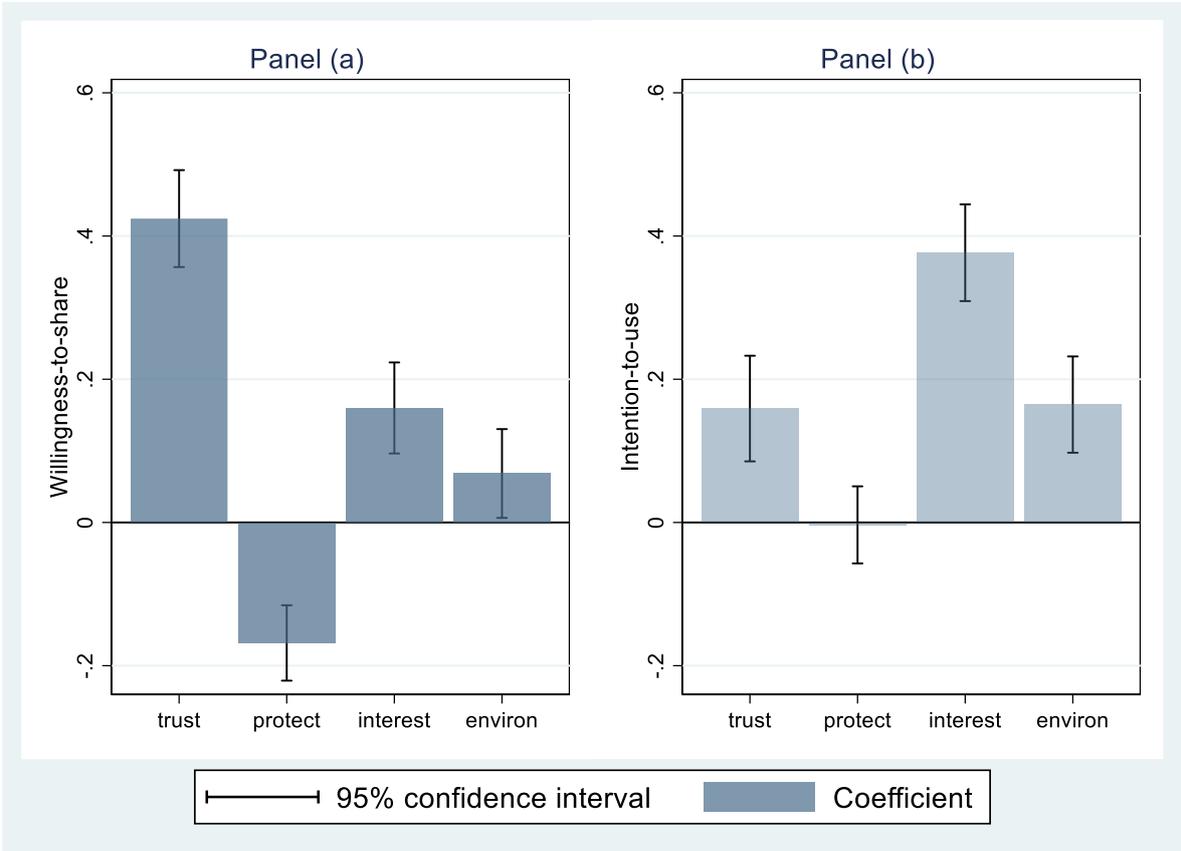


Figure 13: Regression results displayed as bar plot

The empirical results thus support the theoretical basis regarding Hypotheses 1-4. However, there is also evidence that transmission from willingness-to-share to intention-to-use is more complex than the linear hypothesis that underlies the empirical strategy.

Additional analysis.

Figure 3 shows the break-down of the willingness-to-share by two different dimensions. Horizontal bars indicate means, capped bars the respective 95% confidence intervals. In Panel (a), respondents were asked how likely they would agree to sharing data with different actors (1: very unlikely, 5: very likely). The lowest values are obtained for international platforms (Google/Amazon, in red), followed by the European Commission. The highest values are for regional energy suppliers (blue), followed by cities/municipalities. This indicates a preference for local over international actors. In Panel (b), respondents were asked how likely they would agree to share data for specific purposes. This break-down by purpose shows the lowest value for advertising (red), consistent with the platform result. The highest value is for financial savings at home (blue), indicating that personal gains are associated with higher willingness to share than the more collective purposes, such as public welfare and research projects.

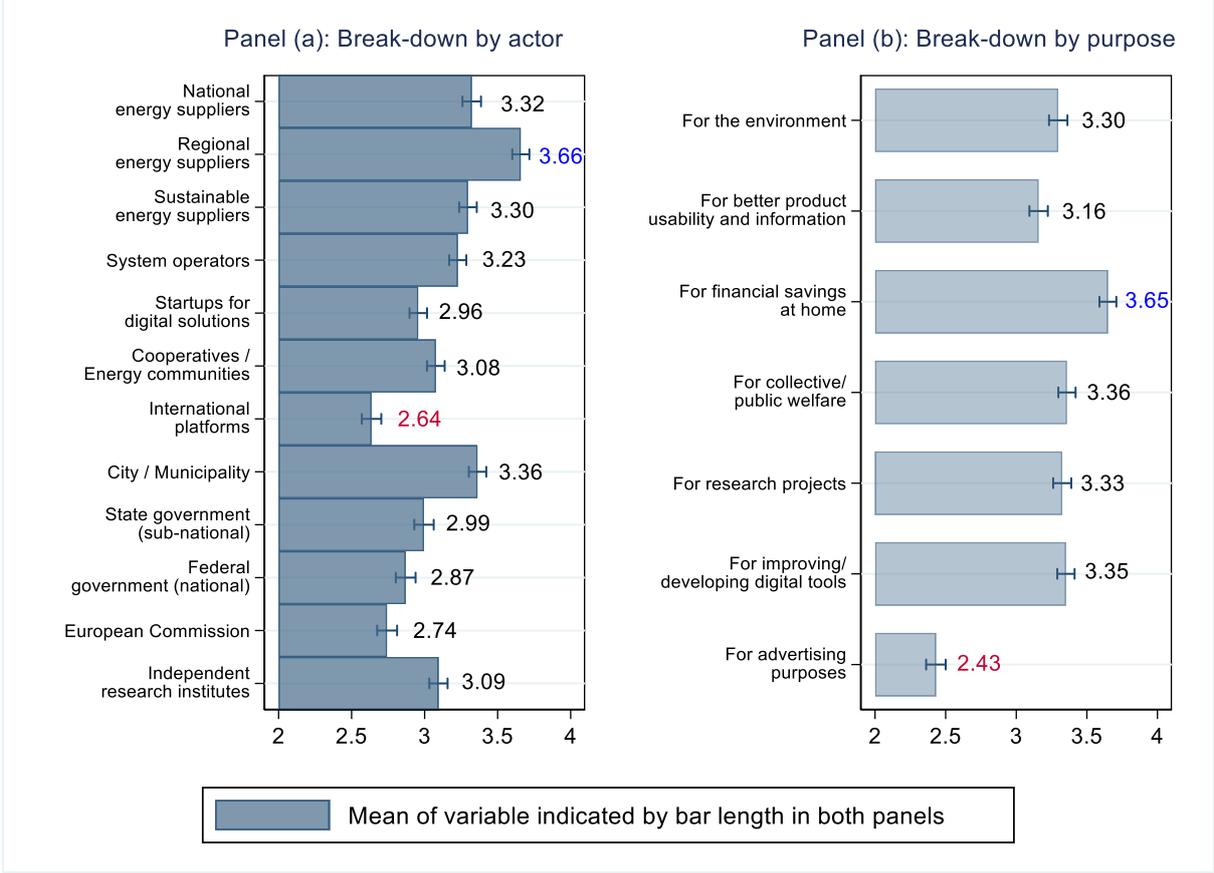


Figure 14: Break-down of willingness to share data

For both break-downs, the results were also calculated for sub-groups with high and low overall willingness-to-share. Interestingly, there are no differences in the relative breakdown, indicating that the distribution above is not a reflection of overall willingness-to-share but actually specific to actors and purposes.

4. Conclusion

With the increasing availability of digital tools and services in the energy sector, data sharing has become a critical factor for the adoption of energy-saving technologies. However, there is a substantial research gap understanding how data sharing decisions and energy-saving behavior interrelate. The results from this contribution are in support of the privacy calculus model: trust in energy suppliers, strong personal interest in digital tools and environmental self-identity correspond to higher willingness-to-share data, while data protection concern work against sharing. However, the results only translate partly to the intention to use digital tools, suggesting that the theoretical basis is more complex than the linear relationships modelled in the regression.

Further work is needed to better understand the full mechanism. Structural equation models and the modelling of complex mediation and moderation patterns could help in this process. This line of work is also of high policy relevance: with cross-sectoral legislation such as the EU Data Act, households are given more control over their data [6]. Whether, how, and why they share this data has an impact on how sectoral behavioral policy can work: without data sharing, energy savings potentials from digital tools cannot be lifted fully. The break-down by actor and purpose indicates two pieces of the puzzle towards a better understanding of household behavior in an increasingly digitalized energy system.

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Stakeholder complexity in energy community projects: Insights from co-creation workshops across four EU countries

Theme 2, sub-topic 2a) and 2d)

Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy communities, Personas, Stakeholder engagement, Regional energy transitions

Extended abstract

1. Introduction

Problem Statement.

Energy communities (ECs) are a key organizational vehicle to foster an energy transition that is inclusive and decentralized [1] [2].⁹ With advances in the EU legal framework, ECs are emerging across Europe, but many challenges remain. This contribution addresses two key challenges. First, ECs are interdisciplinary by design: they require technical tools, social value propositions and viable economic models to function [3][4]. A second, related challenge is the complexity of the stakeholder landscape needed for ECs to work and fulfill their potential [4][5].

⁹ We operate with a broad view of ECs as “Citizen-driven energy actions that contribute to the clean energy transition, advancing energy efficiency within local communities” [1]



Scope and Objective.

This contribution provides new insights on these challenges from an interdisciplinary research project. Using data from a series of co-creation workshops in four EU countries, we develop a deeper understanding of the factors that determine the needs of EC stakeholders and their integration into regional energy systems. The workshops address the four main stakeholder groups shown in Figure 1 and how these interrelate as ECs grow and develop.

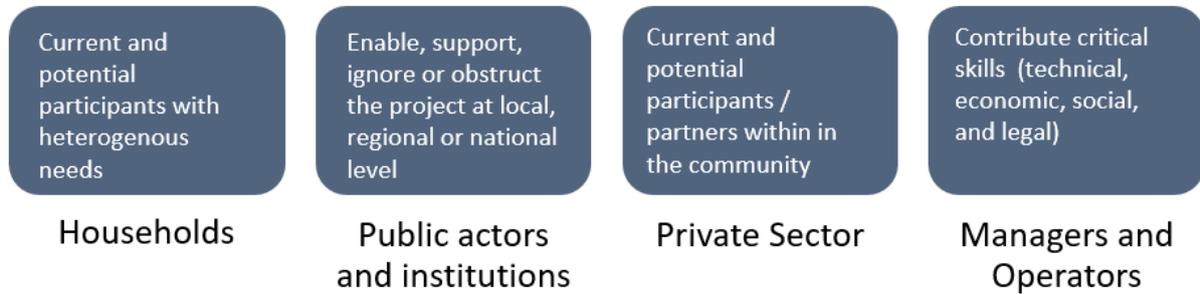


Figure 15: Stakeholder types and their role in ECs

2. Methodology

The workshop series took place in four countries in 2025: Germany, Austria, Czechia and the Netherlands. The concept employed two co-creation methods: (a) **personas** (cf. [6]), and (b) **customer journeys** (cf. [7]). Both were built on a common protocol across countries, and analyzed with a common reporting template for comparability. Country-specific modifications were made to reflect local contexts and situational constraints.

Personas were first built in interdisciplinary expert workshops based on a common structure of attributes, shown in Figure 2. This resulted in an initial list of 32 personas from all four stakeholder types (cf. Figure 1).

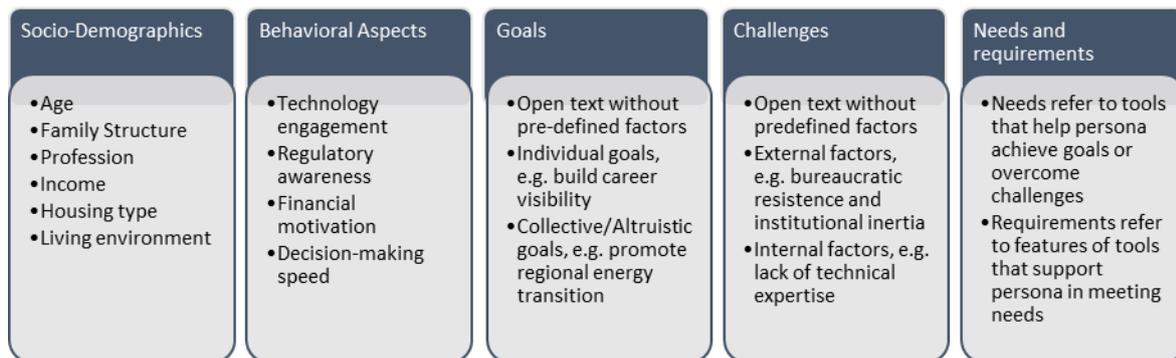


Figure 16: Contents of persona development

This pool was taken to the co-creation workshops, for which the target group was people currently involved in the establishment and operation of ECs. The participants are heterogeneous in the sense that the communities they represent differ widely regarding their stage of development and local/regional context.

In a first step, personas were selected from the pool based on participants’ perceived relevance of the personas to the specific needs of their own project. They were encouraged to validate, extend/adjust, or discard the personas based on practical experience. In a second step, customer journeys for selected personas were developed, which represent a community pathway for each

persona as she/he/they engage and develop through the EC.

The results are analyzed qualitatively, following the structure of Figure 1. For this submission, the focus is on the persona validation, i.e. the agreements, adjustments, and disagreements between the personas developed by interdisciplinary experts and the perception by the practitioners in the local workshops. Particular attention is given to commonalities and discrepancies between different countries in order to inform opportunities and constraints for transnational learning.

3. Results

Households.

Workshop participants put a high focus on communication behavior for households. Participants went into considerable detail regarding the media channels, preferences for interaction, and barriers to the adoption of digital interfaces for specific personas. These aspects were directly linked to specific needs and requirements for communication strategies and supporting technological tools in the energy communities.

Additionally, participants developed new personas that are tailored to context. Examples are the typical big city resident with rising cost of living/housing as the main challenge (Germany), the elderly person with sufficient resources but low digital competence, or the single mother with limited time to sift through conflicting information online (Austria). Through this, the participants stressed that challenges are embedded in households' daily life and not confined to energy behavior.

Public actors and institutions.

Municipalities were emphasized across all countries. However, while they are discussed as potential initiators and trust-building institutions in Austria, the municipality is seen as an external stakeholder with a potential lack of cooperation in Czechia. In the German workshop, there was discussion about why engagement is easier in rural communities than cities. For projects in smaller municipalities, the “mayor” was named specifically as a personal representative. In this context, it was also emphasized that best practices from other countries can be hard to use in convincing local institutions because they are discarded as too different (e.g. learnings from Austria in Czechia).

Regarding the energy sector, the identified factors diverged across countries based on the legislative framework. For example, the Dutch workshop noted that distribution system operators were missing from the persona set, which is regionally important due to high grid congestion. By contrast, Czech participants named data exchange with mandatory national systems as a requirement for progress.

Private Sector.

EC leaders discuss the private sector as a partner, but also as a competitor. For example, business models supporting energy-saving behavior were mentioned as “alternatives” with lower entry barriers than ECs, especially for personas with high financial motivation and time constraints. Economically, the results thus underscore opportunity costs of participation between commercial and community-based approaches targeting energy behavior.

Managers and Operators.

It was found that managers typically have a dual role in ECs because they are also households that participate in the EC. This dual role, which was discussed in several workshops, implies that the behavioral aspects of the individual influence their actions as an administrator and vice versa.

The customer journeys also reveal how managers experience two directions of learning. While some know the community-related aspects and are challenged with the technical aspects, others know energy and technology but are challenged by the social aspects. This was made particularly explicit in the Czech workshop, where the participants represented ECs that differ in structure. Those coming from a technical perspective put relatively lower emphasis on household behavior as a success factor for the overall project.

4. Conclusion

Novelty of contribution.

This submission makes two contributions to the scientific literature. First, personas are explored for transdisciplinary collaboration. Personas are established in the behavioral sciences / psychology [7], but also in technical disciplines / computer science as a method of product development [8]. Bringing these perspectives together allowed the workshop to address interdisciplinary needs perspectives. Second, the results provide a deeper understanding of the stakeholder complexity through the lens of those who are making ECs work in their local context, which is ultimately important to support ECs development and growth at a European level.

Implications.

The results highlight how behavioral aspects like motivation and habits are seen as key success factors from the perspective of those who implement ECs. This is important from a practical perspective because it influences the value of technical solutions *for* ECs, but also from a policy perspective in order to improve support measures that foster inclusivity and participation *through* ECs.

Outlook.

The workshops were conducted as part of the international research project RENvolveIT, funded through the Clean Energy Transition Partnership. The project aim is to build a user-friendly, need-based toolbox designed to streamline the participation of heterogeneous stakeholders in ECs. The workshops were the first step to integrating socio-economic needs, technical requirements and legal constraints. This need for inter- and transdisciplinarity is critical, but much work remains to be done for addressing the challenges ECs currently face.

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Nudging Sustainable Engagement in Businesses: The Role of Cultural Values

Theme 1, sub-topic 1a) 1b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Behavioural messaging, Cross-cultural, Loss framing, Messenger effect, Nudging, Sustainability communication

EXTENDED ABSTRACT

1. Background and Aims

Motivating sustainable choices in organisations is challenging due to competing priorities, incentives, and multiple stakeholders. The environmental footprint of organisational activities is substantial, underscoring the urgency and scale of this problem [1]. For instance, listed companies alone are responsible for ~40% of all harmful emissions [2]. Interventions in these settings, therefore, possess a disproportionately large potential for global climate action.

Whilst behavioural science has made strides in developing effective “nudges” for individuals, much less is known about translating those insights to multi-stakeholder corporate environments, particularly concerning sustainability [3–5]. Moreover, behavioural nudges are not culturally neutral; their effectiveness depends on how cues like loss, urgency, or authority are interpreted—all factors influenced by cultural values [6,7]. Effective interventions must therefore account for broader cultural and systemic factors. Within the cultural values literature, a prevailing focus has been on using country-level measures, which can often overlook significant intra-cultural variations [8–10]. This study, therefore, adopts recommendations for individual-level cultural values, particularly in business settings [8].

The study addresses these gaps by focusing on the limited understanding of behavioural interventions in organisational sustainability and the need for individual-level cultural insights. To that end, we partnered with a global organisation seeking to improve sustainability reporting



and environmental action among its supply chain partners. They are developing a digital partnership platform that makes sustainability reporting more transparent to clients. Our primary aim was to encourage the partners' willingness to engage with this new platform, thereby improving sustainability reporting and scores as a result. This transparency is expected to help end-customers consider environmental factors.

We conducted a cross-cultural experiment to explore how individual-level cultural values moderate the impact of different behavioural messaging strategies on decision-makers' likelihood of engaging with the digital platform.

The research specifically tested three types of behavioural messaging, each rooted in distinct psychological principles:

- i. Loss Framing: Message emphasising potential losses from inaction
- ii. Urgency-Exclusivity: Message creating a sense of limited opportunity and privileged access
- iii. Messenger Effect: Message leveraging the perceived authority of the message source

2. Methodology

2.1. Experimental Design and Participants

We ran an online vignette experiment with a between-subjects design [11]. Participants included business decision-makers ($N=659$) from the UK, USA, and India. The vignette established all relevant details for participants, including a realistic business scenario, organisational priorities, opportunities, and their specific task related to platform engagement. Participants were then randomly assigned to receive one of four email messages, each featuring a different nudge condition: Loss Framing, Urgency-Exclusivity, Messenger Effect, or a neutral Control message.

2.2. Key Measures

Following message exposure, participants completed a brief questionnaire. It contained 7-point Likert-scale items assessing their behavioural intentions and perception of the message. Specifically, *Likelihood of Signing Up* captured willingness to engage with the platform, and *Persuasiveness of the Message* captured the extent to which the message was perceived as convincing.

Subsequently, participants completed the CVSCALE, a standardised scale to measure their individual-level cultural values [8,12]. This scale measured Power Distance, Uncertainty Avoidance, Collectivism, Long-term Orientation, and Masculinity. To account for pre-existing environmental attitudes, the GREEN scale, assessing green consumer attitudes, was also included [13,14].

3. Key Findings

3.1. Persuasiveness of the Messages



A Kruskal-Wallis test indicated significant differences in perceived persuasiveness across the four conditions ($\chi^2(3)=8.20, p=.0420$). The Loss Framing message was rated as the most persuasive overall, while the Urgency-Exclusivity message was rated lowest.

3.2. Persuasiveness as a Mediator between Message Type and Platform Engagement

PROCESS Model 4 tested whether participants' perceived persuasiveness of the message mediated the effect of message type on platform engagement. Compared to the Control group, the Loss Framing condition showed a marginally significant indirect effect on platform engagement through persuasiveness (90%CI[0.02, 0.37]), with message persuasiveness significantly impacting platform engagement ($p<.001$). These results suggest that persuasive perception drove behavioural intention. For the other two experimental groups (Messenger Effect and Urgency-Exclusivity), the mediation models did not yield significant indirect effects.

3.3. Moderating Effect of Cultural Values on the Effect of Message Type on Platform Engagement

Moderation models (PROCESS Model 1) revealed important insights into the culturally dependent nature of nudge effectiveness. The impact of Loss Framing was significantly moderated by cultural values. Specifically, its effectiveness decreased among participants higher in collectivism ($p=.0890$) and increased among those higher in long-term orientation ($p=.0559$). Furthermore, the Messenger Effect became more effective as participants' scores increased on masculinity ($p=.0779$) and long-term orientation ($p=.0378$).

3.4. Manipulation Checks as Predictors

Additional robustness check analyses using participants' nudge perception (manipulation check questions) as continuous independent variables supported the findings of the moderation analyses and indicated potential additional patterns. For example, perceived messenger authority was more predictive of sign-up likelihood in cultures higher in power distance ($p=.0807$).

4. Implications and Recommendations

Our findings highlight the importance of **culturally attuned behavioural interventions** in organisational settings. Nudging strategies that succeed in one cultural context may backfire or underperform in another. Moreover, by using individual-level cultural metrics, this study goes beyond geographic boundaries and offers more granular insight into message tailoring.

While not all primary effects reached conventional significance threshold at 5%, exploratory models using participants' nudge perceptions as continuous predictors supported our theoretical expectations. These analyses revealed more consistent patterns and reinforced the broader point that message framing and cultural fit matter for influencing sustainability engagement in organisational settings.

Reduced impact of Loss Framing among collectivists may reflect their preference for group harmony and shared responsibility, aligning with the 'cushion hypothesis' [15]. Messages emphasising individual loss may be less salient or motivating, as individuals might perceive a collective safety net or prioritise group well-being over individual risk avoidance [16]. In contrast, individuals higher in long-term orientation may respond more strongly to loss framing



because they are predisposed to evaluate outcomes over extended time horizons, making the potential long-term losses from non-engagement more compelling [17].

Similarly, the Messenger Effect's increased effectiveness among participants with higher masculinity and long-term orientation aligns with prior findings: masculinity is associated with competitiveness and achievement, which may heighten receptivity to status-oriented messages from leadership, while long-term oriented individuals may interpret authoritative messages as signals of strategic foresight [17,18]. The finding that perceived messenger authority is more effective in cultures higher in power distance directly corroborates existing literature on power dynamics. In high power-distance cultures, there is a greater acceptance of unequal power distribution and a stronger deference to authority figures, making messages from credible sources more impactful [19,20].

Practically, this means that 1) nudging can be effectively implemented in organisational contexts, and 2) business communicators can benefit from tailoring nudges to cultural values, especially in global B2B settings. While more confirmatory research is required, given some marginal results, the patterns offer important insight and practical relevance to business practice.

Businesses, especially those operating globally, can improve the uptake of sustainability-related initiatives by tailoring messages to resonate with culturally relevant motivations, such as fear of loss in individualist, long-term oriented cultures, or appeals from leadership in power-distant ones.

To validate these insights, we are now conducting a follow-up online experiment with enhanced nudge messages, and a field study with the service provider network of our partner company. These upcoming studies will further test whether bolder messaging and real-world application improve engagement, laying groundwork for scalable, culturally adaptable sustainability communication strategies.

5. References

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Is it the taking part that counts? Exploring the dynamics of community participation in the energy transition

Theme 2, sub-topic 2d

“Policy/practice contribution”

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Keywords: communities, participation, energy transition, volunteering

Extended abstract

Background

Community organisations have the potential to accelerate the energy transition by developing grass-roots support (where a top-down governmental approach could be met with opposition), building capacity within communities, and increasing peer-to-peer collaboration in a shared environment. However, motivating and enabling individuals’ voluntary participation in these organisations is a challenge, despite volunteering having benefits to both the person volunteering and broader society. Understanding what motivates people to participate in environmental volunteerism and what factors lead to defection can inform programme design and improve the rate of participation and retention of volunteers.

To investigate this issue, we conducted 24 semi-structured interviews with Sustainable Energy Community (SEC) volunteers in Ireland. Participants were mostly in leadership roles within their SEC and spread geographically across Ireland, with roughly one third in urban areas and two thirds from rural. Interviews took place in batches from November 2024 to July 2025, with breaks for transcription and analysis.

Findings

Our findings relate to processes of volunteer motivation, recruitment, and level of activity of individual members and the group. Themes included the motivations of volunteers, the internal organisational structure of SECs, their strategic processes, and the external challenges to community activism posed by private industry and bureaucratic systems.

Participants were motivated to add value – to both the SEC as a member and to the community as an SEC. For those hoping to add value as a member, giving back to the community was a motivation for participation but not sufficient – having the “appropriate” skills or knowledge was also necessary. Participants who conceptualised their volunteering behaviour through a lens of professional development sometimes applied this expectation to their fellow committee members, for example stating that the committee didn’t have the necessary qualifications, skills, or expertise to run an effective SEC. This point of view could introduce a hierarchy to participation that caused dissatisfaction with “unqualified” members. Having a group of volunteers with mismatched motivations for participation was a source of conflict within groups, therefore training SEC coordinators to manage inter-personal conflicts may help.

Some participants felt the gains being realised by their SEC did not match the efforts they were making. The cause of this frustration can be grouped into two themes: the invisibility of gains



and the lack of a shared vision. The large volume of administrative and desk-based work associated with running an SEC before producing “tangible” results was at times associated with feelings of futility among some participants who felt they were putting hours into the project but struggling to account for what they accomplished during that time. On the other hand, some participants mentioned that creating a shared vision of the community helped to set parameters, choose a direction of action, and attune the SEC with the needs of the wider community. Understanding the challenges and opportunities in the area and developing a long-term strategic vision with other people allowed some SECs to place themselves (or make space for themselves) within the context of Ireland’s energy transition while developing their community. Encouraging SECs to document their activities and engage with their community could improve the visibility of their actions and refine their agenda, prolonging participation.

The organisational structure of SECs had an impact on both the longevity of the group and the individual members’ levels of motivation and fulfilment. Some SECs had a hierarchical organisational structure, whereby being the chair meant being a leader, mediator, and administrator, the point of contact for mentors and consultants, and having the responsibility of translating complex processes to the committee. Some participants believed an effective chair was pivotal for sustained SEC activity, in part because they provide continuity and stability that allows other members to disengage and reengage. For SECs that subscribed to a hierarchical distribution of power, participants described a significant pressure on the chair, and other members disengaging with the SEC because of dissatisfaction with the leadership style. For SECs with a more horizontal distribution of executive power, democratic or consensus-based decision-making ensured group cohesion, but some participants described activities progressing slower than they would prefer at times.

SEC approaches to project and time management also impacted volunteer longevity. Participants described different approaches to project management, with some groups focussing on one central project, such as retrofitting a community building while others were more modular in their approach, with multiple ongoing projects being led by factions of the group. Working on one central project with high visibility could help galvanise support around a project, but during periods of waiting this resulted in SEC inactivity and sometimes in volunteer disengagement. How SEC activities are organised may be a function of the hierarchical structure and the size of the SEC. Larger SECs with more horizontal power structures had the flexibility to have multiple concurrent activities and allow participants to engage with particular projects they were interested in. Supporting SECs during their formation to develop an appropriate organisational structure may better equip groups in the long run.

Participants from well-integrated SECs described how leveraging relationships in the community can increase the reach, capacity, and longevity of the group. During periods of low participant motivation, well-connected SEC members explained that external commitments to other groups would prolong activity and could be reenergising. Participants from areas with multiple groups in the same locality compared the ability to see the mechanics of a successful SEC to having an unofficial mentor, and described how this relationship inspired action within their own SEC. Developing a well-connected network of SECs could reduce duplication of effort, allow groups to collaborate and share knowledge, and inspire action.

Communities participating in the energy transition faced external challenges, with systems and markets being in conflict with community at times. Participants described funders timing applications inappropriately for volunteers, excessive bureaucratic practices, and programmes not being designed with communities in mind. Participants felt that people volunteering their time were likely to end their participation in SECs because of unfriendly systems, not because they were uninterested in the cause. Some participants asserted that the interests of private

industry were at odds with the interests of communities, for example, energy providers had been obstructive to power-sharing, businesses had masqueraded as community organisations and outbid actual communities for grid access, and businesses had exploited technical loopholes to access community funds. Participants expressed feeling demotivated when they realised how difficult operating as a community group was within systems not fit for purpose. Restructuring grant requirements and conducting a sludge audit could reduce administrative burdens where possible and improve community resourcing.

Conclusion

This research details some of the dynamics of community volunteer groups and presents recommendations for programme design and delivery to improve volunteer experience, group organisational structure, strategic processes, and increase participation and retention of volunteers. The role of communities as a “third pillar” of the energy transition has recently come into focus,¹⁰ so while we focus on Sustainable Energy Communities (SECs) to explore these barriers and drivers of participation, the findings may be applicable more widely to community climate action in Ireland and elsewhere.

¹⁰ Department of Environment, Climate and Communications (2024). [Climate Conversation 2023 Report: From Individual Action to Collective Engagement](#)



Sustainable video streaming: Investigating sufficient use practices among Dutch citizens

5b) Social practices of sufficiency; Infrastructures, enabling conditions, social dynamics and collective practices favoring sufficiency

“Academic contribution”

“Policy/practice contribution”

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Extended abstract

Information and communication technology (ICT) has the potential to contribute positively to sustainability by reducing energy consumption and conserving raw materials in other sectors

[1],[2],[3],[4],[5],[6],[7]. However, using ICT also has negative climate and environmental impacts due to the sector’s high energy and natural resource demands (e.g., fresh water, land, critical raw materials), e-waste disposal and greenhouse gas (GHG) emissions [1],[5],[8],[9],[10],[11],[12],[13]. Despite efforts to mitigate these ICT sector’s negative impacts with technological solutions (e.g., hardware and infrastructure efficiency) [14], the total footprint of the ICT sector still contributes roughly 2% to 4% of all global GHG emissions [10],[14],[15].

ICT-related emissions are predicted to increase as gains from efficiency measures are expected to decrease[1],[13]. Simultaneously, the sector is expected to reach 21% of global electricity demand by 2030 [16], due to more devices, the rise of artificial intelligence (AI) [17] and Internet of Things (IoT), and an increase in video streaming [10],[18],[19]. Hence, a shift is needed from the current technological, efficiency-oriented solutions [20] towards sustainability approaches based on demand reduction via changes in user behaviour (sufficiency) [13],[21],[22],[23],[24],[25]. A suitable focus for research on digital sufficiency is video streaming, as this is the most common data-intensive online activity [16],[26],[27],[28]. Video streaming accounted for 66% of all internet traffic in 2022 [29], thereby contributing significantly to the aforementioned environmental impacts [16]. Hence, it is important to look at users’ video streaming behaviour and possible ways to change this behaviour in a more sufficient way.



For users to change their behaviour, they must be facilitated in a way that makes these changes last [30]. Therefore, more knowledge is needed on users' drivers and barriers for interacting sufficiently with ICT devices and services. Based on the insights from our previous qualitative research on video streaming [31], we set up the current quantitative study. Here, we aim to investigate the contexts in which audiovisual media are consumed and the underlying motivations of users. In the current study, we broadly define video streaming behaviour as: streaming content from video streaming platforms, on social media, through commercial video on demand platforms and TV programs via a digital connection (live, replay, on demand), participating in video calls or video conferences including online learning activities, and (cloud) gaming.

Using the Theory of Planned Behavior (TPB) [32],[33] as framework, we quantitatively investigated Dutch citizens' video streaming practices and intentions for more sufficient use. We conducted an online survey among a representative sample of 2060 Dutch participants aged 13 to 94 years old. With the survey, we researched participants' use of video streaming, their intention to stream less, their attitude towards video streaming, the subjective norm regarding video streaming, and their perceived behavioural control over their own video streaming. Additionally, we asked for awareness of negative consequences of their screen time on sustainability and health, personal values, and possible alternative activities for video streaming.

Our results show that video streaming is deeply embedded in daily routines, with smartphones being the most commonly used device (44%), followed by (smart) TVs (26%). Streaming mostly takes place in solitary contexts and is motivated by desires to relax, be entertained, or escape daily stress. Most participants perceive one to four hours of daily screen time as normal, with 31% identifying two to three hours as normal. Almost two third of respondents (65%) reported doing other activities during screen time, such as household chores, waiting, and traveling on public transportation. Among teenagers aged 13 to 15 years old, more than half (52%) said that they are not allowed to video stream during homework or dinner, making it the most common rule in households.

Only 16% of all participants indicated a clear intention to reduce their screen time over the next three months, with the strongest intention to do so on social media (31%) and the weakest intention to reduce streaming TV programs (13%). More participants have the intention to reduce screen brightness (50%) than to compromise on display size (22%) or video quality (16%).

Regression analyses revealed participants' intention to video stream less was predicted by TPB constructs, $F(3, 1817) = 30.66, p < .001, adj. R^2 = .047$. Attitude towards screen time was negatively associated with intention to reduce ($\beta = -0.297, p < .001$), where a positive attitude towards video streaming results in a weaker intention to reduce. Surprisingly, perceived behavioural control and subjective norms showed no significant predictive effects. Awareness of the negative consequences of streaming and personal values showed stronger associations, $F(1, 1861) = 87.29, p < .001, adj. R^2 = .044$. Greater awareness of the environmental and social impacts of streaming significantly increased the intention to stream less. Motivations for reducing screen time are a digital detox ($\beta = 0.15, p < .001, adj. R^2 = .035$) and saving energy ($\beta = 0.17, p < .001, adj. R^2 = .032$). The explained variance of these predictors in intention range between 4,7% and 3,2%, and are thus very low, suggesting there are other important predictors for intention to stream less.

Moreover, we observed demographic differences. Generations significantly differ in their intention to reduce screen time, $F(2, 1859) = 7.13, p < .001, \eta^2 = .007$. The 'baby boomer



generation' (60+ years old) intends more strongly to reduce screen time than 'GenZ' (aged 16-29) and 'GenX/Millennials' (aged 30-59; Table 1). Generations also differ in a digital detox ($F(2, 2059) = 36.51, p < .001, \eta^2 = .03$) and saving energy ($F(2, 2059) = 10.60, p < .001, \eta^2 = .01$) as motivations to reduce. A digital detox and saving energy motivates mostly younger generations to reduce their screen time (Table 1).

Additionally, unemployed/retired participants reported a significantly stronger intention to reduce their screen time than those employed/in education, $t(1815) = 3.34, p < .001, d = 0.17$ (Table 1). A digital detox as motivation to reduce ($t(1441) = 5.10, p < .001, d = 0.24$) was less prominent among unemployed/retired participants than those employed/in education (Table 1). However, saving energy as motivation to reduce ($t(2006) = -.09, p = .928$) was equally important for unemployed/retired participants and participants who are employed or in education.

Moreover, participants living together without child(ren) expressed a stronger intention to reduce their screen time than those living alone or together with child(ren), $F(2, 1826) = 3.74, p = .024, \eta^2 = .004$ (Table 1). A digital detox ($F(2, 2022) = .92, p = .397$) and saving energy ($F(2, 2022) = .09, p = .910$) as motivations to reduce were equally important for participants living alone and living together with, or without child(ren) (Table 1).

Table 1. Means and Standard Deviations of Intention to Video Stream Less, and Digital Detox and Saving Energy as Motivations to Video Stream Less

	Intention to reduce		Digital detox		Saving energy	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Generation						
'GenZ' (aged 16-29) ^a	3.3	1.2	2.8	1.7	2.5	1.5
'GenX/Millennials' (aged 30-59) ^b	3.3	1.3	2.3	1.6	2.2	1.4
'Baby boomer' (60+ years old) ^c	3.5	1.3	1.9	1.4	2.1	1.3
Employment status						
Unemployed/retired ^d	3.5	1.3	2.0	1.5	2.2	1.3
Employed/in education ^e	3.3	1.2	2.4	1.6	2.2	1.4
Household situation						
Living alone ^f	3.3	1.3	2.2	1.6	2.2	1.4
Living together without child(ren) ^g	3.4	1.3	2.3	1.6	2.2	1.4
Living together with child(ren) ^h	3.2	1.2	2.3	1.5	2.2	1.4

Note. $N = 2060$. ^a $n = 420$. ^b $n = 929$. ^c $n = 514$. ^d $n = 530$. ^e $n = 1288$. ^f $n = 480$. ^g $n = 851$. ^h $n = 496$.

These findings suggest, to reach digital sufficiency, interventions and policies should go beyond the efficiency focus and instead emphasize personal and environmental benefits of less screen time. Interventions increasing awareness of the negative environmental and health impacts of streaming may be more effective than those relying on social norms or perceived control. Messaging should be tailored to age: younger users may better respond to environmental frames and appeals of digital detox than older users. Moreover, applying behavioural insights into designing digital services provides perspective for 'bright patterns' (design practices prioritizing user goals and well-being, making users do things they meant to do) as opposed to dark patterns, to encourage sufficient use.

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Consumer acceptance of innovative resource-efficient Mycelium-Bound Composites*

3b): Stakeholder and public acceptability and ownership of low-carbon projects and technologies

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Stakeholder acceptance, innovative low-carbon products, consumer response, sufficiency orientation

Extended abstract. A more efficient use of resources is required to mitigate climate change. In this respect, Mycelium-Bound Composites (MBCs) offer the advantage that their substrate can be made from lignocellulosic agricultural or residual waste (e.g., rice straw, corn husk, hemp shives, and waste wood) with comparatively low greenhouse gas (GHG) emissions [1, 2]. Furthermore, this innovative biobased material can be used for a wide range of application areas at different price segments [3]. Although the material is still in an early stage of development, understanding which MBC-based applications are most likely to gain consumer acceptance would allow product developers, prospective marketers, and decision-makers to target marketing campaigns that may increase the visibility and sales of material-specific products. Due to the yet limited market launch and popularity of MBC-based products [4], the question of consumers’ most favored applications from the material has not yet been fully analyzed [3]. Along with this, the characterization of more and less interested consumers in material-specific applications remains unclear as well.

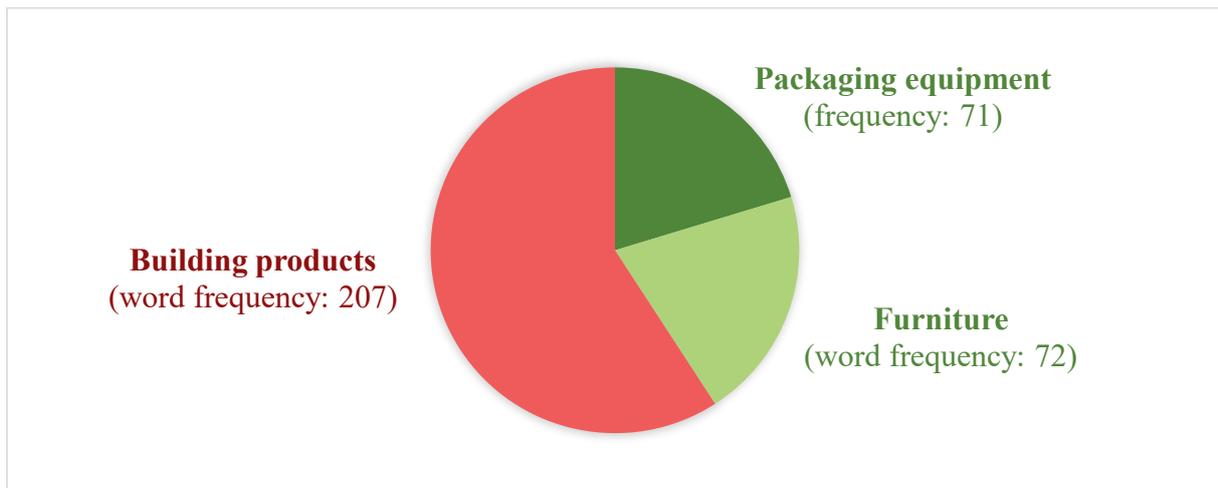
To address these questions, two empirical studies were carried out. The first study (qualitative) was based on explorative focus group research with 56 consumers in several German regions using a semi-structured interview guideline. Two samples of MBC were shown to demonstrate the material-related properties. After showing these examples, the questions were centered on the topic of the respondents’ most favorable applications. The consumer insights obtained were analyzed with qualitative content analysis using the software MaxQDA [5]. The second study was designed to verify the qualitatively gained results by means of an online survey with German consumers between 18 and 75 years. This sample was close to being representative to the German population, since a quota technique regarding age, gender, and household income levels was used. Without considering straightliners along with obviously careless responses [6],



3,084 participants were acquired through the survey in early 2025. The following statistical assessment was carried out with the software package SPSS IBM Statistics (version 29.0.1.0).

By analyzing the focus group discussions from the first study, the content analysis included an initial frequency assessment of words [5]. Table 1 shows the frequency of wordings related to MBC-based product categories. Accordingly, the highest use potential of mycelium-bound material was indicated by focus group participants for building applications (especially for in-built insulation material, but also more visible products such as interior wall coverings), followed by furniture and packaging equipment. To validate these exploratory results, purchase intentions of specific MBC-based applications such as packaging, furniture, and building products (e.g., thermal insulation and interior walls) were integrated into the survey for their subsequent use as dependent variables.

Table 1: Word frequencies on MBC-based product categories from the focus group discussions.



Based on the consumer responses from the online survey, three binary logistic regression models were estimated to identify predictors of purchase intentions across three MBC-based product categories (furniture, building materials, packaging). Aligning with previous consumer segmentation studies on low-carbon products [7-9], demographic characteristics such as gender, age, income, and residential size were included as predictors in each model and treated as dummy variables. A sufficiency orientation indicator (directly measured by the statement: “*I would give up some goods for a cleaner environment*” [10]) was added as a further independent variable. Buyers served as the reference group in each binary regression model. Accordingly, higher odds ratios (Exp[B]) indicated a greater likelihood of group membership among buyers.

As shown in Table 2, the pseudo determination coefficient varied by product category, with the furniture model showing the highest explanatory power (Nagelkerke’s $R^2 = 0.267$). Across all models, female respondents as well as individuals aged 40–59 and over 59 were consistently less likely to belong to each application-specific buyer group. Conversely, consumers with a strong sufficiency orientation were significantly more likely to belong to the group of prospective buyers for all product categories. This effect was observed for potential buyers of MBC-based packaging (Exp[B] = 1.741), furniture (Exp[B] = 2.106), and building components (Exp[B] = 1.752). Besides that, the respondents’ income played a significant role in predicting the group membership of potential buyers in relation to MBC-based packaging and building products. Accordingly, individuals from middle-income (€2.000 to 4.000 € net household income level) and higher-income groups were more likely among the MBC-based packaging and building product buyers. By contrast, residential size did not emerge as a significant predictor in any of the models. Table 3 gives a detailed overview of these results.

Table 2: Determination Coefficients of the models.

	2 Log-Likelihood	Cox & Snell R ²	Nagelkerkes R ²
Packaging	1793.561 ^a	.086	.128
Furniture	595.593 ^a	.186	.267
Building Products	1680.469 ^a	.103	.149

Table 3: Regression coefficient B and odd ratio scores (Exp[B]) of each model

	Coefficient B (Packaging)	Exp[B] Packaging	Coefficient B (Furniture)	Exp[B] (Furniture)	Coefficient B (Building products)	Exp[B] Building products
Age (40-59)	-.288	.750*	-.757	.469***	-.407	.665***
Age (>59)	-.573	.564***	-1.542	.214***	-.569	.566***
Income (€2,000- €4,000)	.465	1.592***	.408	1.505 (n.s.)	.639	1.894***
Income (> €4,000)	.583	1.792***	.197	1.217 (n.s.)	.890	2.434***
Gender (female)	-.186	.830 (n.s.)	-.581	.560***	-.629	.533***
Sufficiency Orientation	.555	1.741***	.745	2.106***	.561	1.752***
Res. Size (2,000 - <5,000)	.142	1.153 (n.s.)	-.488	.614 (n.s.)	.101	1.106 (n.s.)
Res. Size (5,000 - <20,000)	.077	1.080 (n.s.)	-.360	.697 (n.s.)	.172	1.188 (n.s.)
Res. Size (20,000 - <50,000)	.173	1.189 (n.s.)	.026	1.027 (n.s.)	.173	1.189 (n.s.)
Res. Size (50,000 - <100,000)	.128	1.136 (n.s.)	-.069	.934 (n.s.)	.070	1.072 (n.s.)
Res. Size (100,000 - <500,000)	.357	1.429 (n.s.)	.093	1.098 (n.s.)	.091	1.095 (n.s.)
Res. Size (500,000 or more)	.387	1.473 (n.s.)	.566	1.760 (n.s.)	.244	1.276 (n.s.)
Intercept	-.824	.439***	-2.684	.068***	-.794	.452***

n.s. = not significant; *p < 0.05; **p < 0.03; ***p < 0.01.

From a scientific perspective, the findings partially diverge from previous studies on other low-carbon products. As a similarity, younger respondents showed a higher tendency to accept the new emerging material and to use it as a substitute for various product categories [7]. However, unlike previous findings that have revealed a higher acceptance of women in this context [7, 9], the considered MBC-based products within this study were more appealing to male consumers. From a marketing perspective, the findings show that individuals with stronger sufficiency orientation were likely to express interest in buying MBC-based product substitutes, particularly in the furniture domain. Accordingly, future consumer research on this material may benefit from applying theoretical perspectives on post-consumerism and anti-consumption.

Beyond consumers' intentions to purchase different MBC-based products, their willingness to sacrifice in exchange for different goods made from this low-carbon material has not been



assessed. Therefore, analyzing consumers' willingness to pay for MBC-based packaging, furniture, and building products is proposed as an interesting but challenging future research avenue.

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Unravelling Behavioural Complexities in Dutch Homeowner Associations: A Systems Approach to Energy-Efficient Renovations

Theme 2, sub-topic 2a) & 2d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Behavioural Systems Mapping, Causal Loop Diagrams, Decision-Making, Energy Retrofit, Homeowner Associations, Systems Thinking

Extended abstract

This paper examines the decision-making processes and governance of Dutch homeowner associations (HOAs, or VvEs - Verenigingen van Eigenaren - in Dutch) in the context of energy efficient renovations. In the Netherlands, HOAs represent a significant yet underutilised framework for democratising the energy transition, encompassing 143,835 registered associations managing nearly 1.2 million dwellings - approximately a quarter of the Dutch private housing stock [1]. This research explores how plural ownership models can support just transitions to net-zero economies, by positioning HOAs as hybrid institutions transcending traditional public-private dichotomies [2] rather than laggard governance structures, in an effort to minimize barriers in their EER decision-making process.

The urgency of addressing HOAs in the energy transition cannot be overstated. With the European Union's ambitious climate targets requiring a 55% reduction in emissions by 2030 and climate neutrality by 2050, the residential sector's transformation is critical. HOAs present unique challenges compared to single-family homeowners, as decision-making involves multiple stakeholders with potentially divergent interests, financial capacities, and motivations [10]. Understanding these complexities is essential for developing targeted policy interventions and support mechanisms that can unlock the retrofit potential of this substantial housing segment.



Our theoretical framework synthesises Community Wealth Building (CWB) principles [3] with socio-technical transitions theory [4,5,6] to analyse how HOAs' institutional characteristics - democratic governance, collective financial responsibility, and long-term asset management - align with community wealth building objectives. CWB emphasizes local ownership, democratic participation, and wealth retention within communities, principles that naturally align with HOA structures. By examining HOAs through this lens, we reveal how existing collective ownership models can be leveraged for transformative sustainability outcomes while ensuring equitable distribution of benefits and burdens.

The socio-technical transitions perspective allows us to understand HOAs as part of a broader regime of housing provision and energy consumption, subject to both niche innovations and landscape pressures [4]. We employ stakeholder analysis methods [7] to map decision-making networks and systems thinking approaches [8,9] to visualise causal relationships between governance structures, retrofit decisions, and community outcomes. This integrated approach enables us to identify leverage points where interventions can most effectively catalyse change within HOA decision-making processes.

Prior studies, building on various data & methods (or combinations of such), reveal complex implementation pathways. Such pathways are shaped by a multitude of different aspects, including but not limited to household characteristics, behavioural factors, building characteristics [10], financial, legal, social, and technical barriers [11], as well as governance and institutional logics and transaction costs [12,13]. Research has shown that HOAs face additional complexities compared to individual homeowners, including the need for collective agreement (often requiring over 70% approval rates), coordination challenges, and the "weakest link" problem where the least motivated or financially capable member can block progress [13].

Our empirical investigation draws on a mixed-methods approach combining both qualitative and quantitative data, enabling triangulation of findings and comprehensive understanding of HOA retrofit dynamics [8]. Primary data collection includes: (1) a literature review examining international best practices and theoretical frameworks for collective decision-making in energy retrofits. (2) Two different survey datasets (n=200-300 each) of Dutch residents being HOA members, collected in 2024 & 2025, examining attitudes & preferences regarding energy retrofits, experiences & expected barriers in EER decision-making, socio-demographics & socio-economics, behavioural characteristics, and peer influence. (3) semi-structured interviews with HOA board members and other stakeholders/experts conducted in 2025, exploring decision-making processes, barriers, and successful retrofit strategies.

The stakeholder analysis and group model building workshops planned for Q4 2025 will contextualise, discuss, and synthesize the previously collected data. These workshops will bring together 15-20 participants including HOA board members, property managers, energy advisors, municipality representatives, and policy makers. Using the Group Model Building (GMB) methodology [8], participants will collaboratively develop causal loop diagrams that represent the systemic interdependencies affecting HOA retrofit decisions. Employing behavioural systems mapping [9] allows to identify feedback loops, delays, and unintended consequences within HOA decision-making processes. This participatory approach ensures that the resulting models reflect the lived experiences and tacit knowledge of practitioners while maintaining scientific rigor.

Our systems approach aims to account for the fact that interventions targeting single factors in isolation are unlikely to succeed; and instead identifies pathways for coordinated



strategies addressing multiple leverage points simultaneously show greater promise. This way, our research should uncover how HOA retrofit decisions are influenced by complex interactions between individual-level factors (e.g., environmental attitudes, financial capacity), collective-level dynamics (e.g., social cohesion, leadership quality), and institutional arrangements (e.g., voting rules, professional support).

This research contributes to emerging scholarship on community-based sustainability transitions and institutional innovation for just transitions. By examining HOAs through a CWB lens, combining socio-technical transitions and systems thinking, we reveal how existing collective ownership structures can be mobilised for transformative change. Our findings have important policy implications, addressing governance capacity, social dynamics, and decision-making processes, beyond solely financial incentives.

The methodological innovation of combining behavioural systems mapping with participatory research methods offers a template for studying other complex socio-technical systems where collective decision-making intersects with sustainability imperatives. As cities worldwide grapple with decarbonizing their housing stocks while ensuring social equity, understanding the behavioural complexities of collective ownership models becomes increasingly vital for achieving inclusive and effective climate action.

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What Drives Energy-Efficient Renovations? Exploring the Uptake of Thermal Insulation Among Austrian Homeowners

Topic 1, sub-topics 1a) & 1d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy-Efficient Renovation, Homeowner Decision-Making, PLS-SEM, Multigroup Analysis, Climate Policy, Policy Targeting

Extended abstract

Improving the energy performance of existing buildings is critical to achieving the European Union’s legally binding goal of net-zero emissions by 2050. Buildings account for around 40% of final energy use and 36% of energy-related CO₂ emissions, yet roughly 75% of the EU’s building stock remains energy inefficient [1–3]. Despite large-scale fiscal instruments like the Renovation Wave, the building sector remains critically off-track for 2030 targets: between 2015 and 2022, CO₂ emissions decreased by 14.7% against the required 27.9% [4, 5]. This gap underscores the need to better understand the behavioral drivers and barriers that shape renovation decisions—particularly in the residential sector, where homeowner heterogeneity calls for more targeted policy design to accelerate mitigation of housing-related emissions [6–8]. Our study explores how contextual, social, and psychological factors influence a set of energy-efficient renovation (EER) behaviors classified as thermal insulation in the Austrian region of Styria.

Methodology

Sampling and data collection. We partnered with Energie Agentur Steiermark to survey Styrian homeowners who sought energy consulting or subsidies for EER measures between 2013–2023. Of 30,000 invitations, 2,841 households (9%) responded in June–July 2023. Excluding renters, incomplete responses, and out-of-region entries yielded a final sample of 1,787 homeowners across age groups, income/education levels, and building vintages/types.

Survey instrument. The online questionnaire comprised seven modules: screening, EER history, EER intentions, information and social influences, household context (e.g., building characteristics, life events), psychological constructs (e.g., environmental attitudes, building perceptions), and socio-demographics.

Statistical analysis. We followed a three-phase analysis. First, we conducted descriptive statistics and bivariate ANOVA tests to identify preliminary differences between adopters and non-adopters. Second, we built a Partial Least Squares Structural Equation Model (PLS-SEM) to estimate direct and mediated effects of latent constructs on insulation behavior. The model (Figure 1) draws from established socio-psychological theories—i.e., Theory of Planned



Behavior [9], Diffusion of Innovations [10], and Value-Belief-Norm [11]. Measurement reliability (composite reliability > 0.70) and convergent validity (AVE > 0.50) were confirmed. Nonparametric bootstrapping (10,000 subsamples) was run to assess path significance. Third, we performed Permutation Multigroup Analysis (PERM-MGA; 5,000 subsamples) to test differences in parameter estimates across socio-economic status (SES) (Low vs. High) and life stage (Generation 1946–1964 vs. post-1965) groups, revealing behavioral heterogeneity among homeowners.

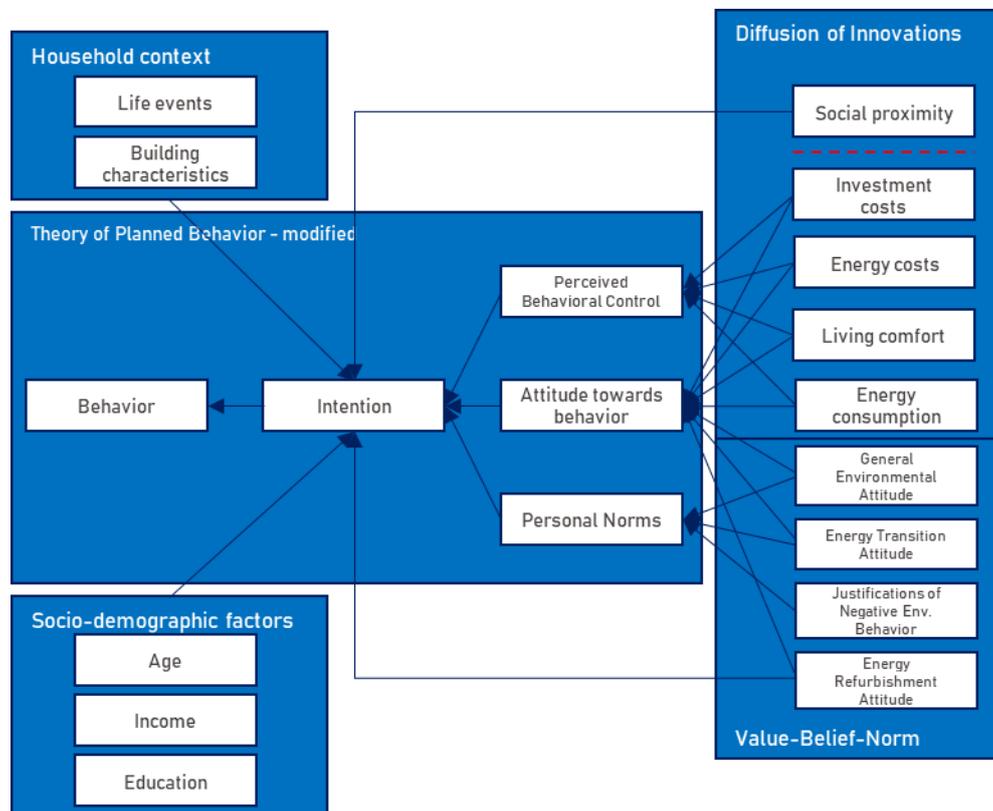
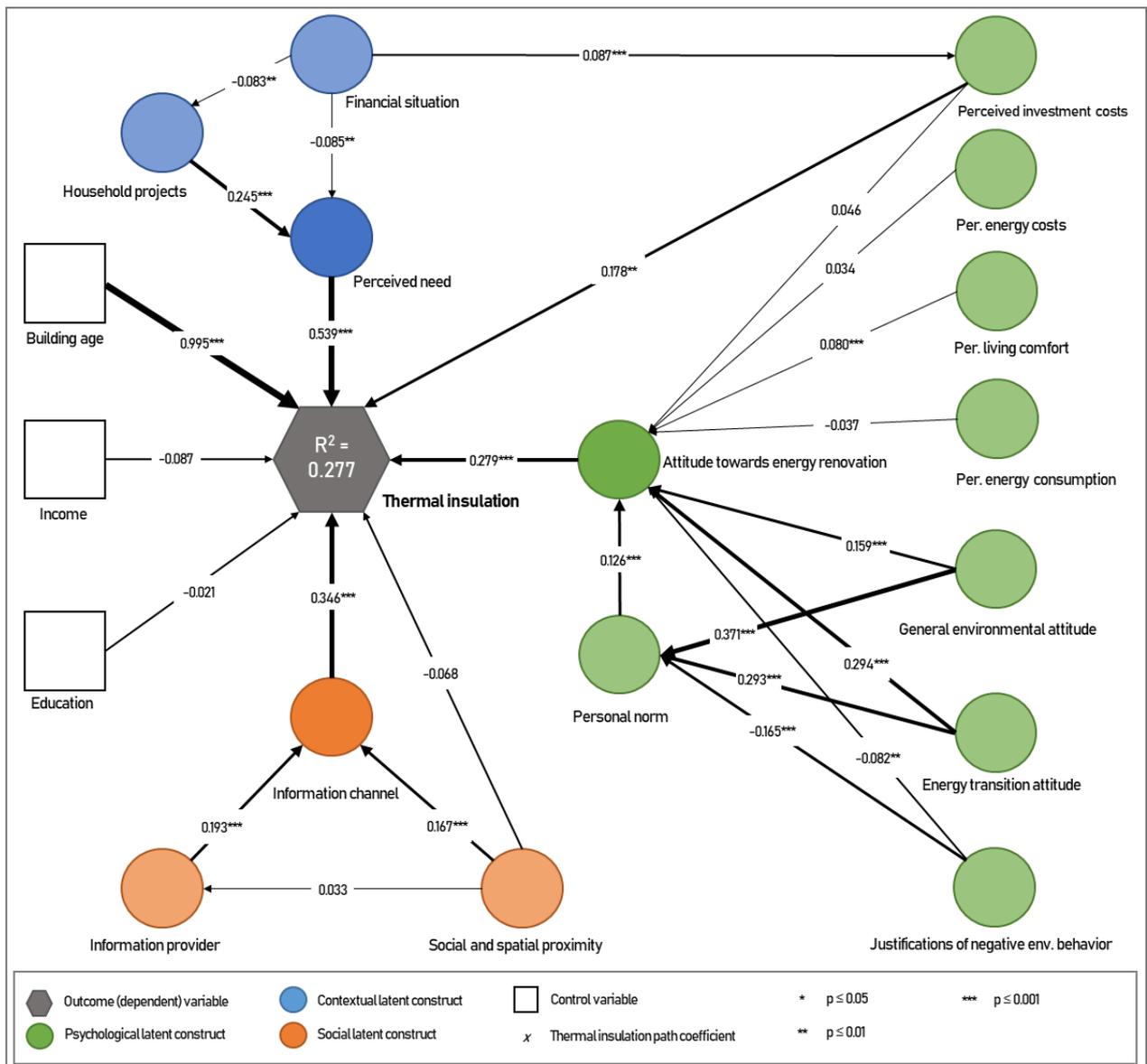


Figure 17. Theoretical model to understand EER behavior.

Results

Context is determinant. The descriptive analysis reveals that adopters and non-adopters of thermal insulation differ mainly in contextual variables. Insulation adopters report significantly older dwellings than non-adopters ($p < 0.001$). Adopters perceived stronger renovation needs based on building characteristics ($M = 3.67$ vs. 2.94 on a 5-point scale; $p < 0.001$). Similarly, we observe differences in social variables related to the use of information—e.g., adopters more often used the internet ($M = 3.45$ vs. 2.8) and personal contact with social peers ($M = 3.9$ vs. 2.95) to gain EER-related knowledge ($p < 0.001$).





What drives EER? In our PLS-SEM (Figure 2), Perceived Need emerges as the most powerful predictor of EER behavior ($\beta = 0.539$; $p < 0.001$). This underscores the importance of physical and contextual cues—e.g., building condition, household situation—in motivating action. Access to Information significantly influences insulation ($\beta = 0.346$; $p < 0.001$), showing that reliable, socially reinforced EER-related knowledge enables renovation [7]. Attitudes toward EER have weaker but still significant effects ($\beta = 0.279$; $p < 0.001$), in line with evidence that pro-environmental values and norms strengthen EER intention but are insufficient to overcome the intention-behavior gap [6]. Finally, Perceived Investment Cost is positively associated to insulation ($\beta = 0.178$; $p < 0.01$), suggesting that the more homeowners understand the upfront costs and long-term benefits—such as energy savings and comfort gains—the more likely they are to adopt [12].

Homeowner heterogeneity matters. Using PERM-MGA, we reveal that SES significantly moderates the drivers of insulation behavior. Perceived Need is over twice as influential for Low-SES vs. High-SES homeowners ($\beta = 0.860$ vs. 0.388 ; $p < 0.01$). Conversely, Information Channels are more important for High-SES. For this group, their effect is four times larger

than for Low-SES ($\beta = 0.440$ vs. 0.110 ; $p < 0.05$). Regarding life stage, Attitude towards EER have stronger effects among Generation 1946–1964 ($\beta = 0.373$ vs. 0.122 ; $p < 0.05$). Meanwhile, Building Age influence on thermal insulation is stronger for post-1965 generations ($\beta = 0.889$ vs. 1.174 ; $p < 0.001$). These differences also reflect the stronger mediated effect of pro-environmental values and norms among older homeowners.

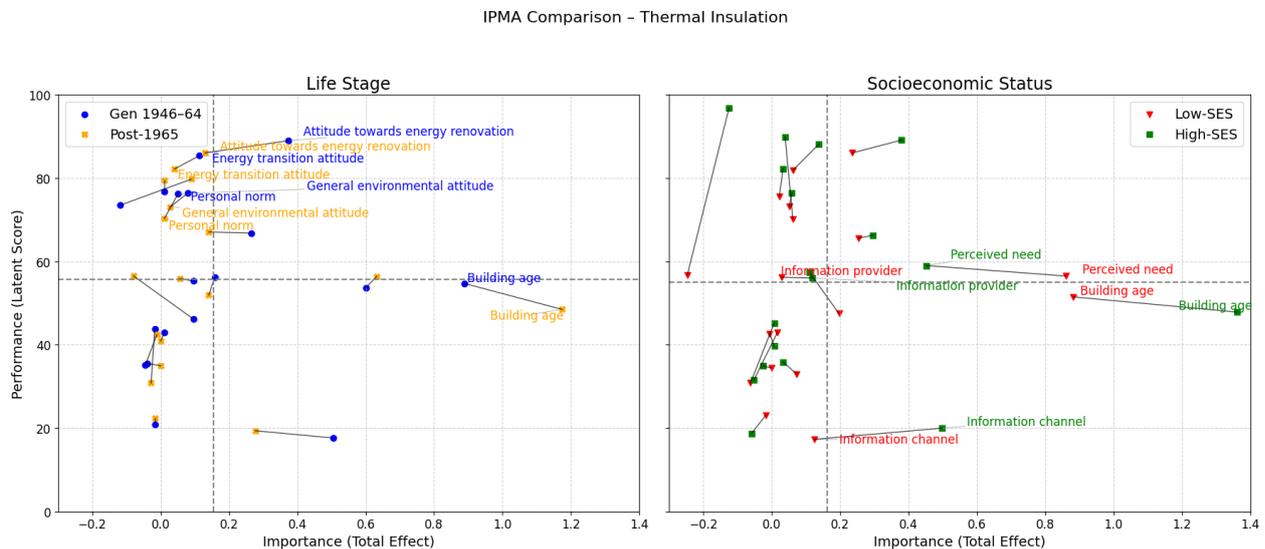


Figure 19. Importance-Performance Maps (IPMA) visualizing PERM-MGA results. The labeled constructs correspond to those with significant differences in total effect.

Discussion and policy implications

The goal of our study was to measure the effect of contextual, social, and psychological drivers on thermal insulation behavior among Austrian homeowners and to analyze variation by SES and life stage. Our findings confirm that behavioral drivers are not uniform. We observe that Perceived Need remains the strongest predictor of insulation uptake, especially among Low-SES homeowners, whose decisions respond primarily to building-related deficiencies. In contrast, High-SES homeowners tend to make knowledge-driven decisions, underscoring the importance of reliable, timely information across all EER project phases [13].

We also find that influences on EER behavior change across generational lines. Generation 1946–1964 are more value-driven and less dependent on contextual cues than younger cohorts. This suggests that pro-environmental motivations strengthen in later life stages [14]. These patterns show that the predictors of EER behavior vary systematically with SES and life stage, reinforcing the need to move beyond one-size-fits-all policies in favor of tailored interventions that recognize group-specific capacities and motivations [15, 16].

Accordingly, we recommend:

- Strengthening local advisory services via one-stop shops bundling technical advice, subsidies, and streamlined applications—overcoming gaps on information and technical support over the project lifecycle [17].
- Expanding high-quality information access for High-SES homeowners—e.g., through ROI calculators and personalized energy consulting.
- Activating legacy-focused messaging for Generation 1946–1964 to engage pro-environmental norms and intergenerational responsibility in EER uptake [18].



Our findings align with the research agenda by [16], who call for impact-oriented research that investigates high-agency groups capable of triggering rapid change dynamics—namely, activists, affluent individuals (here, High-SES), and Generation 1946–1964. This targeting of actors with greater access to resources and information is grounded in the notion that they can become change agents for their social peers, amplifying change through social contagion [19, 20].

Limitations and future research

Our sample may overrepresent proactive individuals, as it includes homeowners already engaged in advisory services. Future research should assess whether our findings generalize to broader populations. Longitudinal or experimental designs—e.g., agent-based modeling—could further test whether targeting potential change agents fosters broader EER adoption.

Conclusion

This study advances understanding of the heterogeneity underlying EER behavior at the household level, specifically regarding thermal insulation among Austrian homeowners. By identifying which factors matter most—and for whom—we contribute to more effective, evidence-based climate policy. Instead of one-size-fits-all strategies, we argue for tailored interventions that activate homeowners best positioned to adopt and spread EER. Our findings echo calls for combining universal incentives with targeted interventions to accelerate positive change for sustainability.

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When are the benefits enough? An experimental study of support for sufficiency policies in Ireland

Theme 3, sub-topic 3a

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Policy support, Behavioural experiment

Extended abstract

Background

There is an increasing realisation that energy efficiency measures aimed at “greening” consumption are not enough to address our climate and ecological crises. Instead, we must complement efficiency measures with radical reductions in absolute consumption levels, particularly amongst the highest consumers. “Sufficiency” is a term used to describe this aim of reducing absolute consumption while ensuring decent living standards for all people [1]. Strong policy measures across sectors are needed to create conditions that both facilitate and solicit changes in how we interact with our environments to reduce consumption. Some sufficiency-oriented policies have been in place for some time even if they haven’t been labelled as such (e.g. active travel infrastructure), whereas other measures have yet to be widely implemented (e.g. vehicle mass tax).

Sufficiency-oriented policies challenge widely accepted values of consumerism and unfettered economic growth [2]. As such, there is a risk that implementation of such policies is faced with opposition, and there has been a suggestion that the term “sufficiency” itself could be viewed negatively. Opposition is especially likely among those with most influence over climate policy and associated discourses (politicians, corporate decision makers and lobbyists, journalists, economists, senior civil servants), as these are likely to be among those consuming the most and thus more affected by sufficiency measures. For context, in the UK, the top 10% of earners account for almost three times the amount of carbon than people in the bottom 30%; they use more energy flying than the bottom 20% use in total [3].

On the other hand, public support for climate action in a general sense is unequivocally widespread – a recent survey of 130,000 people from 125 countries found that 89% demand intensified political action, and 69% report willingness to contribute 1% of their personal



income to fighting climate change [4]. This high level of support is commonly underestimated – the same participants believed that only 43% of other people in their countries would do the same and other research has shown that politicians severely underestimate public desire for climate action [5]. Further, a common feature of many sufficiency policies is that they come with co-benefits in other domains (e.g. health, housing, poverty alleviation), which may serve to increase support.

Determinants of policy support

Research to date has tended to focus on the intrinsic characteristics of sufficiency-oriented policies that influence support. Sufficiency policy is more likely to be supported when focused on fair, equitable implementation, and where it is perceived as effective [6]. Support for stricter policies such as taxing above-average living space or a meat tax has been shown to be lower than support for softer policies such as meat-free days in canteens in multiple European countries [7].

There has been less focus on extrinsic factors affecting support, however, namely how sufficiency policies are presented and communicated. When sufficiency policies are framed as “overcoming” issues rather than “punishing” behaviours, support is greater [7], but other potentially important sufficiency policy characteristics remain unaddressed. For instance, despite the existence of co-benefits for many sufficiency policies, the extent to which emphasising these affects policy support has not been studied. Consideration of co-benefits of climate policies is generally lacking in policymaking [8].

People tend to favour maintaining the current state of affairs over changing it [9]. The effect of this “status quo bias” on support for sufficiency policies is also understudied. It may be that a new policy measure might be less susceptible to status quo bias if people are aware of its successful implementation elsewhere.

The present study

This study uses an online survey experiment to measure support for a set of energy sufficiency policies under different conditions in a representative sample of the Irish population.

Using a between-subjects experimental design, we investigate whether support for energy sufficiency policies is greater or lesser when these are presented as measures to reduce energy demand compared with when emphasis is instead placed on their co-benefits. We also investigate whether support differs depending on other features of the policy in question (e.g. degree of restrictiveness, target behaviour) or how it is presented (e.g. highlighting where policies have already been successfully implemented).

Alongside individual support for policies, we also measure perceived effectiveness and whether participants would publicly express their private support or opposition to policies. We also record political orientation, various sociodemographic variables, and measures of current energy consumption behaviours to control for personal impact of the policies that are presented.

As well as providing the first comprehensive measure of public support for energy sufficiency policies in Ireland, we provide more generalisable evidence on the relative support for sufficiency policies depending on how these are presented. Future work can build

on these results to compare attitudes of policymakers and climate experts towards the same policies.

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Decoding household preferences for behind-the-meter home energy transition over time based on interpretable machine learning

Theme 1, sub-topic 1d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Home energy transition, Household preferences, Interpretable machine learning, XGBoost, Latent class analysis

INTRODUCTION

The decarbonization of the residential energy system is pivotal to the energy transition [1] because residential energy consumption accounts for 25.2% of total consumption across the EU. The behind-the-meter (BTM) systems located at residences or in commercial buildings involve the production and consumption onsite, with the advantages of positively impacting the integrity and stability of the electricity network in front of the meter on the utility side, and further facilitating the transition to low-carbon residential energy consumption [2]. The BTM technologies mainly include rooftop solar photovoltaic (PV) systems to supplement the energy supply, electric vehicles (EVs) and heat pumps (HPs) to electrify residential transport and heating to adjust households’ energy usage.

To force the adoption of the BTM technologies, the drivers and barriers for each individual technology have been widely explored. Primary determinants are financial factors (e.g., disposable income, grants, etc.); other determinants include social-psychological factors, demographic factors, building characteristics, etc. While existing studies provide valuable insights into household preferences for individual BTM technologies, such as PV [3], EV [4], and HP adoption [5], there are three critical limitations: (i) limited attention to the shifts in households’ preferences for BTM technologies over time, (ii) insufficient attention to characteristics of preference formation across different BTM technologies, and (iii) inadequate consideration of the priority of different technology adoption.

Net zero climate goals require very widespread and almost simultaneous adoption of multiple BTM technologies – not one or two in isolation. This is a household BTM energy transition, occurring in parallel to an energy transition at grid-scale. The main questions addressed in this paper are (i) whether there is evidence that such a transformation is underway and (ii) what are the characteristics of those who are likely to participate in the energy transition and those who are not. The findings will be helpful in better understanding energy transition at the residential level, and further be beneficial for planning home energy transition from a systemic perspective.



METHODS

This study compared households' preferences for BTM energy transition based on survey data from 2018 and 2024, and explored households' preferences heterogeneity by combining the latent class analysis (LCA) with an interpretable machine learning, XGBoost. The survey questionnaire in the two years includes three parts with a similar framework: (i) demographic questions for general respondents, (ii) building, retrofitting, energy sources, and energy bill information, (iii) households' attitude to and status quo of HPs, solar PVs, EVs, and different tariffs.

RESULTS

A three-class model provides the best fit for the data of this study based on the AIC, BIC, and maximum log-likelihood. 48% and 53% of the respondents are predicted to belong to the ambivalent class in 2024 and 2018 survey data. 20% and 33% of respondents are predicted to belong to the enthusiast class in 2024 and 2018 survey data. And 32% and 14% of respondents are predicted to belong to the resistant class in 2024 and 2018 survey data (Table 1). While there are 6.67% and 5.21% EV adopters, 8.82% and 4.80% PV adopters, 7.10% and 3.56% HP adopters in 1225 and 1208 respondents in 2024 and 2018, respectively.

Although the actual adopters increased over time, indicating progress in the energy transition, the declining proportion of the enthusiast class reflects the rebound effect, which should be noticed and prevented. Moreover, the decreasing proportion of the ambivalent class also reflects the progress of energy transition, as households know more about home energy technologies and energy transition over time.

Table 1. The conditional item response probabilities in the three classes over time

Answers	2024 survey data (Observation number = 664)			2018 survey data (Observation number = 924)		
	enthusiast	resistant	ambivalent	enthusiast	resistant	ambivalent
Predicted class memberships	0.20	0.32	0.48	0.33	0.14	0.53
Maximum log-likelihood:	-2736.751			-3821.57		
AIC:	5549.50			7719.14		
BIC:	5720.44			7902.64		

Based on the normalized weighted sum of the likelihood of adopting each technology (Figure 1a and 1b), the probability of households' energy transition is similar over time in a specific class.



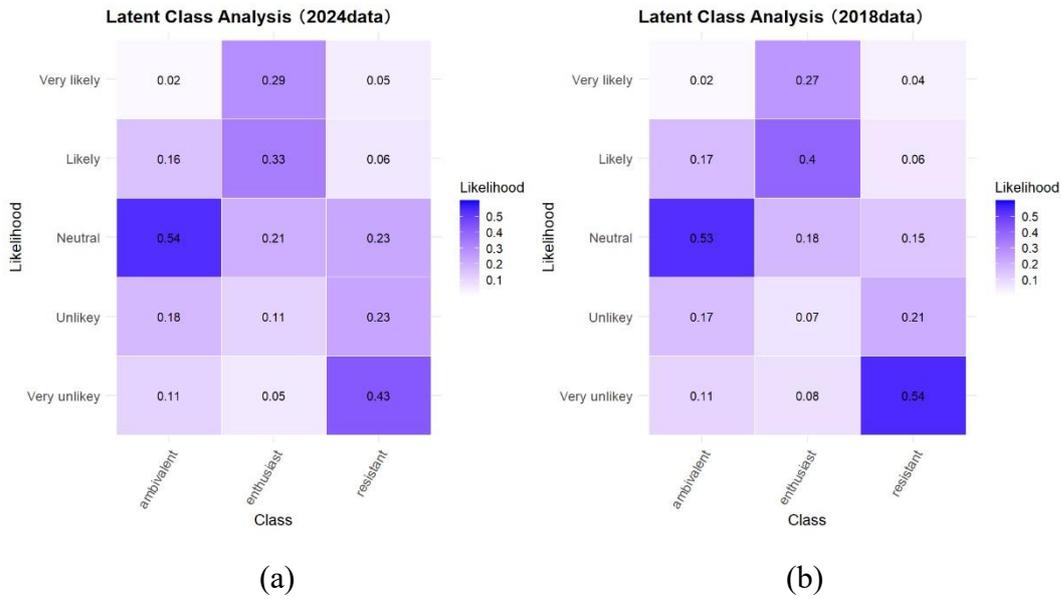
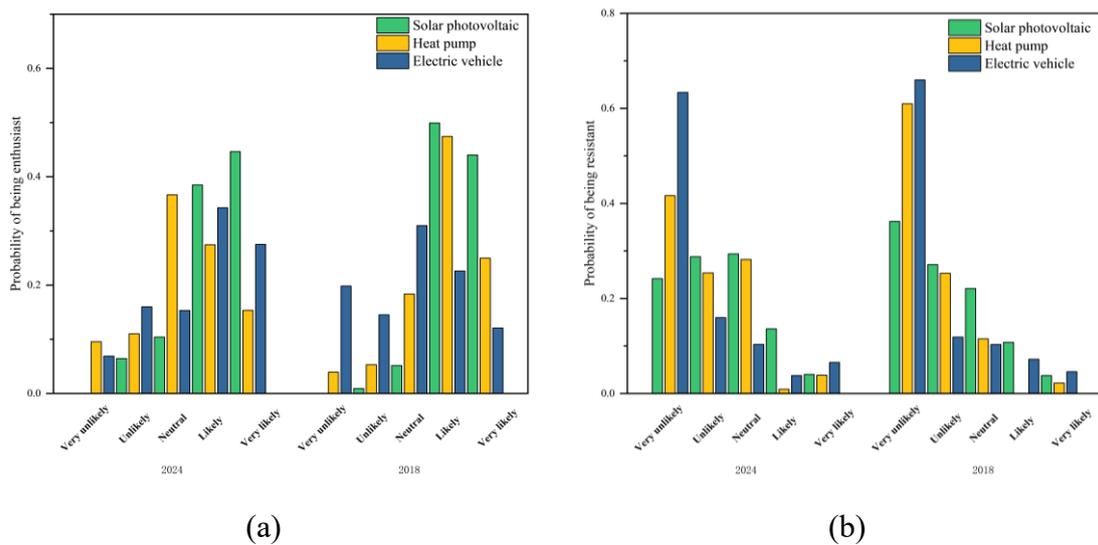
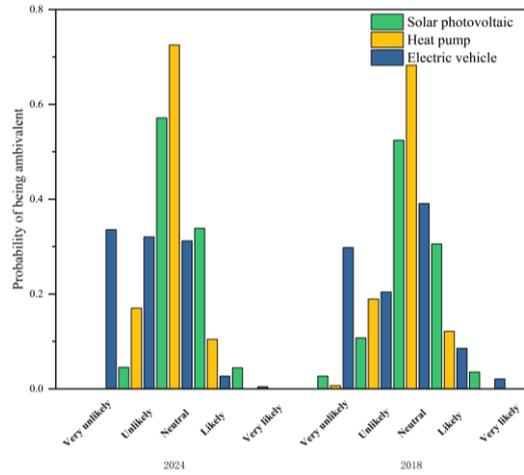


Figure 1. Households' likelihood of home energy transition

Conditional item response probabilities are presented for each of the three latent classes, which are labelled based on their respective likelihoods of adopting specific technologies, reflecting household preferences for specific CETs, as shown in Figure 2. Households' enthusiasm for PVs remains significant and substantial, for EVs increased, but for HPs decreased over time

(Figure 2a). In the resistant class, they showed less resistance to PVs, and more resistance to EVs, with over 60% very unlikely to purchase an EV in both years. Their resistance to HPs decreased over time (Figure 2b). Households showed the most ambivalence to HPs in both years, with over 60% likely to be neutral or don't know. And they showed less ambivalence to EVs over time (Figure 2c).

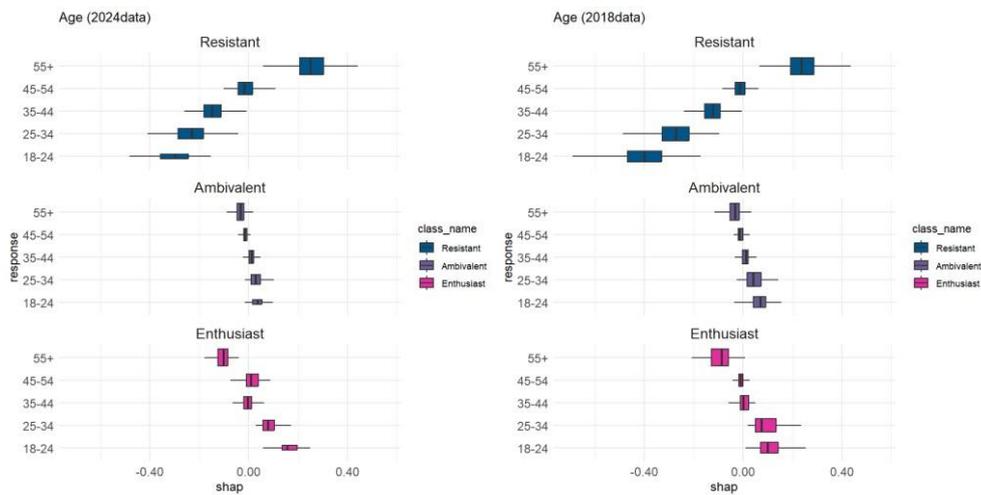




(c)

Figure 2 Households’ likelihood of adopting each technology

Demographic, building and heating, psychological and social factors differ in diverse households, which can help interpret households’ preferences and adoption of home energy transitions (HETs). In terms of demographic factors, age contributes significant SHAP values across all three classes. The age of respondents shows a negative correlation with their preferences for energy transition (Figure 3a). Educational level of respondents shows a positive correlation with their preferences (Figure 3b). The houseowners with property built after 2005 show an enthusiasm for energy transition (Figure 3c). The higher the bi-monthly electricity bill, the more enthusiastic for energy transition (Figure 3d). Households’ annual income and property type don’t show a significant impact on their types of energy transition.



(a)



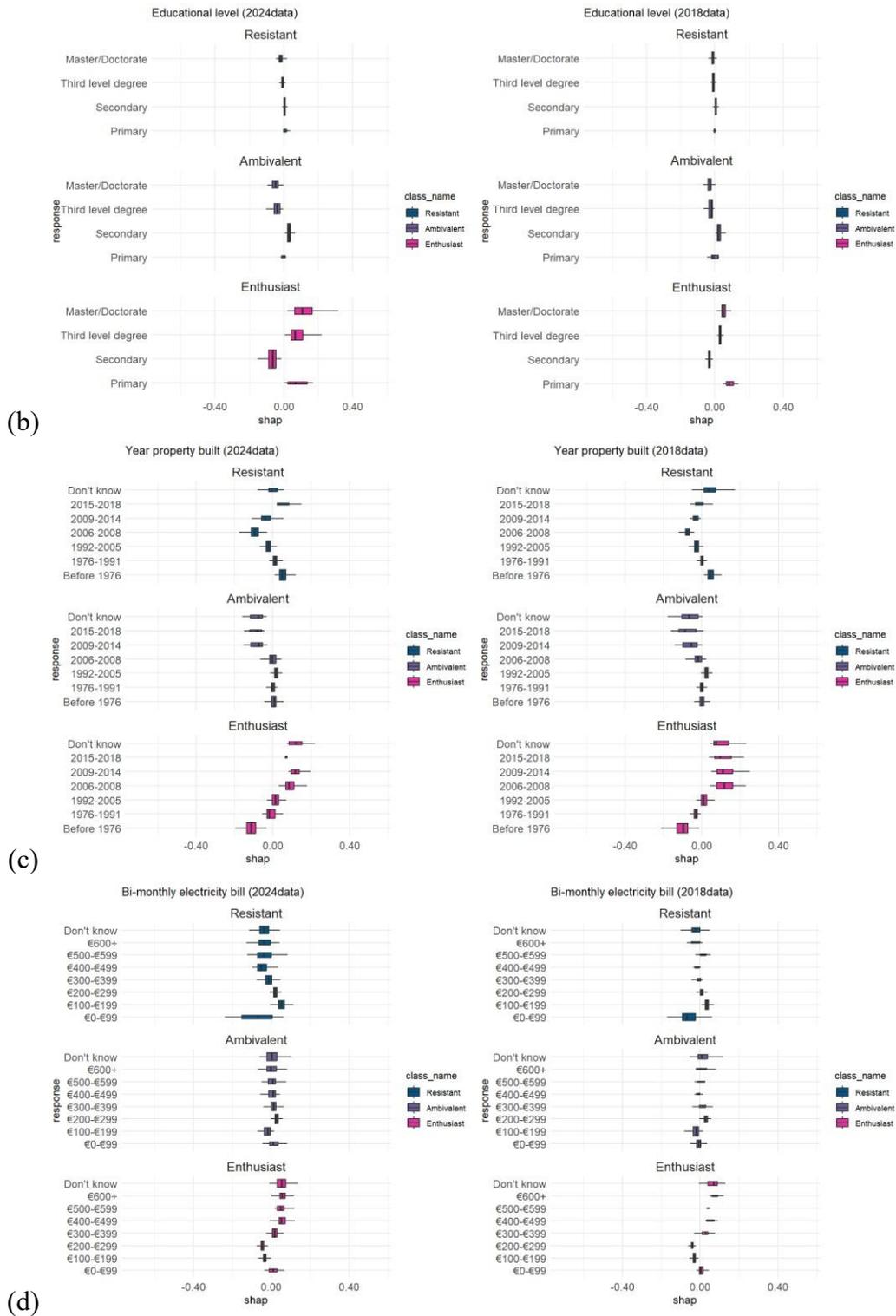
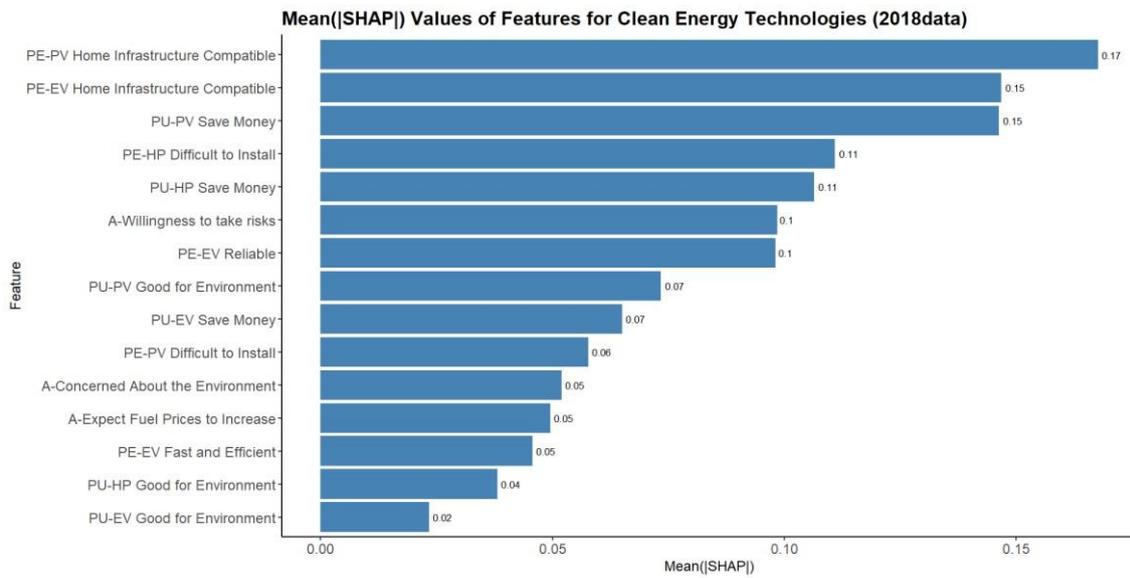


Figure 3. Distribution of SHAP values across different attributes

According to the TAM [6], households' intention and behaviour of acceptance of technology are affected by three aspects: i. perceived usefulness (PU), ii. perceived ease of use (PE), and iii. attitude towards using (A), as shown in Figure 4. In 2018 households cared more about the compatibility of PV and EV (Figure 4a). In 2024 they still cared about the compatibility of EVs, but less about the compatibility of PVs (Figure 4b). Households care more about the installation difficulty of HPs and PVs in 2024. Especially, households reported more consideration about the reliability of EVs in 2024 than in 2018.



(a)



(b)

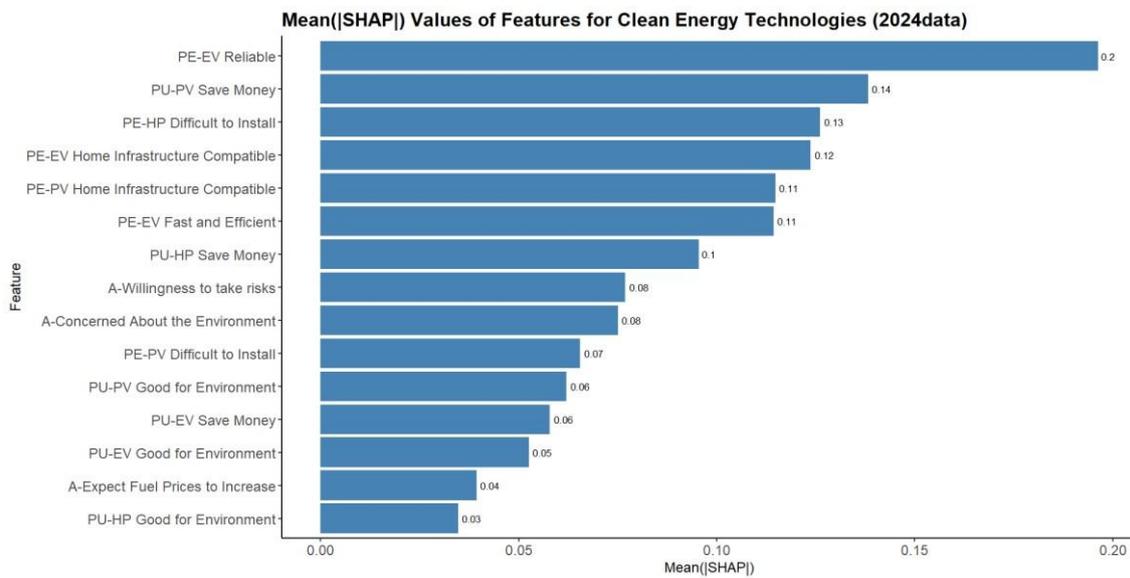


Figure 4. Influencing factors of household preference heterogeneity for home energy transition based on SHAP values

CONCLUSIONS

Thus, this study compared households' preferences for ET based on survey data from 2018 and 2024, and explored households' preferences heterogeneity by combining the latent class analysis (LCA) with an interpretable machine learning, XGBoost. The main results are:

- i. Although the actual adopters increased over time, indicating progress in the energy transition, the declining proportion of the enthusiast class reflects the rebound effect, which should be noticed and prevented.
- ii. Households' enthusiasm for PVs remains significant and substantial, for EVs increased, but for HPs decreased. In the resistant class, they showed less resistance to PVs and more resistance to EVs. Their resistance to HPs decreased over time. Households showed the most ambivalence to HPs in both years.



- iii. Households aged over 55, or don't know their property's built year, or with property built before 1975, are likely to be resistant; while households with an educational level higher than a third degree and bi-monthly electricity bills exceeding 300 euros are likely to be enthusiastic about the energy transition. iv. The perceived ease of use of technologies has a greater influence on households' willingness to adopt a technology.

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Translating and Operationalizing the Stage Model of Self-Regulated Behaviour Change for Renewable Technology Adoption: A systems thinking and modelling perspective

Theme 6, sub-topic 6a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Renewable Energies, Behavioural Change, Investment Decision, Technology Diffusion

Extended abstract

The shift toward decentralized renewable energy systems is not only a technological challenge but also a deeply behavioral one. Individual investment decisions play a pivotal role in this transformation, yet behavioral dynamics are still underrepresented in mainstream energy modeling [1]. Several reviews point out the importance and lack of behavioral sciences in energy system modelling [2–5].: Addressing this gap, this study links behavioral science and system modeling to better understand and model adoption patterns of renewable energy technologies.

In this study, we contextualize, adapt and operationalise the Stage Model of Self-Regulated Behavioral Change (SSBC) to the context of investment decisions in decentralized renewable energy technologies. By doing so, the original behavioral phase model is translated into the specific context of the energy transition and extended with a feedback perspective. Furthermore, the study aims to contribute to advancing behavioral theory by operationalizing psychological constructs—such as intentions, self-efficacy, and social norms—within a dynamic modeling framework. This approach bridges behavioural theory-building with systems modeling, enabling a more nuanced understanding of behavior in energy-related decision-making processes.

The foundation for our study lays the Stage Model of Self-Regulated Behavioral Change (SSBC) by Bamberg [6, 7], which conceptualizes behavioral change as a staged process involving four transitions: predecisional, preactional, actional, and postactional. Each stage is associated with specific cognitive and normative processes, including the formation of



goal, behavioral, and implementation intentions. In the original form, the SSBC model is generic, and has not been specifically tested on the case of energy decisions. The original SSBC model is tailored for the behavioral pattern of individual decisions, hence it does not recognize feedback processes that evolve on system or individual level that might govern the decision processes of actor groups over time.

In our study, we build on the SSBC model and (a) apply it to the context of residential renewable energy investment decisions, (b) expand it conceptually by adding a feedback perspective, and (c) operationalize the model to a fully quantified simulation model.

The developed conceptual model, presented in Figure 1, is developed through a structured theory-building approach that synthesizes the SSBC with elements from the framework proposed by [8, 9], complemented by a targeted literature review.

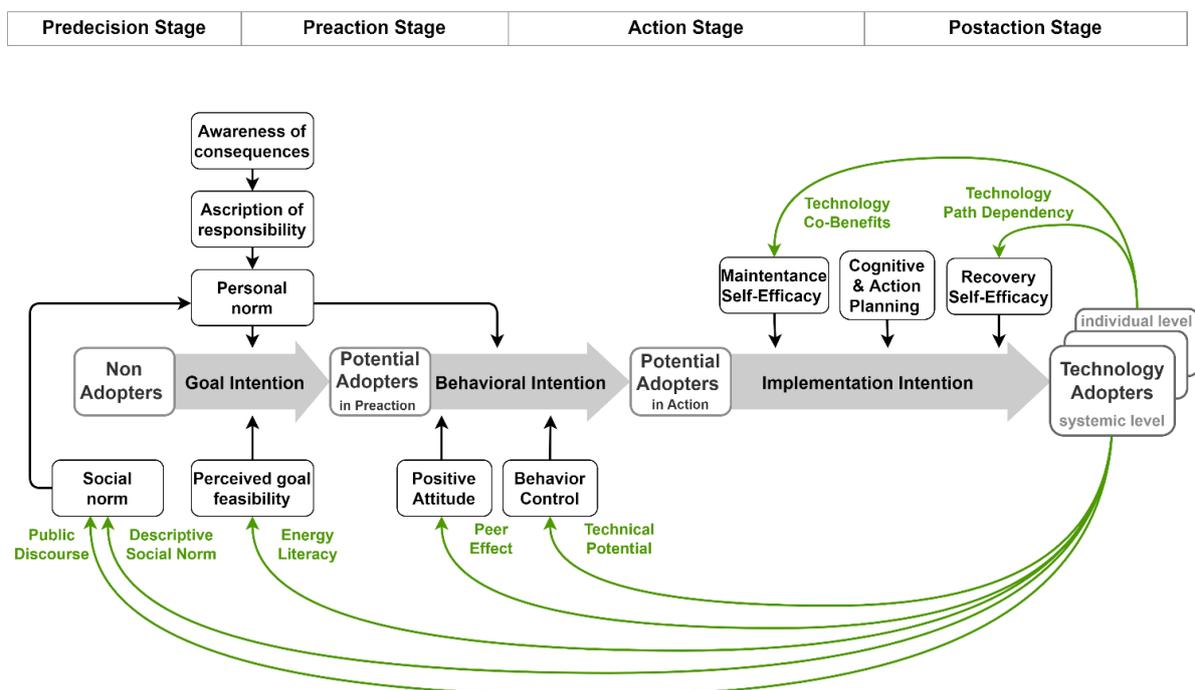


Figure 1: Theoretical framework for consumers' decision in renewable energy investments

In our approach, the four stages are modeled stock variables, representing the number of actors progressing through the stages of adoption. This stock-flow logic aligns the SSBC with System Dynamics thinking, allowing the model to simulate the accumulation of adoption potential and action over time. The conceptual model integrates relevant systemic and individual-level feedbacks that shape renewable investment behavior. Key systemic feedbacks include (represented in the lower half of the conceptual model):

- Social norms, reinforced by adoption behavior,
- Public discourse, as a fluctuating influence on perceived norms,
- Energy literacy, influencing perceived goal feasibility,
- Technical potential as building compatibility, which affects behavioral control.

At the individual level, the model includes (represented in the upper half of the model):

- Technology co-benefits (e.g. comfort, autonomy), which reinforce investment valuation as the maintenance self-efficacy,
- Technology path dependency, representing recovery self-efficacy, where prior adoption choices constrain or enable future decisions.

In the **Predecision Stage**, individuals are classified as non-adopters, meaning they have not yet formed a goal intention to adopt renewable energy technologies. Individual factors include the perceived goal feasibility, which shapes how realistic and desirable the goal appears. Systemic factors such as personal norms, formed by the ascription of responsibility and social norms, further shape goal intention by embedding the decision within a broader societal and moral context. Once individuals develop a goal intention, they enter the **Pre-Action Stage** as potential adopters. At this point, behavioral control and positive technology attitude play a role in determining which technology is suitable. Availability constraints (scarcity effects) related to building conditions may limit adoption, while peer effects (social influence on technology-specific attitude) can reinforce the motivation to proceed. In the **Action Stage** phase, the focus shifts to evaluating the investment and preparing for implementation. Maintenance self-efficacy, influenced by perceived co-benefits of the technology, shapes confidence in sustaining the investment over time. Simultaneously, cognitive and action planning processes address practical steps and challenges, such as delays in installation or logistical uncertainties. This stage reflects a transition from motivation to concrete preparation, where both psychological readiness and contextual constraints influence whether the intention leads to actual adoption. Finally, in the **Postaction Stage**, individuals become technology adopters and contribute to broader system behavior by adopting technologies such as heat pumps, solar PV, or batteries. This stage also reinforces systemic feedback loops, where adoption trends influence future potential adopters via social norms and peer effects, thereby shaping the diffusion process of renewable energy technologies.

By embedding these mechanisms into the conceptual structure of the SSBC, the model highlights how discrepancies between attitudes and actions—commonly often also referred to as the attitude–behavior gap—emerge and evolve across decision stages. It captures not only the motivation to adopt but also the frictions and reinforcements that modulate behavior over time. Designed as a generic framework, the model is applicable to various decentralized energy technologies (e.g., photovoltaics, heat pumps) and can be adapted for different contexts of energy-related decision-making.

The conceptual model is fully formalized as a quantitative System Dynamics model. We study the technology diffusion of heat pumps, solar photovoltaic, batteries and combinations of these technologies. The analysis focuses on the diffusion pattern and influence strengths of the feedback processes considering the uncertainty of the parameters relevant for quantifying the SSBC model in the energy context. Figure 2 provides an example of the quantitative simulation results and illustrates the projected number of building units being non adopters, potential adopters and technology adopters from 2020 to 2050. The graphic emphasizes the bandwidth of the technology adoption process within a sensitivity analysis.



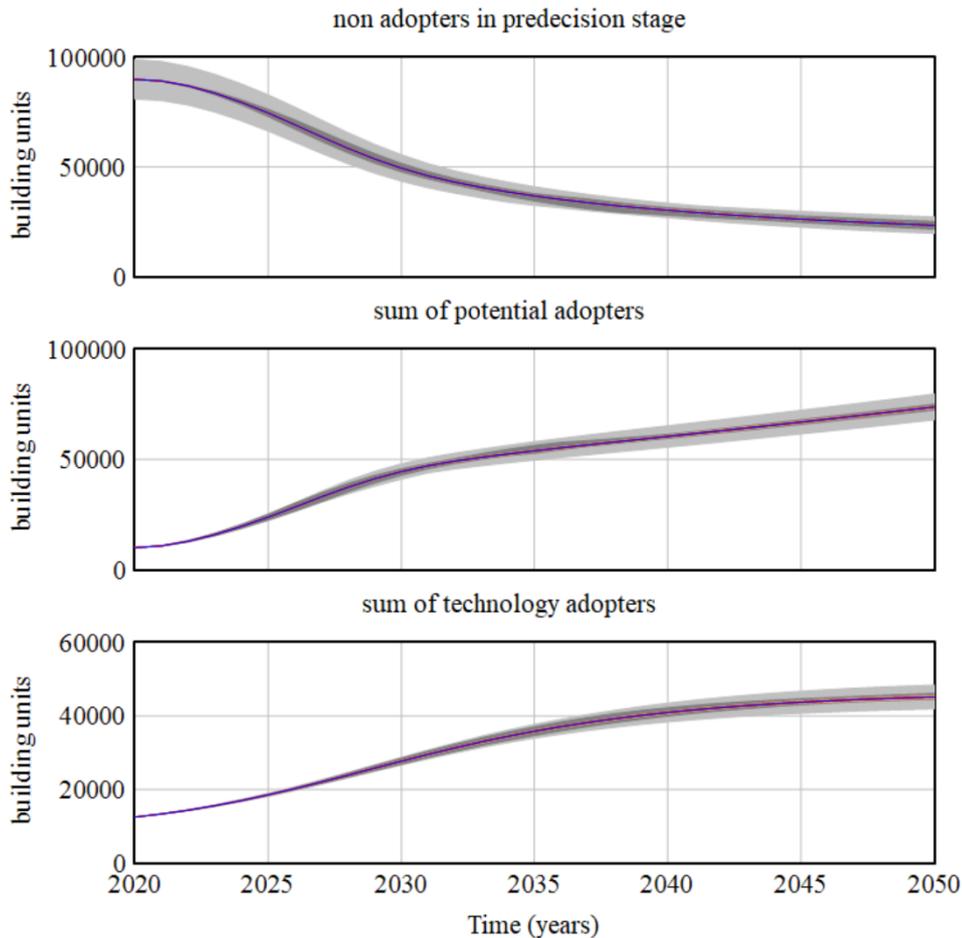


Figure 2: Development of non adopters, potential adopters and technology adopters of an example system

By translating behavioral theory into a systemic modeling structure, this work contributes to the methodological advancement of behavioral energy modeling. It offers researchers and practitioners a structured way to conceptualize, simulate, and ultimately support behavioral change processes critical to achieving a just and rapid energy transition. The model may serve as a base for bringing social science knowledge into techno-economic energy models.

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Rethinking work for a sustainable future: development of a scenario-based assessment tool of emerging working models and their energy and CO₂ impacts in Swiss companies

Theme 1, sub-topic 1b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords New working models, mobility, office buildings, rebound effects, scenario-based assessment tool, energy efficiency.

Extended abstract

In the context of climate change and rising environmental pressures, companies are increasingly expected to contribute to sustainability goals [1] - not only through technological innovations, but also by enabling behavioural and organisational changes. One particularly promising area, especially for companies mainly performing office work, lies in the transformation of working models. Commuting—28% of daily travel in Switzerland, mostly by car [2]—is a key energy-related work behaviour, but it's only part of a wider system involving office infrastructure,



heating, digital use, and the organisation of work, care, daily tasks, and leisure. This paper explores the potential of emerging working models as behavioural levers for reducing overall energy demand and CO₂ emissions in the Swiss context, with a specific focus on company-level implementation. The goal of this project financed by the Swiss Federal Office of Energy (SWEET program) is to provide a practical tool that helps companies estimate the energy and carbon savings of different working models in their specific context.

Driven by the Covid-19 pandemic and advances in digitalisation, companies across sectors have started to experiment with alternative work arrangements. These include working from home [3], coworking spaces, mobile work in “third places” (such as trains, cafés or parks) [4], as well as desk-sharing concepts [5], reduced working hours [6] or compressed work schedules [7].

This study develops and analyses a set of plausible working model scenarios (see Table 1), tailored to the Swiss labour market and workplace culture. These scenarios are constructed based on an extensive review of the literature [8] semi-structured expert interviews, and four multi-stakeholder workshops with representatives from companies, public institutions, and academia, performed between September 2024 and June 2025. Each scenario combines one or more working models—such as home office, coworking, or desk sharing—with behavioural and infrastructural parameters. Forty parameter combinations have been explored so far, with more scenarios planned.

Table 3: Morphological box of the working model scenario.

Parameters	Configurations			
Working time arrangement	<i>Classic: 40 hours a week, 5 working days</i>	Short week (4 days week): 32 hours a week, 4 working days	Short workdays: 32 hours a week, 5 working days (~6.5 h/day)	Compressed work week: 40 hours a week, 4 working days (~ 10 hours/day)
Remote working days	1	1.5	2	2.5
Energy optimization of office building [Y/N]	Yes: building operation is being turned down, when building is empty		<i>No: Building is operated during the whole workweek (5 days)</i>	
Desk sharing [Y/N]	Yes: desk sharing is applied, no unoccupied workstations		<i>No: no desk sharing, all employees have their own desk</i>	

Note: To define a specific scenario, a configuration of each parameter needs to be defined, in italics: Swiss average scenario [9].

The tool has been developed with a modular approach, considering in this first version the calculation of impacts related to the building (heating, cooling, ventilation, electricity and hot water) and mobility (commuting as well as business travel and the rebound effects on non-commuting); for these aspects, energy consumptions and greenhouse gas emissions are calculated. Although non-commuting travel of employees are not part of any scope (1-3) of action of a company, as defined within the GHG protocol [10], it has been decided to account for the difference in non-commuting mobility in comparison to the Swiss average induced by a change of the working model (i.e. rebound effect of less commuting, which foster more non-commuting travel).

To quantify the energy and CO₂ implications of each scenario, a transparent, Excel-based calculation tool with graphical illustrations has been developed. This tool allows for a consistent comparison of different working arrangements. Input parameters include technical factors (e.g. characteristics of the building, emission factors for transportation modes [11]), spatial indicators

(e.g. shared-office space ratio), and behavioural factors (e.g. commuting distance, mode of transport [2]). Building-related energy consumption is modelled with the dynamic simulation tool energy plus [12], with the following variables taken into account: building size, envelope performance (poorly/well insulated), geographical location and orientation, heating/cooling/ventilation system characteristics and operational schedule. The simulation allows for the calculation of the consumption over the year (heating, cooling, ventilation, hot water, electricity for technical equipment, illumination and appliances). Mobility-related energy consumption is calculated with the respective emission factors [11] and distances per transport mode, that are defined by the scenario. The tool incorporates Swiss average values for the parameters but will also enable users to adjust key assumptions to reflect company-specific or sector-specific conditions.

A key innovation of our approach is the integration of indirect and spill-over effects into the scenario modelling. These effects are often overlooked in technical assessments but are crucial for understanding the real-world impact of behavioural interventions. For example, possibility to work at home may motivate people to relocate to suburban or rural areas, increasing average commuting distances—thereby partially offsetting initial energy savings. Likewise, working from home and reduced working time models may lead to increased leisure travel.

It is too early in the development of the tool to focus on numerical results. Nevertheless, preliminary findings reveal substantial differences in energy and CO₂ performance across the evaluated working models. In Table 2 five different scenarios are defined and in figure 1 energy consumption is illustrated for an exemplary company with 16 employees in Lugano, Switzerland, situated in a small-sized (250 m² of usable surface) insulated building from 2010 with a gas heating system, mechanical ventilation and cooling and the potential opportunity to manage heating and cooling based on the occupancy of the building. Swiss average data [2] are used to calculate mobility impacts.

Table 4; Scenario Specifications for exemplary working model arrangements

Scenario specifications				
Name	Working time arrangement	# Remote working days (RD)	Energy optimization of office building (EO)[Y/N]	Desk sharing (DS)[Y/N]
0-Classic-RD:0-EO:N-DS:N	Classic	0	N	N
1-Classic-RD:2-EO:N-DS:N	Classic	2	N	N
2-Classic-RD:2-EO:N-DS:Y	Classic	2	N	Y
3-Classic-RD:2-EO:Y-DS:N	Classic	2	Y	N
4-ShortWeek-RD:2-EO:N-DS:Y	Short Week	2	N	Y

Models that combine remote work with space-optimised office use (e.g. through desk sharing and co-working) offer the highest potential for reducing energy demand and emissions—if office space is actually reduced (see scenario 2). If a company reduces working time to a 4 day week, additional savings are possible due to even less workspace needed as well as reduced commuting (see Scenario 4). Furthermore, the active management of office building occupancy and thus the possibility to temporarily close the office building (or parts of it) on certain weekdays also shows saving potential, as heating/cooling/ventilation can be decreased or even totally turned off – however these savings are relatively small in this case (see scenario 3). This requires relatively extensive regulations and thus restrictions on employees' flexibility regarding the weekdays on which they can or must work in the office. Conversely, models that lead to reduced presence in the office but maintain legacy infrastructure (e.g. unchanged office space or heating patterns) may lead to efficiency losses (see scenario 1). These dynamics



between individual behaviour and acceptance for worktime or location restrictions and a company’s facility management strategies highlight the importance of aligning behavioural interventions with infrastructural and organisational adjustments.

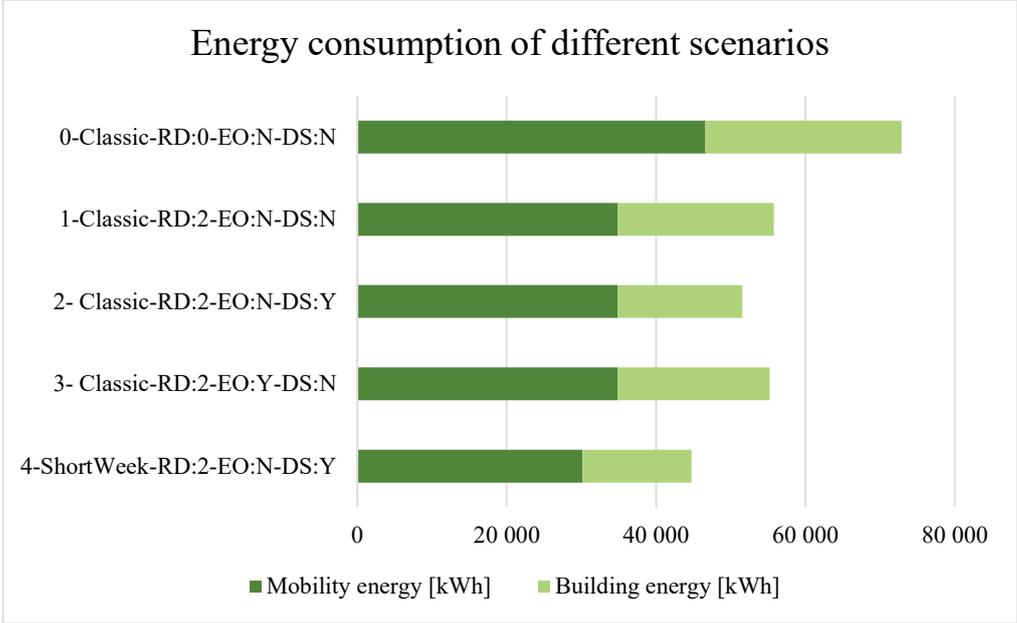


Figure 20: Energy consumption of scenarios defined in Table 2

A key insight is that organizational factors are crucial for the specific scope of action of a company. For example, building ownership affects how fully energy-saving models can be implemented. Flexible working models can be supported by allowing employees to work from nearby branches. Ultimately, employee preferences, workplace culture, and trust strongly influence remote work adoption, making behavioural and organizational readiness just as important as technical feasibility.

The scenario framework and tool help companies and policymakers assess the energy and CO₂ impacts of workplace strategies, supporting informed decisions. They can simulate planned changes, evaluate interventions like desk sharing or shorter workweeks, and weigh flexibility against environmental performance. The energy model still requires fine-tuning to better reflect actual consumption, but the tool already enables meaningful comparisons between scenarios and the Swiss average, clarifying the impact of different choices. Its strength lies in aggregating results across building and mobility aspects, offering a holistic view rather than isolated insights. Thanks to its modular design, the tool can later be expanded to include factors like household and external consumption, diet, and leisure activities.

By supporting companies in navigating the transition toward more sustainable work practices, our approach contributes to both organisational innovation and broader climate goals.

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From energy efficiency to (self-)sufficiency in agriculture: A systemic approach

Theme 1, sub-topic 1a) a) Contributions of multidisciplinary approaches to behaviour and social practices

- “Academic contribution”
- “Policy/practice contribution”

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Keywords: Energy transition, Sufficiency, Agriculture, Flexibility, Behaviours

Extended abstract

The increasing deployment of renewable energy sources (RES) is a key element of the energy transition contributing to current decarbonization efforts. However, this trend presents various challenges. For example, increasing the PV capacity to 450 GWp by 2030, as foreseen by the European Solar Energy Strategy, will intensify competition for land use between food and energy generation [1]. Also, the widespread deployment of decentralized RES requires enhanced flexibility from the power grid to accommodate variable production while considering demand patterns and aiming for cost-efficiency. Traditionally, flexibility in the energy system has primarily relied on supply-side resources. It is crucial to explore new sources of flexibility from the demand-side by making the most of the adaptive capability of some consumption to prices and other grid signals. Agriculture has been overlooked in this regard, despite possessing valuable flexibility resources through equipment such as water pumps, heat pumps, water tank towers, on-site renewable generation, and electrical storage (including static batteries and electric vehicles). Various sociotechnical challenges have been identified to unlock flexibility in this sector, namely inadequate regulation, lack of incentives, stakeholders' coordination, automation and communication technologies, complexity of productive processes, and organizational and behavioral issues such as literacy and motivation of farmers.

This work presents a systemic approach developed to assess the potential of agriculture to provide demand-side flexible services to the power grid, while promoting (self-)sufficiency. An organic farm in the Centre of Portugal was taken as case study, which integrates animal, vegetables and fruit production, as well as decentralized energy generation and storage (PV in the roof, agrivoltaics and electric batteries).

The methodology combines engineering and social science approaches, specifically energy audits and semi-structured interviews. It encompasses the characterization of production



processes and load profiles, identification and implementation of energy efficiency measures, and the integrated management of energy resources through continuous monitoring of energy production, consumption, storage, and direct load control actions, informed by a parallel modeling and optimization process within a digital twin environment. Other key components include the upgrade of communication and control infrastructure and the continuous engagement with stakeholders, including both technical staff and top management.

Preliminary results suggest that the most energy-intensive loads - such as irrigation motors and pumps, refrigeration systems, and livestock wastewater treatment pumps - offer the greatest potential for flexibility. However, smaller loads can also make meaningful contributions. Optimized load management considering weather conditions, photovoltaic production, electricity prices, and productive requirements can significantly reduce operating costs without compromising agricultural productivity. It can also enhance farms' energy self-sufficiency and support the stability of the power grid.

Despite these benefits, efforts to maximize self-sufficiency through decentralized energy production and demand-side flexibility in agriculture face several challenges. These include economic barriers (e.g., high investment costs and low profitability), market limitations (e.g., dominance of energy technology providers interests), legal and regulatory hurdles (e.g., inadequate legislation and incentives specifically tailored to agriculture), technical constraints (e.g., lack of interoperability, ICT infrastructure and deficient electric grid), operational complexity (e.g., process interdependencies), organizational issues (e.g., conflicting roles and interests within the same entity), and behavioral factors (e.g., low energy and agronomic literacy, and lack of trust).

This study underscores the importance of adhering to the “energy efficiency first” principle, emphasizing that solutions must be tailored to the specific conditions of each agricultural setting. Rather than focusing solely on renewable energy generation, it advocates for an integrated approach to energy resource management - maximizing self-sufficiency and on-site consumption. Findings highlight the need for energy policies to account for the unique characteristics of agriculture and prioritize its primary role as a food-producing sector. Finally, the study illustrates agriculture's relevant role in the energy transition and demonstrates how a more proactive approach to energy management by farmers can reduce operational costs, strengthen resilience, and contribute to broader climate and energy policy objectives.

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The impact of sufficiency in the French residential sector on investments for energy transition

Theme 5, sub-topic 1a)

Theme 1, sub-topic 1c)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: sufficiency, residential sector, investments, renovation policies

Extended abstract

Overview

Achieving carbon neutrality in 2050 for France raises technical but also macroeconomic challenges [1]. Over the next ten years, decarbonization will require substantial investments. For instance, investments requirements by 2030 are estimated at 21 billion euros a year (heating and insulation) to renovate the French building stock [1]. Financing such investments would require public funding, which may raise challenges in a context of budget restrictions [2].

The drivers of transition in the building sector can be analyzed within the “Sufficiency, Efficiency, Renewables” (SER) framework [3]. Investments for transition in the building sector may be modulated by the three elements of the SER framework.



Sufficiency is already considered as a key element for energy transition [4]. In Europe, up to 19% of the mitigation potential of the building sector could be captured by 2050 through sufficiency interventions [5]. Sufficiency is defined as “*avoiding the demand for energy and materials over the life-cycle of buildings and goods*” [4]. In economic terms, sufficiency can be defined as “*the reduction in energy demand that does not result from gains in energy efficiency*” [2].

At the building stock scale, the number of new main residences or the surface area of existing buildings are for instance key parameters [6] [7]. At the building scale, sufficiency can for instance refer to reduce the actual energy consumption for heating [6].

The potential of sufficiency to reduce the energy demand has been assessed in French national scenarios. The “négaWatt” scenario estimates that 17% of the reduction in final energy consumption in the building sector can be achieved with sufficiency in 2050, compared with 2020. ADEME mentions a 28% reduction between its most sufficient scenario (“S1”) compared with a scenario without sufficiency (“S3”)[6].

How much investments for residential construction and renovation can sufficiency save? The impact of sufficiency on investment needs for construction renovation policies is not exhaustively assessed. Quantifying the impacts of sufficiency scenarios on financing needs is an important step to enable optimal design of a low-carbon strategy and public policies.

In this study, we assess the impacts of five sufficiency levers at 2050 horizon in France on CO_{2eq} emissions, energy demand, and public investments.

Methods

We consider sufficiency measures applied to the French residential sector using Res-IRF [8]. This agent-based energy demand model for the French residential sector aims to assess the impact of energy efficiency policies on renovation dynamics. It is therefore a relevant tool to study the interplay between sufficiency, efficiency and the public financing needs.

We introduce sufficiency by modifying 5 model input parameters which are defined in Table 1.

Table 1: Sufficiency levers implemented into Res-IRF

#	Lever	Sufficiency scale	Res-IRF parameter modelling
1	Building less	Building stock level	Increasing the percentage of multi-family dwellings in new constructions
2			Reducing the average area of new single-family dwellings
3			Reducing the number of new constructions per year
4	Limiting space per person	Building level	Decreasing the average area of existing multi-family dwellings
5	Decreasing thermal needs		Capping the maximal heating intensity (ratio between actual and conventional heating consumption)

We first independently assess the impact of each lever, and then assess the potential combined effects of the five levers. To this end, we run a yearly simulation between 2025 and 2050. This allows us to evaluate yearly trajectories and associated dynamics.

We finally consider the combined impact of each sufficiency lever with renovation policies as defined in 2024 in France such as “*MaPrimeRénov*” subsidies, zero-interest loan, white



certificates, carbon tax and rental ban on inefficient housing. We analyse the results with the following indicators:

- Heating-related energy consumption
- Heating-related greenhouse gas emissions
- Investments for renovation subsidies

Results

The impact of the fall in new construction and the surface area of new buildings (levers 1, 2 and 3) on the three indicators is limited. As new buildings are energy-efficient, the decrease in energy consumption is low.

The reduction in the surface area of existing homes (lever 4) leads to a more significant decrease in renovation investments, as it modifies the total surface area of the existing stock.

The impact of decreasing thermal needs through heating intensity (lever 5) remains unclear. Further analysis is needed to clarify the impact of modifying a driver of the heating intensity, for instance the setpoint temperature.

Conclusion / discussion

This analysis focuses on the impact of sufficiency levers on energy demand, CO₂ emissions and the need for renovation and building construction investments in the French residential sector by 2050.

The study could help to better design public policies and investments in a scenario integrating sufficiency levers.

Future research could additionally discuss the political and social feasibility of implementing sufficiency and the associated needed behavioral changes.

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Building a sustainable future: Predicting innovation capability in SMEs in the construction sector through company-level and individual factors

Theme 4, sub-topic 4a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy transition, Sustainable innovation, Construction sector, Sustainable building

Extended abstract

As part of the European Green Deal, the energy performance of European buildings has to be improved [1], which will require renovating at least 35 million buildings by 2050. In order to achieve that, the construction sector has to evolve to be able to drive sustainable renovations [2] through for example innovation in materials [3], [4], [5], processes [3], [5], [6], [7], energy systems [6], [8], [9] and (digital) tools [3], [5], [8]. However, the current annual energy-renovation rate is 1%, too slow to achieve climate neutrality by 2050 [10]. Additionally, 95% of the construction sector consists of small- and medium-sized enterprises (SMEs) [11], which often lack the financial means or knowledge to invest in innovation [9], [12], [13], [14], [15]. Moreover, the construction sector is rather conservative, with companies adhering to the current way of working and resistance of stakeholders to change [3], [12], [13], [14], [16]. Subsequently, collaboration between construction businesses is often linear, with clear divisions of responsibilities [3], [13]. Encouraging innovation within SMEs is crucial to accelerate and reach the targets set within the Renovation Wave in Europe [2]. Thus, it is important to understand why building professionals (do not) innovate [15]. While there has been research on innovation within companies, there is an absence of studies focusing on construction [17]. Additionally, most literature on barriers to sustainable building practices focuses on functional barriers or consumers [15]. Therefore, this research aims at filling that gap by identifying which company-level and individual factors can drive innovation capability within construction SMEs. Prior research identified the importance of company culture and the mindset of employees, as well as the relevance of company leadership for fostering innovation [18]. For SMEs specifically, both company and individual characteristics could influence the innovation capability of the firm in general.

First, past research highlights the importance of a network of likeminded stakeholders and professional relationships as catalysts for innovation [3], [15], [18], [19]. However, currently there is limited willingness for collaboration in the construction sector [13], [18]. We hypothesize that network capability building will be positively associated with innovation capability (H1). Second, the building sector is described as conservative, with a tendency to



favour the familiar over the new [15], [16]. Additionally, employees in larger companies tend to adhere less to the status quo, which leads to higher adoption intention for innovation [15]. Thus, we hypothesize that adhering to the status quo bias will be negatively associated with innovation capability (H2). Third, considering individual characteristics, we see that technological innovativeness is relevant for promoting innovation within a company, especially since green technologies are often complex in nature [3], [14]. Additionally, a lack of technical knowledge could impede SMEs from adopting new technologies or processes [18]. Therefore, we hypothesise that technological innovativeness will be positively associated with innovation capability (H3). Lastly, Rizos et al. [18] underline the importance of mindset and commitment from the staff, as well as the importance of a hands-on and proactive mentality. Thus, we hypothesize that problem-solving ability will be positively associated with innovation capability (H4). All hypotheses are visualised in Figure 21.

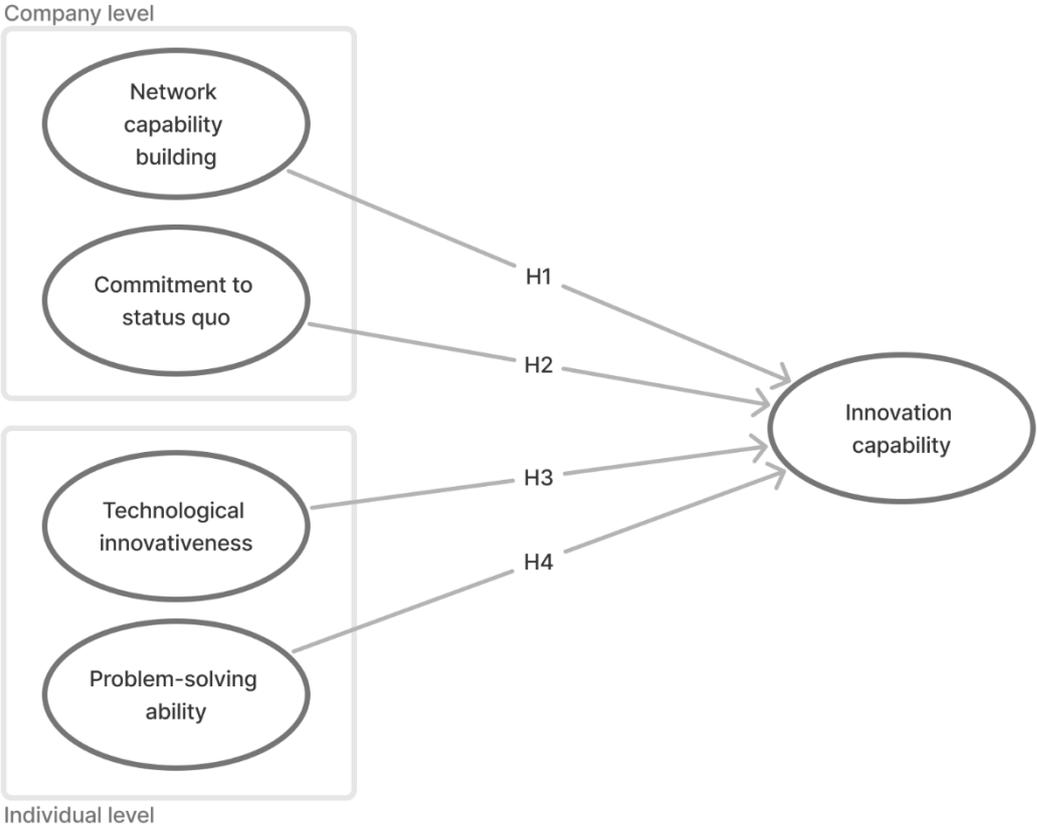


Figure 21: Research framework and hypotheses

To test our hypotheses, we conducted a quantitative survey with 150 participants employed in a construction SME, during May 2024. The survey was launched in six European countries (Belgium, France, the Netherlands, Germany, Italy and Lithuania) through a network of professional organisations. Our research setup and hypotheses were pre-registered (<https://osf.io/guajv>) and a priori power analysis indicated a required sample size of 150 for medium effect sizes. We assessed the following variables using pre-validated scales: innovation capability using a 4-item scale [20], network capability building using a 3-item scale [21], commitment to status quo using a 4-item scale [22], technological innovativeness using a 4-item scale [23] and problem-solving ability using a 4-item scale [24]. All items were assessed using a 5-point Likert scale (completely disagree – completely agree).

Our sample consists of 114 men (76%) and 34 women (23%), with a small proportion choosing not to disclose their gender (n = 2, 1.3%). The majority of SMEs focus on both new construction and renovation (n = 119, 79%), and the mean value (3.78) of innovation capability indicates that our sample is skewed towards firms that see themselves as innovative.

We performed regression analyses to examine the predictors of innovation capability. We first conducted separate models (model 1 – 4) including each variable individually, followed by model 5 which includes all predictors. Table 5 gives an overview of all results.

Outcome: Innovation capability					
	Model 1	Model 2	Model 3	Model 4	Model 5
Network Building	0.62***				0.43***
Commitment to status quo		0.06			0.05
Technological Innovativeness			0.62***		0.29***
Problem-solving Ability				0.59***	0.17*
Constant	1.23***	3.61***	1.57***	1.37***	0.13
Observations	150	150	150	150	150
R ²	0.38	0.003	0.24	0.29	0.46
Adjusted R ²	0.37	-0.003	0.24	0.28	0.44
Residual Std. Error	0.63 (df = 148)	0.79 (df = 148)	0.69 (df = 148)	0.67 (df = 148)	0.59 (df = 145)
F Statistic	90.05*** (df = 1; 148)	0.51 (df = 1; 148)	47.18*** (df = 1; 148)	60.17*** (df = 1; 148)	30.72*** (df = 4; 145)

Table 5: Regression analysis of model 1 to 5, with * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Analysis in model 5 shows that network building ($\beta = 0.43$, $p < 0.001$), technological innovativeness ($\beta = 0.29$, $p < 0.001$) and problem-solving ability ($\beta = 0.17$, $p < 0.05$) are significant predictors of innovation capability, accepting H1, H3 and H4. Commitment to status quo ($\beta = 0.05$) is not significantly associated with innovation capability, rejecting H2. The overall model explains 46% of the variance in innovation capability ($R^2 = 0.46$), with an adjusted R^2 of 0.44, indicating a good fit.

On a company level, our study highlights the importance of strong partnerships, with network building being the strongest predictor of innovation capability. This implies that in order for SMEs to innovate within the company, they can benefit from fostering connections with other companies in the construction sector that are innovative, seeing them as allies instead of competitors. Second, analysis reveals that status quo commitment is not significant, meaning that adherence to established practices may not have as strong of an effect on limiting innovation as expected. This challenges the idea that conservatism is a hindrance to innovation in the context of the construction industry. On an individual level, analysis shows that technological innovativeness and problem-solving ability are both significant predictors of innovation capability. This implies that employees who embrace new technologies and have strong and proactive problem-solving skills can contribute to a company's ability to innovate.



Overall, our results indicate that fostering innovation within SMEs in the construction industry requires a focus on external collaboration, technological adaptability and proactive opportunity searching, while internal conservatism may be less impactful. Further research could explore other potential predictors of innovation, as well as expand and diversify the sample to include more traditional SMEs.

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Material choices and lifestyle shifts for a low-carbon Swedish building sector

Theme 6, sub-topic 6b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Building sector, Life-cycle emissions, Material efficiency, Lifestyle change, Carbon neutrality, Sweden

Extended abstract

The built environment plays a central role in climate change mitigation, with building construction and use accounting for a large share of global greenhouse gas (GHG) emissions. While policy efforts have traditionally focused on reducing operational emissions, there is a growing recognition that embodied emissions from the production and use of construction materials must also be addressed. In Sweden, embodied emissions are already the dominant source of building-sector GHG emissions, making a whole life-cycle approach to decarbonization both urgent and essential.

This paper presents a novel, integrated modelling framework that combines life-cycle assessment (LCA), dynamic building stock modelling, and scenario analysis to examine the material demand, energy use, and GHG emissions associated with Sweden’s building sector through 2045. It is used to explore how structural material choices (concrete, steel, timber), technological pathways (electrification, bio-based materials, carbon capture), and lifestyle-driven changes (space efficiency and reduced construction needs) influence the sector’s transition to carbon neutrality. Our work advances beyond current analyses [1, 2], by integrating the latest insights on materials, energy efficiency, and climate scenarios across multiple scales (from materials to the national building stock) into one model, enabling deeper pathways to carbon-neutral construction.

Objective and Scope

This paper aims to quantify and analyze the potential impacts of different development pathways on Sweden’s building-sector GHG emissions, with particular attention to:

- Current patterns of material use across building typologies and elements;
- Changes in demand for structural materials under different technology and policy scenarios;
- The relative effectiveness of material efficiency strategies;
- The importance of lifestyle factors in reducing emissions from both new construction and the existing building stock.



By focusing on Sweden as a case study, where data granularity and policy ambition allow detailed analysis, we offer insights that are relevant both nationally and in other high-income countries facing similar transition challenges.

Methodology

At the core of the study is an expanded version of the ECCABS model [3, 4], a bottom-up simulation tool for building stock analysis, adapted to capture whole life-cycle carbon (WLC) emissions in line with the EN 15978 standard [5]. This includes:

- Phase A (A1-A5): Material production, transport, and construction processes [6, 7];
- Phase B (B1-B7): Operational energy use, maintenance, and renovation emissions, including the trade-offs of building renovations between reduced operational energy and increased impact from the renovation materials and construction processes (Figure 3);
- Phase C (C1-C4): End-of-life processes including demolition, transport, and waste treatment.

The model uses archetype buildings to represent the Swedish building stock. Archetypes are defined across 16 building typologies, segmented by size, construction year, climate zone, heating system, ventilation, frame type, and solar PV adoption. A total of 840 archetypes were created for new buildings. The calculation includes different building parts (foundation, load bearing structural frame, roof, facades, non-load bearing elements), in accordance with the Swedish national regulations for climate declaration of buildings.

Material intensities for each archetype were derived from a national dataset maintained by the Swedish National Board of Housing, Building and Planning (Boverket) [8], validated using the Byggsektorns Miljöberäkningsverktyg (BM) LCA tool [9]. Emission factors were harmonized across phases and aligned with energy system scenarios used in Swedish national climate planning.

Scenario Design

Four scenarios were developed to simulate different technological and behavioral trajectories:

- Baseline (BAU): Assumes continuation of current practices and energy system development.
- Bio-CCS Pathway: Emphasizes bio-based materials and carbon capture in industrial processes.
- Electrification Pathway: Focuses on reducing fossil energy inputs by electrifying construction and materials production.
- Material Efficiency Pathway: Prioritizes reduced material use, substitution, and structural optimization.

The model incorporates stock dynamics (changes in building demand based on population growth, household size, and latent housing needs) thus allowing investigation into the role of lifestyle parameters in shaping material demand and emissions.

Key Results

Material demand (Figure 1): Concrete remains the dominant material by mass in most building typologies, particularly in multi-family and non-residential buildings. Steel is especially significant in non-residential buildings, while timber dominates in single-family homes.



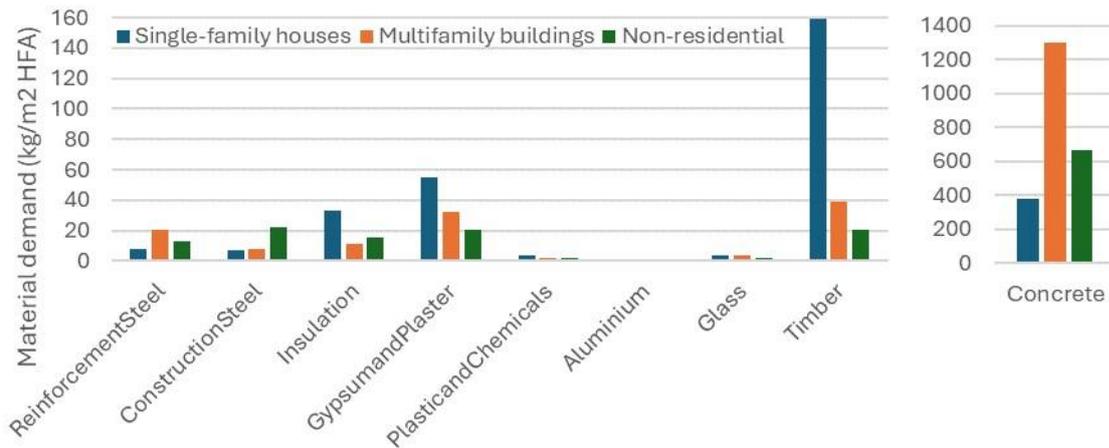


Figure 1 Material demands per building typology in the baseline year 2022. Note the different scale of the Y-axis for concrete (right).

Hotspots in emissions: Ground slabs, walls, and prefabricated concrete elements are major contributors to embodied emissions. Optimization in these areas offers high mitigation potential.

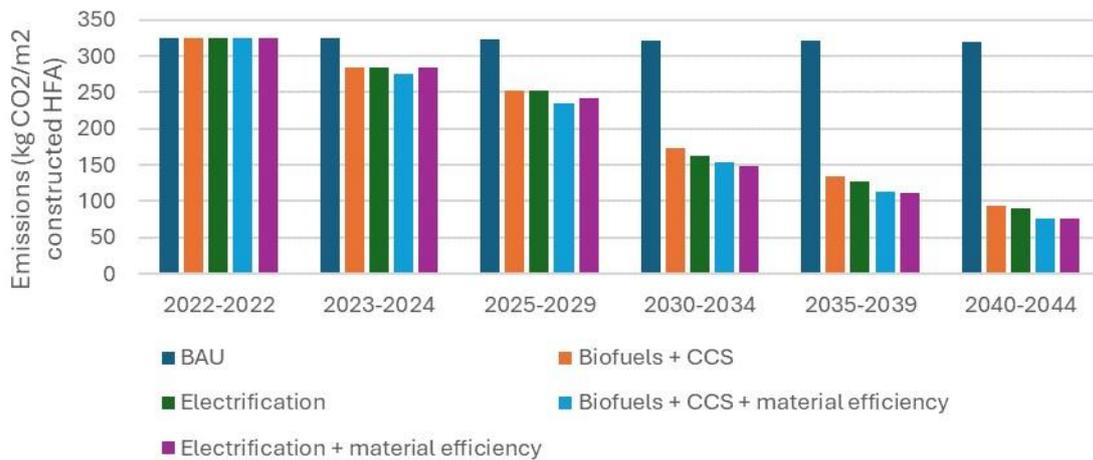


Figure 2 Evolution of emissions per heated floor area (HFA) of phase A1-A5 through year 2045, for the different scenarios.

Scenario comparison (Figures 2, 3): Bio-CCS and Electrification pathways offer substantial emission reductions in material production and use, but do not on their own reach net-zero by 2045. Material efficiency measures, particularly those that reduce the floor area of new construction and extend the use of existing buildings, provide the largest relative reductions, especially in the medium term (2030–2035).



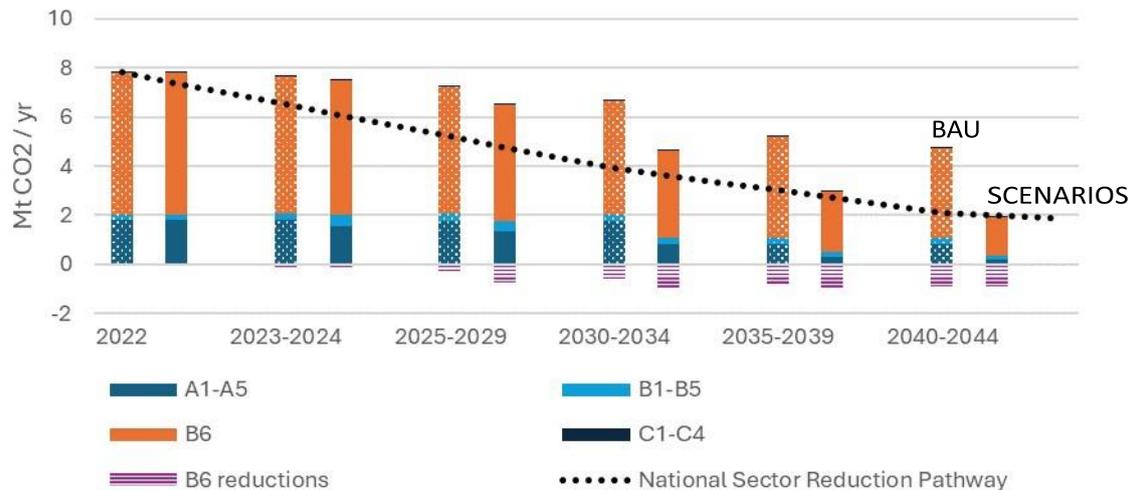


Figure 3 Total annual emissions for the different life-cycle phases through year 2045, for the different scenarios.

Role of lifestyle: Even in the most ambitious technological scenarios, emissions targets are not met without demand-side interventions. Lifestyle-driven reductions in per-capita space and construction needs are essential to closing the carbon gap. These include shifts in housing preferences, shared space models, and policies encouraging densification and adaptive reuse.

Conclusions

This study underscores the need for an integrated approach to building-sector decarbonization that bridges operational and embodied emissions, considers material flows across the life cycle, and embeds structural lifestyle change alongside technological innovation. In Sweden, where embodied emissions are already the majority, focusing only on greener materials or building codes will not suffice.

Key recommendations include:

- Policy frameworks must expand beyond technical standards to support lifestyle change (e.g. incentives for co-housing, floor area taxation, or adaptive reuse).
- Material efficiency should be mainstreamed in construction guidelines, with clear targets for structural optimization and reuse.
- Scenario modelling should be used in planning to highlight synergies and trade-offs between different decarbonization measures.
- Further research is needed on social acceptability, equity impacts, and governance of lifestyle-oriented measures to ensure a just transition.

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Co-Transforming Regional Energy Landscapes

– The Spatial-Narrative Turn in Participatory Energy Governance

Theme 3, sub-topic 3b); Alternative: Theme 2 sub-topics 2a), 2c) or Theme 6, sub-topic 6c)

- “Academic contribution”
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Keywords: energy justice, spatial identity, participatory governance, energy visions, narrative co-design, regional transformation

Extended abstract

1. INTRODUCTION

Achieving a climate-neutral energy system is not merely a technical challenge – it is a profoundly social and spatial transformation. Regional energy transitions unfold within place-specific legacies, emotional geographies, and socio-political constellations [1]. Yet, governance models and infrastructure planning often neglect this spatial dimension. This paper applies the metaphor and methodology of the spatial-narrative turn to examine how place, participation, and co-created visions shape public ownership, legitimacy, and the governance of regional energy transitions [2].

Our central research question is:

How can knowledge of regional identities and place attachments integrated via transdisciplinary and participatory approaches of research contribute to a just energy transition on the local and regional level in rural areas?

2. RESEARCH AIMS AND THEORETICAL BACKGROUND

Our goal is to synthesise theoretical and empirical insights to place attachments and how energy transition is perceived on the local and regional level in order to make participatory governance more spatially sensitive and thus take better account of local and regional interests in decision-making. Building on the spatial-narrative turn in governance theory, we emphasise that space is not a neutral backdrop, but an active arena imbued with meaning where power, identity and legitimacy are constructed.



We argue this based on our “co-transformation governance approach to energy transitions” [2]. We view these transitions as collective societal projects that require procedural justice, symbolic inclusion, and democratic ownership. Our analysis is guided by five strands of literature:

- energy justice (distributional, procedural, recognition) [3, 4],
- spatial identity, place attachment, emotional geographies [5, 6],
- energy democracy and co-creation [7, 8],
- narrative governance and socio-technical imaginaries [9, 10]
- and participatory transformation and visioning [11, 12].

3. METHODOLOGY

We synthesise qualitative data from two regional case studies we analysed in the German research project “Kopernikus ENSURE” (Phases II & III):

- as a prospering rural RE pioneer region: the district of Steinburg (as a baseline region),
- as a rural structural change region under pressure to transform: the Leipzig district.

Based on multi-stage desk research involving document analysis and a literature review, as well as expert interviews and participatory workshops with local stakeholders, six themes were identified. A comparative analysis was conducted in line with the developed co-transformation governance framework, incorporating tools of co-narration and co-visioning, as well as the application of our generic "participation cycle analysis (PCA)"-tool [2].

4. SYNTHESIS: KEY FINDINGS

Across the two research regions, we found strong evidence that successful co-transformation requires much more than just formal participation formats. Rather, co-transformative energy governance depends on the capacity to integrate local identities and narratives in participatory formats and to develop a shared vision of a local/regional energy transition. Three cross-cutting insights emerged:

(1) Spatial identity plays a crucial role in achieving sustainable regional transformation

Energy transitions are filtered through collective memory, symbolic territory and regional identity.

For illustration:

- Leipzig's post-coal and post-socialist identity requires careful consideration of future changes which means that there is a need to generate a narrative and vision focusing on chances through renewable energy on the local/regional level;
- Steinburg illustrates how rural energy cultures are anchored in decentralised participation, an established culture of rural solidarity and the long-standing utilisation of wind power (‘wind farmer’-narrative) [13].

Our transdisciplinary research shows that historical experiences such as Leipzig's legacy of coal-fired power generation shape how people perceive and proactively advocate energy projects. Affective geographies influence public judgements about fairness and legitimacy.

(2) Narratives can be powerful tools of inclusion, capacity building and knowledge transfer

Rather than merely providing information, spatial narratives such Borna's transformation from a coal-centred region into an innovation hub for the transition to a green hydrogen economy act as framing devices that can foster collective ownership and long-term engagement. They translate complex technical systems into culturally resonant visions.



(3) Visions bridge scales and timelines

Participants of co-creation settings such as a visioning workshop support their commitment for the energy transition. Visioning builds shared meanings while accommodating diversity. Jointly developed visions can provide a normative goal orientation. Individual measures, strategies or projects can be repeatedly checked against this goal. Such visions can be supported by positive narratives which may foster a sense of self-efficacy and collective commitment to the greater good.

(4) Participation must be designed to resonate spatially and be context-sensitive

There is no one-size-fits-all solution for participation. Rather, participation needs to be designed in reference to local/regional requirements and conditions. Effective co-design must reflect regional governance cultures, levels of trust and institutional capacities. Resonance depends on sensitivity to context in terms of the symbolic, historical, and procedural aspects. Our co-transformation governance approach, which is supported by the tools of a participation cycle analysis as a starting point for cooperation with stakeholders in a specific local setting, as well as our participatory visioning formats, enables such context-aware design from a methodological perspective.

5. DISCUSSION AND POLICY IMPLICATIONS

When viewed through a spatial-narrative lens, participation becomes an organic cultural and territorial process rather than a formal procedural one. Our findings suggest that planning authorities, energy agencies, climate initiatives and local administrations should move beyond participation forms which are often understood or conceptualised for information rather than participation as co-design. A participatory governance for co-transformation is based on spatial specificities and co-visioning.

To support regional co-transformation, we recommend that public and private stakeholders involved in the European energy transition towards climate neutrality do the following:

- embedding spatial sensitivity and diagnostics early in planning cycles via mapping of local identities and narratives of local and regional energy cultures into planning procedures,
- facilitating co-creation through participatory formats that link technical options with socio-spatial requirements and options for the future,
- support and activate intermediary actors (e.g. local energy forums, municipal networks, real-world labs and innovation hubs), who can translate between policy, technology, and place-based concerns and agency,
- evaluate participation in terms of both procedural inclusion, symbolic ownership and narrative legitimacy within the local community [14].

6. CONCLUSION

Space is dynamically constituted by actors and has both a normative and a symbolic power. The spaces in which we exist and our relationships with them influence our interpretations and actions regarding the energy transition, which is a key to sustainability transformation. Current political trends demonstrate that collective narratives and visions of a better future can influence meanings, perceptions and actions.

The Energy transitions in Europe will only succeed if people are part of these transformations. The call for a ‘spatial-narrative turn’ to energy transition governance invites a strategic reorientation that recognises local context, values memory and fosters collaboration to create a shared understanding of climate neutrality.



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Who is Most Influenced By Sludge? Experimental Evidence

(Theme 2, sub-topic 2c & Theme 3, sub-topic 3b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: administrative burden, sludge, incentives, behavioural experiment, information processing, environmental decisions

Extended abstract

As a consequence of anthropogenic climate change, there is an urgent need to transition away from unsustainable energy sources such as oil, coal and to a lesser extent natural gas [1]. Common alternatives are hydro, solar and wind power. Despite their environmental benefits and broad public support, wind farm developments face significant opposition at the local level, which has been identified as a key barrier to the rapid rollout of these technologies [2-4]. Common concerns include visual disruption, noise, perceived health risks, or lack of local consultation [5]. This lack of public acceptance can delay projects, increase costs, and ultimately hinder national targets for renewable energy generation and emissions reductions [6,7].

As a result, public acceptance has become an important focus of energy policy, with growing attention being given to how procedural and distributive fairness can influence support for low-carbon infrastructure. One solution that some governments have begun to turn to in order to address this issue is the use of community benefit schemes such as Ireland’s RESS community benefit fund [8]. These schemes provide compensation or funding opportunities for individuals and organisations located near wind farms. Funds might be used for household improvements, local facilities, or community-led projects.

While these schemes are intended to promote fairness and engagement, their implementation often involves administrative processes that other challenges. Accessing these schemes typically involves an application process. The forms, eligibility documents, and submission procedures involved can be difficult to understand or navigate, especially for individuals with limited time, administrative experience, or digital literacy. If the goal is to increase trust and participation, these procedural hurdles may unintentionally exclude those most affected.

Administrative burden, referred to as sludge in the behavioural economics literature, refers to frictions that make it harder for individuals to complete otherwise simple tasks, that are in their best interest [9]. These frictions may take the form of long or unclear waiting times, confusing forms, complex instructions, or unnecessary steps [10]. Though often unintentional, sludge can



reduce take-up of beneficial programmes, impede accurate decision-making, and lower welfare by forcing individuals to expend effort unnecessarily. Additionally, administrative tasks are pervasive in everyday life. Martin et al. (2024) suggest that individuals spend on average between 32 and 85 minutes per day on administrative tasks. Therefore, these unintentional burdens can accumulate, resulting in significant costs for individuals.

The effects of sludge are not homogenous. One’s vulnerability to sludge is thought to differ across various factors. Individuals with higher administrative literacy or stronger digital skills may be better equipped to navigate complex processes, while those with fewer resources may be disproportionately affected. Temporary conditions like tiredness or stress may also influence a person’s capacity to complete burdensome tasks, even when they would otherwise be capable of doing so.

These differential effects raise concerns about equity. If some individuals are consistently more affected by administrative burden than others, sludge may reinforce or even exacerbate existing inequalities in access to benefits, services, or participation. While this possibility has been noted in the literature [11], empirical evidence remains limited. To date, most sludge-related research has focused on aggregate effects, with less attention paid to how the burden is distributed across different types of individuals. This study uses an experimental design to quantify these effects and identify who is most affected by sludge in a realistic, policy-relevant task.

Using a within-subject experimental design, 1,005 participants evaluated three environmental grant information sheets under randomized conditions of low, medium, or high sludge, with the goal of finding relevant information in order to answer a set of questions. Each participant received all three treatment levels, with the order in which they encountered each one randomised across individuals. Higher treatment levels consisted of longer forms with more complex language and jargon, intended to hinder easy access to the relevant information. In addition to the within-subject treatment, a between-subject manipulation varied monetary incentives (either €5 or €200 prize draw). This design allows causal estimation of both the main effects of sludge and incentive level, as well as interactions with cognitive and behavioural traits.

The primary outcome was the number of correct responses per grant. Results show that performance decreases monotonically as sludge increases: mean correct scores fall from 3.59 (low sludge) to 3.30 (medium) and 2.75 (high). The difference between low and high sludge is both substantively large and statistically significant. This supports the hypothesis that sludge significantly impedes accurate evaluation of information. See figure 1.

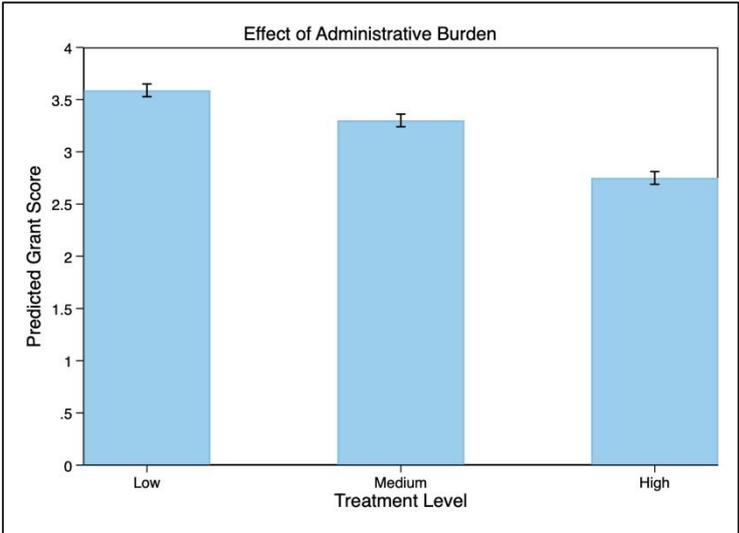


Figure 22 - Treatment Effects

Incentives produced a modest overall effect. Participants in the high-incentive condition scored marginally better on average (3.25 vs 3.17), although the magnitude of the effect was small and not significant in all specifications. This suggests limited impact of monetary motivation in countering the cognitive costs imposed by sludge. To understand heterogeneity in treatment effects, we examine several

moderator variables. Notably, computer literacy and administrative literacy are strongly associated with better overall performance and significantly moderates the effect of high sludge. Mental health, current tiredness, and conscientiousness also interact significantly with sludge levels. For instance, tired participants perform worse overall and suffer disproportionate declines under high sludge. By contrast, procrastinators appear less affected by medium sludge, though their baseline performance is lower.

Table 6 - Vulnerability to Sludge

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Admin Lit	Comp Lit	Procrast	Mental Health	Busyness	Tiredness	Conscientious
Medium Treatment	-0.289*** (0.0301)	-0.289*** (0.03)	-0.289*** (0.03)	-0.289*** (0.03)	-0.289*** (0.03)	-0.289*** (0.0301)	-0.289*** (0.0301)
High Treatment	-0.84*** (0.040)	-0.84*** (0.04)	-0.84*** (0.04)	-0.84*** (0.04)	-0.84*** (0.04)	-0.84*** (0.04)	-0.84*** (0.04)
Predictor	0.147*** (0.032)	0.280*** (0.038)	-0.047** (0.024)	0.112*** (0.028)	-0.036 (0.024)	-0.098*** (0.022)	0.073** (0.029)
Controls	YES	YES	YES	YES	YES	YES	YES
Constant	3.154*** (0.175)	2.427*** (0.22)	3.823*** (0.139)	3.328*** (0.16)	3.758*** (0.13)	3.881*** (0.129)	3.440*** (0.158)
Observations	3,012	3,012	3,012	3,012	3,012	3,012	3,012
R-squared	0.134	0.153	0.126	0.133	0.125	0.135	0.127

Robust standard errors clustered at the individual level. Each column presents a separate regression model estimating the interaction between sludge treatment and the listed moderator variable. All models include demographic controls. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

These findings have implications for the design of public programmes that rely on voluntary uptake or citizen engagement. If certain individuals are more affected by administrative burden than others, then even well-intentioned policies may lead to unequal outcomes. In the context of climate and energy policy, where community benefit schemes are intended to promote fairness and local participation, this is particularly important. Procedural frictions may reduce take-up among those with lower administrative capacity, undermining the stated goals of inclusion and fairness. Reducing sludge in the application process may therefore improve both the effectiveness and equity of such programmes.

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Guiding Municipalities Through Participatory Processes: A Framework for Participation in Climate-Resilient Transformation

Theme 2, sub-topic 2c)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Citizen participation, Climate resilience, Municipalities, Public space

Extended abstract

Public spaces are critical to the quality of life for residents of a village, town, or city. However, making these public spaces climate-resilient is often a major challenge for local authorities. When citizens are actively involved in developing climate-resilient projects in municipalities, it fosters transparency, accountability, and trust between the local government and its residents. This engagement not only empowers individuals but also enhances the quality and sustainability of municipal projects by incorporating diverse perspectives and solutions [1]. Moreover, citizen involvement can lead to increased support and smoother project implementation, as people are more likely to back initiatives they had a hand in shaping.

To support the involvement of citizens in municipal projects, the project “MitBestimmt Klimafit” developed an online guide that takes municipalities step-by-step through the preparation, planning, and implementation of participatory processes in the realm of climate-resilience measures to (re)design public spaces. The main aim is to provide municipalities with easily accessible guidance on involving citizens and stakeholders in processes for the climate-resilient transformation of public spaces.

To identify the steps for a participatory process and develop the guide, a qualitative methodology consisting of a literature review and expert interviews was applied. In a literature review, existing research on climate change adaptation and citizen participation was analysed with an emphasis on usage conflicts, maladaptation, and methods of conflict avoidance. 14 semi-structured interviews were conducted with representatives from municipalities and managers of climate adaptation regions which have been involved in participatory processes in their municipality or region.

Based on these methods, a 10-step framework for conducting participatory processes in municipalities was developed. Figure 1 shows an overview of the framework which can be divided in preparation (Steps 1-4), planning (5-6), implementation (7-8), and reflection phase (9-10).



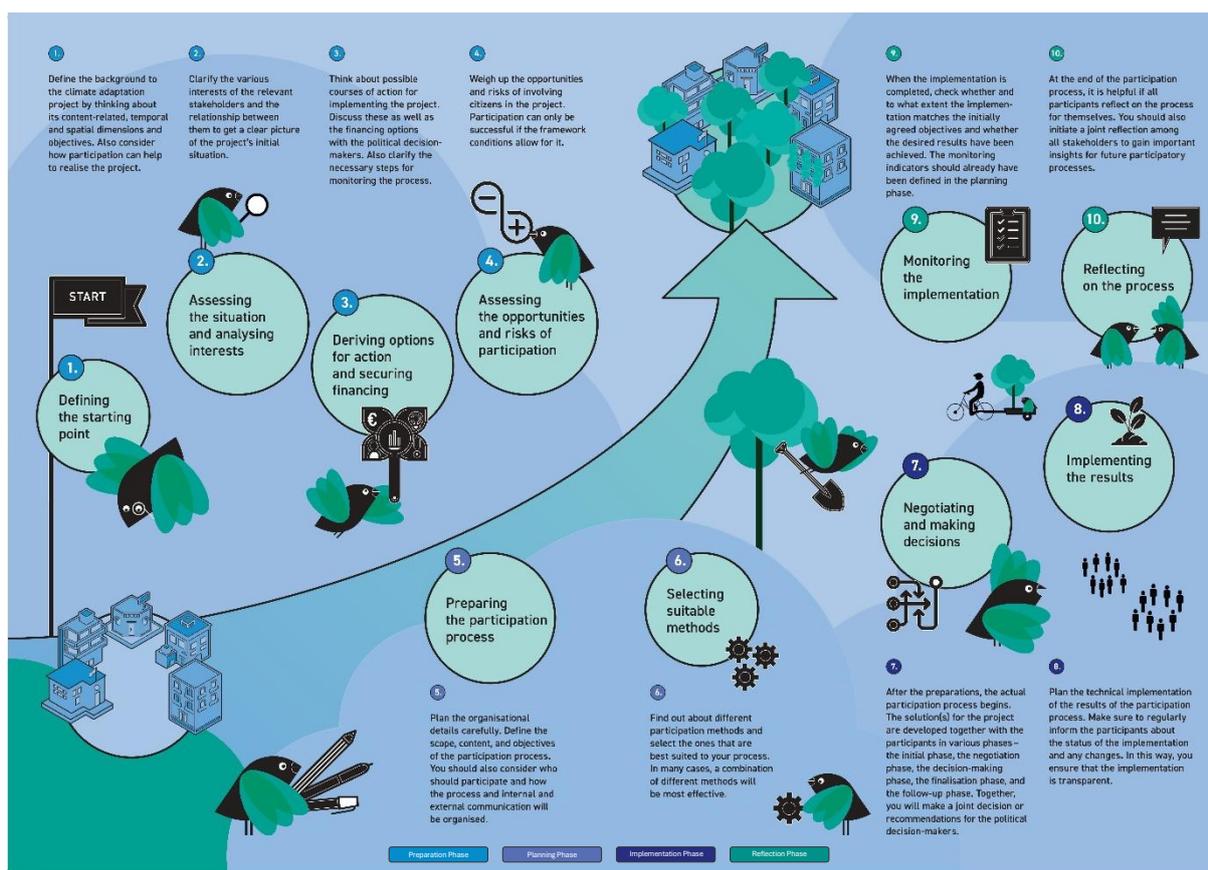


Figure 1: Framework for conducting implementing participatory processes in municipal projects

1. Defining the Starting Point. In the first step, the coordinators of a climate-resilience project must gain an in-depth understanding of the background of the project and its framework conditions. They should try to answer questions such as who has brought the project forward and who is affected, what are the goals of the project, and what are the content-related, temporal, and spatial dimensions of the project.

2. Assessing the Situation and Analysing Interests. The second step serves to further understand the interests of different actors involved in or affected by the planned project. Especially, clashes of interests and tensions between stakeholders should be analysed to allow for an open dialogue during the citizen participation. When researching the necessary information local stakeholders, politicians or policy makers, and local media can be valuable sources.

3. Deriving options for action and securing financing. In the third step, different paths of actions for implementing the climate adaptation measures are evaluated. The coordinators must discuss these different options and ways to involve citizens with local authorities to ensure political and financial support for the project. Also, questions about how the implementation of climate-resilience measures can be monitored should already be discussed at this point to ensure effective data collection throughout the project.

4. Weighing the Opportunities and Risks of Participation. The fourth step is necessary for projects where the involvement of citizens in climate adaptation projects is not set as a given. For example, when local authorities and other stakeholders must be convinced of the benefits of participation, coordinators should weigh the opportunities and risks of participation for the respective project and question whether citizen participation should be

applied.

5. Preparing the Participation Process. The fifth step is the most extensive since the organizational details of the participatory process are determined. Coordinators must define the goals and the subject of the participatory process to ensure that the outcomes of decision-making are realistic and useful. Also, the coordinators decide upon the participants of the process and develop a communication concept. During the events of the participation process, the goals, subject, and selected participants should also be discussed with the participants to ensure that their needs and interests are taken into account.

6. Selecting Suitable Participation Methods. Part of preparing the participative process is also to select suitable methods for engaging citizens. Coordinators analyse what type of participation should be achieved by the process. Whether citizens and stakeholders should be merely informed, whether they are consulted about their interests and opinions, or whether they should actively be part of the decision-making process. Depending on the type of participation different methods are applied.

7. Negotiating and Making Decisions. After the participatory process has been well developed, actual citizen participation can take place. Citizens and stakeholders are engaged to voice their opinions, negotiate different measures, and make decisions during the respective events and the entire participation process.

8. Implementing the Results. After the participation has taken place, the outcome of the citizen participation – with the approval of the local authorities – is implemented. In this step, it is important that coordinators ongoingly communicate with the participants to ensure that political decisions taken, and changes in implementation are comprehensible and relatable to the participants.

9. Monitoring the Implementation. The ninth step deals with monitoring of the implementation of the decided-upon measures. Monitoring indicators have already been discussed in Step 3 which now serve as a basis for monitoring whether the measures are implemented as planned.

10. Reflecting and Evaluating the Process. The final step deals with the evaluation of the participatory process which can happen at the same time as the monitoring of the implementation. The coordinators should reflect upon themselves and together with involved stakeholders and citizens on the strengths and weaknesses of the participatory process. The results from the evaluation can be useful for future participatory processes.

Next to the framework, five aspects that are especially important for ensuring a successful participation process in practice were identified in the interview results. First, clear objectives and transparent procedures promote the trust of those involved and increase the acceptance of the implemented results. Second, continuous and target group orientated communication with those involved throughout the entire process is essential for transparency and accountability. Third, the various interests of those affected should be analysed at an early stage. During the process, the focus is on negotiating these interests. Fourth, planning of the process and the choice of methods should allow for flexibility and adaptation to unexpected changes and specific needs. Finally, a realistic assessment of the time and financial outlay is of great importance. The largest part of the effort lies in the preparation and planning of the participatory process.



The results of this research were converted into a practical guide that supports municipalities in the planning and implementation of participatory climate-adaptation projects [2]. Whilst the guide focuses on participation in climate adaptation measures, the steps guiding through developing and planning a participatory process can also be applied to other topics such as energy efficiency measures or mobility projects. Given the practical relevance of the guide, it enables municipalities to plan and execute participation processes efficiently which makes an important contribution to promoting participatory approaches in municipal climate policy.

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Neighbourhood Patterns in Home Retrofit Uptake: Evidence of Spatial Clustering in Scotland’s Energy Performance Data

Theme 1, sub-topic 1d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Peer effects, Spatial econometrics, Home retrofit, Sufficiency, Just transition, Scotland

Extended Abstract

Background and Motivation:

Decarbonising the existing housing stock is essential for achieving net-zero targets, particularly in countries with ageing, energy-inefficient homes like the UK. The uptake of retrofit measures remains patchy and socially uneven. Growing evidence points to peer effects, which is the tendency for households to copy nearby adopters, as a powerful but under-used driver of change¹⁻⁵. Yet Most peer-effect studies focus on a single, highly visible technology, solar photovoltaics (PV). Little is known about whether peer diffusion also drives “fabric-first” measures that deliver energy sufficiency but are less conspicuous, nor how these dynamics play out across Scotland’s small-area “Data Zones (DZ)” where retrofit meets place-based deprivation and the just-transition duties of local authorities.

Research Questions and Objectives:

This study investigates whether retrofitting behaviours, such as installing PV, heat pumps (HP), or insulation, exhibit spatial clustering across Scottish neighbourhoods. Specifically, we ask:

RQ1) To what extent do retrofit measures cluster geographically across DZ? Does retrofit uptake in one DZ depend on uptake in neighbouring DZs (spatial peer effects)?

RQ2) Are these patterns consistent across different technologies? Do spatial and temporal effects vary by retrofit visibility (PV > HP > wall insulation)?

RQ3) How do deprivation, tenure and dwelling type mediate patterns, and what does this imply for future policy design, especially regarding local targeting and peer-based interventions?



Methods and Data:

We use a longitudinal panel of over 150,000 Energy Performance Certificates (EPCs) for residential properties in Scotland, covering 2015–2023. Each EPC record includes building location, retrofit recommendations, government grant scheme used, and description of building fabric and systems. Property-level EPCs are cleaned (outliers removed; floor-area 20–600 m²; habitable-rooms 1–15) and aggregate retrofit activity by year and DZ to derive counts and rates of PV, HP and wall-insulation installations. We combine EPC data with 2012/16/20 Scottish Index of Multiple Deprivation (SIMD) indicators at DZ level (\approx 500–1 000 people) and DZ Shape files. Several spatial analyses were performed including:

- Constructing spatial weights using Queen contiguity of DZ geometries;
- Computing Global and Local Moran's I to detect clustering;
- Comparing spatial patterns across retrofit types and adoption rates using econometric modelling, estimating Spatial Durbin Models (SDM) for each measure.

Results and Discussion:

We find significant spatial clustering for most retrofit measures, but the strength and pattern of clustering vary by technology. PV panel uptake shows consistent high-high clusters, while HP and wall insulation exhibit more fragmented or low adoption zones. Clustering often occurs in urban and semi-urban contexts but with localised exceptions. Housing stock controls reveal higher shares of pre-1965 dwellings boost insulation adoption but dampen HP uptake, aligning with sufficiency principles that prioritise demand-reduction before electrification. These patterns suggest that spatial proximity, shared infrastructure, or socio-demographic factors may influence uptake, even if peer effects cannot be conclusively identified at this stage.

Our findings empirically demonstrate that visibility matters: conspicuous PV arrays act as social signals that catalyse larger peer multipliers, consistent with previous studies ^{1,3}. Less visible wall insulation still benefits from proximity learning, but policy levers other than mere demonstration, e.g., targeted advice visits or “street-by-street” campaigns, are needed to trigger comparable cascades. Importantly, spatial contagion alone does not close equity gaps; deprived or renter-dominated DZs remain less responsive without complementary support.

Policy Implications:

Our findings underline the importance of place-based strategies in retrofit policy. Recognising where clustering occurs and which technologies are being adopted can support more targeted outreach, funding, and communication strategies. This spatial awareness is especially relevant for designing behavioural interventions that leverage local visibility or social norms. Although more work is needed to isolate true peer influence, identifying zones of consistent uptake is a first step toward smarter deployment.

Conclusion:

Neighbourhood peer effects are a powerful, yet unequal, engine of retrofit diffusion in Scotland. Spatial econometric evidence underscores the need for policy mixes that amplify positive spillovers while safeguarding sufficiency goals for all households. Embedding social-learning mechanisms within area-based retrofit programmes can accelerate progress towards a just, carbon-neutral housing stock by 2045.

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Sustainability transformation potentials of non-urban mobility in Switzerland: Perspectives from residents in non-urban areas

Theme 5, sub-topic 5a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Mobility, mobility habits, non-urban areas, barriers, drivers

Extended abstract

1. INTRODUCTION

Transport accounts for 30.4% of Switzerland’s CO₂ emissions¹, with private cars accounting for 71% of them². Households in non-urban areas are more likely to own a car, and they drive more compared with households in cities³.

This suggests that there is considerable potential in Switzerland to shift from car-based transport towards more sustainable options, which is especially high in non-urban areas. However, changing mobility behaviour is challenging because it is habitualised and tied to contexts⁴⁻⁶, such as public transport (PT) options. Respective change in non-urban regions is even more difficult because of a lack of PT options, longer travel distances, and topography⁷.

However, research suggests that mobility habits can be changed if changes occur in context^{8,9}. Such changes can occur at the individual level (e.g., birth of a child) or the collective level (e.g., carsharing). To design effective solutions that encourage habit change, it is crucial to understand the perspectives of potential users. Failing to do so risks low acceptance and usage, leading to unprofitable outcomes¹⁰. This is especially pronounced in non-urban areas, where lower population density inherently complicates the viability of mobility services.

2. SCOPE AND OBJECTIVE OF THE PAPER

This paper aims to better understand how mobility habits in non-urban regions can be shifted towards more sustainable practices. With this purpose in mind, we identify people’s current mobility habits as well as barriers and drivers of sustainable mobility options. We understand sustainable mobility options as options that have lower CO₂ intensity compared to private car use. This could be, e.g., PT, walking, cycling, or carsharing¹¹.



3. METHOD

We conducted 13 qualitative, semi structured interviews^{12,13} with residents living in non-urban areas of Switzerland (e.g., cantons of Berne, Valais, Basel-Landschaft) between the age of 23 and 62. The interview guideline focused on people's activities requiring mobility during a typical week, respective influencing factors and drivers and barriers for using more sustainable mobility options. All interviews were transcribed, content analysis was done with MAXQDA.

4. RESULTS

4.1. Mobility habits

Interviewees' mobility habits are influenced by factors at both collective and individual levels. **On a collective level**, living conditions in non-urban areas of Switzerland differ significantly. Some interviewees reside in well-connected areas with ample PT options, while other regions lack these services, especially during off-peak hours. The availability of jobs, shops, leisure activities, and schools also varies. These living conditions were both crucial in interviewees' choice of residence and also shaped mobility habits. For instance, the presence of high-quality PT was crucial for some interviewees' choice of their place of residence. Conversely, those living in areas with fewer amenities often did not mind car driving to reach their preferred destinations. Some interviewees mentioned living in cities earlier, relying on PT, but changing to cars or even bikes after moving to less connected rural areas.

On an individual level, key influencing factors for mobility patterns evolved around the concepts of comfort and flexibility. Many interviewees find cars indispensable for daily tasks such as grocery shopping and transporting equipment due to the lack of comprehensive PT in their areas. The flexibility and time efficiency provided by cars were highlighted, especially when dealing with sparse PT schedules in non-urban areas. Privacy and independence were also significant drivers for some, leading them to rely on cars. Conversely, health benefits and a sense of independence motivated those relying on cycling.

4.2. Barriers for sustainable practices from users' perspectives

Several barriers for sustainable mobility practices have been identified in the interviews. Interestingly, barriers such as lacking flexibility in PT were often framed as drivers for car use by interviewees.

One major challenge is the **scarcity and sometimes unreliability of PT options** in non-urban areas. Interviewees mentioned that bus connections were often sparse or bus stops were far away from their home, leading to difficulty in covering the first and last miles. Moreover, the **need to plan trips** well in advance due to infrequent schedules limited spontaneity. Also, often **longer travel times** with PT, unreliability of bus and train services, including delays and unplanned cancellations, added to frustration.

The **overfilled conditions during rush hours** were also mentioned as a barrier for using PT.

Many interviewees stated that the **high costs** of PT, especially without discount passes, make PT less appealing. Interestingly, interviewees often compared ticket prices and fuel costs without considering further costs of car use (purchase of vehicle, insurance, parking costs, etc.). Some interviewees were concerned about their **safety when traveling by PT alone or during late hours**, especially in non-urban areas where many people did not use PT. Others mentioned that the perceived **lack of privacy and personal space as well as noise** in crowded PT pushed them toward car use.



Regarding bike use, some interviewees mentioned **weather conditions** (e.g., snowy, icy roads) as a barrier.

Interestingly, some interviewees that currently use sustainable means of transport mentioned that **having children** would be a reason for them to start driving as they expected a car to be more convenient compared to PT and safer compared to cycling with kids.

4.3. Drivers for sustainable mobility practices from users' perspectives

The interviews revealed several drivers for sustainable mobility practices in non-urban areas from a user perspective.

For biking, **health benefits** emerged as a significant motivator, with many interviewees noting improved physical and mental well-being. The ability to clear one's mind after work and maintain a healthy lifestyle was frequently mentioned, along with the flexibility that biking offers. **Environmental concerns**, such as combating climate change, also played a role in choosing the bicycle over the car for some interviewees. However, for many, environmental concerns were not the decisive factor; other aspects such as bike paths played a more significant role, making environmental concerns of secondary importance.

Regarding PT, the ability to **utilize travel time** productively was a key driver. Many interviewees valued the opportunity to read, work, or relax during their travel time, which they felt was not possible when driving a car. The convenience of **avoiding congestion and the stress** associated with finding parking spaces were also highlighted. Moreover, participants would appreciate **incentives from employers**, such as contributions to PT subscriptions.

5. CONCLUSIONS

Our study sheds light on barriers and drivers of sustainable mobility practices of non-urban residents, providing a basis for developing sustainable and at the same time socially accepted mobility options with mobility providers.

Some of these barriers and drivers are specific to non-urban areas such as limited PT options, while others are more general, such as the flexibility and privacy associated with cars. The scarcity, infrequency, and unreliability of PT options in non-urban areas represent significant barriers. But also, the lack of amenities close-by increases the dependence on cars. On the other hand, health benefits are drivers for biking in non-urban areas. Also, avoiding stress (e.g., congestion) and utilizing travel time can be a driver for more sustainable mobility practices. Improving the reliability and availability of PT seems crucial. On-demand systems¹⁴ could potentially address people's need for flexibility and still provide a reliable and affordable PT solution in non-urban Switzerland. Biking promotes health and well-being. Enhancing biking infrastructure, such as safe lanes and convenient parking at transport hubs, could support a shift towards biking in non-urban Switzerland.

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Empowering Communities through Participation: Collaborative Visioning and Literacy Building in Energy Communities

Theme 1, sub-topic 1a), Theme 2, sub-topic 2d), Theme 6, sub-topic 6b)

- “Academic contribution”
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Keywords: Energy literacy, Shared imaginaries, Energy communities, Positive Energy Districts, Sustainable energy solutions, Community engagement.

Extended abstract

The transition to sustainable energy systems is fundamentally a social process, with community energy initiatives at the forefront of efforts to achieve net-zero goals and ensure a just, inclusive transition. Central to the success of these initiatives is the concept of energy literacy: the knowledge, skills, and confidence required for citizens to meaningfully participate in shaping their energy futures. This extended abstract presents a focused account of a community-centred energy literacy programme, developed and piloted in two European communities, that demonstrates how participatory methods can overcome traditional barriers to engagement and empower citizens as co-creators of local energy solutions.

Community energy projects, where citizens collectively own, manage, and benefit from local energy initiatives- are widely recognised as vital for accelerating the energy transition and delivering the Sustainable Development Goals (SDGs), particularly those related to clean energy, sustainable cities, and climate action. Achieving net-zero emissions and affordable, clean energy (SDG 7) is contingent on transforming the way energy is produced, consumed, and managed. Positive Energy Districts (PEDs), which aim to achieve net-zero energy import and CO₂ emissions annually while integrating surplus renewable energy into broader energy systems, have become key components of this transformation [1]. By embedding people at the heart of energy systems, such initiatives promote trust, build social capital, and ensure that the benefits and responsibilities of decarbonisation are shared equitably. However, traditional energy literacy interventions tend to rely on top-down information campaigns, consultations, or awareness-raising activities. While these can increase general awareness, they rarely empower communities to lead, shape, or co-create energy initiatives. Most existing approaches are not



designed to foster collective agency or democratic ownership; as a result, citizens are often positioned as passive recipients of top-down techno economic initiatives rather than active agents. There is a clear need for participatory, context-sensitive approaches that make energy literacy a shared, negotiated, and empowering process.

Energy literacy encompasses understanding of energy systems, technologies, behaviours, and the broader social and environmental implications of energy choices. It is not merely technical knowledge, but an enabler of agency and collective action. Inadequate energy literacy can prevent communities from engaging with complex issues such as demand response, local energy markets, and co-design of energy futures. This gap is especially acute for groups with less access to information or technical expertise, risking their marginalisation from the benefits of the energy transition. To address these limitations, this research developed a participatory design (PD) approach that goes beyond conventional educational tools. PD is grounded in a socio-technical perspective, emphasising the importance of understanding context and practice when developing new designs. "Practice" refers to the activities people actually engage in within their daily lives [2]. Central to this methodology was the use of an Energy Literacy Game (ELG), designed as an interactive, accessible entry point for diverse demographic groups and those with lower technical confidence. Co-design represents a useful tool in improving literacy and referred to designing *with* rather than *for* people, offering potential benefits for designers and their communities, researchers, and organisations.

A framework developed by Sanders et al. was used as the starting point in developing the ELG [3]. This framework is structured involving non-designers around three main dimensions: form, purpose, and context. The 'form' dimension refers to the nature of interactions among participants, which can involve making, telling, or enacting. The 'purpose' dimension explains the objectives behind using these tools and techniques, which may include probing participants, immersing them in the topic of interest, understanding their current experiences, or generating new ideas and future scenarios. Each form can be paired with any purpose. Lastly, the 'context' dimension considers factors such as group size and composition, whether the activity is conducted face-to-face or online, the venue, and the relationships between stakeholders. The workshops were designed to be accessible to diverse demographic groups and those with lower technical confidence. The following is an example of the methodological approach used at one site (Findhorn Ecovillage, Scotland).

Phase 1: Shared Learning/ Meanings: The initial part of the workshop focused on building energy literacy through participatory learning. Participants engaged with picture cards that illustrated the meanings of various terms, fostering shared imaginaries for the community. This activity encouraged all attendees, including both stakeholders and citizens, to propose their own terms, ensuring inclusivity and the co-creation of a common vision. Five key topics, each with several subtopics, were initially identified for the community:

- Energy (building, solar, wind)
- Storage (electric battery, thermal)
- Grid (grid scenario, flexible charging, tariff)
- People (practices, comfort, peer-to-peer trading)
- Infrastructure (ownership, third party control, EV)

For each subtopic, initial definitions using plain language were prepared to start negotiation of meanings. The workshop involved 16 citizens, divided into two groups. Each group worked with a picture board, discussing the provided meanings and engaging in the process of reaching consensus, while also adding terms and concepts they considered important for their energy future. Key outcomes of this phase included:



- Consensus on the meanings of subtopic by the end of the session
- Identification and incorporation of new sub-topics raised by participants (e.g. Micro Grid, Flexible smart pricing, Residents and non-residents rates, Hybrid V2G, Management and maintenance, Poor design, Impact of participating in peer-to-peer trading, Friction, Educating people, Disposal of energy, Flick switch, Seasonal Storage)
- Establishment of a common language and shared understanding around energy, bridging technical and lay perspectives.

Phase 2: Visioning and Co-Creation: The second part of the workshop moved from shared learning to collaborative visioning. Participants were asked to envision what Findhorn would look like in 10 years, using the previously established topics as a framework. Working in two groups, they created a total of six storyboards that reflected their needs, interests, and concerns for their evolving Energy Community following a framework of Butler et al., 2016 [4]. The outcomes of this phase provided a rich foundation for developing actionable scenarios based on the community's own vision, ensuring that future strategies are rooted in shared understanding and collective aspiration.

Phase 3: Shared Imaginaries: Narratives were developed from these visions and presented as *'A Day in the Life of Findhorn in 10 Years'* scenarios, allowing participants to relate to them. These narratives reflected local needs and aspirations and can directly inform the design of demand response (DR) strategies, practical exploration of energy management (e.g., scheduling, forecasting, automation), and the co-creation of content for future community-led initiatives.

Future research should explore the scalability of participatory literacy and visioning approaches, their impact on social cohesion and trust, and their role in fostering genuinely democratic, resilient energy systems, on energy community formation, and governance. This paper argues that a just and inclusive energy transition must begin by building energy literacy within the communities it seeks to serve. User-centred design holds the key to unlocking the energy saving potential of new domestic technologies [5]. The use of sustainable technologies and the inclusion of gamification features positively influence citizens to engage in more pro-environmental behaviours, which enhances their sense of empowerment; consequently, both pro-environmental behaviour and empowerment significantly increase citizens' intention to participate in local energy communities [6]. By embedding literacy and participation at the heart of energy initiatives, we can create more adaptable, resilient, and democratically grounded systems for the future.

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Changing behaviour in smartphone postal collection: comparing barrier reduction and commitment strategy in a field experiment.

Theme: instruments, interventions and evaluation of behaviour change and evolution in social practices in the field of energy and the environment

Sub-topics: contributions of multidisciplinary approaches to behaviour and social practices, Behavioural solutions in companies

“Academic contribution”

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Keywords: Behaviour change, Circular economy, E-waste collection, Commitment, Experimental method, Public policy

Extended abstract

Introduction

Changing consumer behaviour is important to advance the circular economy, especially in the management of electronic waste [1,2]. Despite rising public awareness, individuals still rarely engage in effective recycling or reusing behaviours, highlighting the need for rigorous behavioural science interventions to bridge the intention-behaviour gap.

In a 2022 literature review [3], we identified seven key behavioural barriers to smartphone collection: keeping the phone being the default and easier behaviour, lack of information about alternatives, mistrust towards recycling organisations, privacy concerns, perceived usefulness of old devices, object attachment, and low environmental concern. Based on these findings, we designed a field experiment to test two behavioural strategies aimed at increasing the return rate of unused phones in a postal collection campaign in the 19th arrondissement in Paris, along with a producer responsibility organisation specialised in e-waste (Ecologic). We tested two distinct approaches to increase collection rates, tackling the main barriers (lack of information and mistrust) as a baseline communication for the experiment, from which we derived two strategies. The first strategy was to target a major behavioural barrier (the privacy matter), providing participants with assistance to delete personal data before sending their old phone.

Our second strategy relied on commitment paradigm [4,5], consisting in giving the opportunity for participants to state whether they preferred their old phone to be recycled or reused.

Method

The field experiment was conducted in the 19th arrondissement of Paris in 2024, replicating and expanding a previous pilot conducted in the 14th arrondissement. Participants (N = 87 311 households, for approximately 180 000 inhabitants) received one of four printed flyers in their mailbox, each corresponding to a distinct experimental condition:



- A. **Control condition**, with persuasive arguments and standard information about the collection campaign and its stakeholders.
- B. **Data deletion assistance**, guiding participants to securely erase personal data from their phones before sending them.
- C. **Commitment paradigm**, providing participants with the opportunity to express their preference between recycling and reusing the phone they would send us, operationalised by circling the recycle or reuse logo on the envelope.
- D. **Data deletion assistance + commitment paradigm**, to complete the 2×2 design.

Along with one of the four possible flyers, participants received a prepaid secure envelope to return up to four phones. Flyers were randomly assigned at the building level (cluster randomisation), ensuring that all residents in each building received the same flyer version.

Results

From the 3,167 phones we received, 2,140 were smartphones and 1,024 basic phones. Apple (42%) and Samsung (26%) were the most frequently returned smartphone brands. Across all devices, 36% had screen damage, 25.3% failed to power on, and 14.5% were system locked. There was no statistically significant difference for those variables between the four conditions.

A log-linear regression model revealed that the commitment condition, prompting the participants to express their preference between recycling and reusing their phone, significantly outperformed the other groups:

- Control condition ($\beta = -0.137$, $p = .005$),
- Data deletion conditions ($\beta = -0.130$, $p = .008$),
- Data deletion + commitment ($\beta = -0.282$, $p < .001$), suggesting a possible interference effect.

These beta estimates correspond to relative reductions from 13% to 25% in collection rates, compared to the commitment condition. Table 1 shows the number of basic and smartphones returned by experimental condition. There was no statistical difference between the three other conditions.

	Basic phones	Smartphones	Total
Argument only (control)	295	498	793
Data deletion	357	430	787
Commitment	338	565	903
Data deletion + commitment	257	427	684
Total	1 247	1 920	3 167

Table 1. Number of basic phones and smartphones collected by experimental condition.

Conclusion

This study highlights three main takeaways.

First, targeting behavioural barriers in isolation may not always yield high impact, especially when the mechanisms behind these barriers are uncertain or context sensitive. The lack of knowledge regarding underlying causes of our choices and behaviours is a rationale of behavioural science [6–8]. Consequently, inquiring about individuals' reasons for non-compliance with a pro-attitudinal and socially desirable behaviour may yield justifications to alleviate cognitive dissonance and social pressure.



Second, relying on stable paradigms, such as commitment paradigms, social norms [9,10], or intention implementation [11], can provide consistent results, regardless of the behaviour, making interventions much more scalable and systematic.

Third, although data deletion assistance did not significantly increase returns, it improved the functional quality of collected smartphones by reducing lock-related issues, thereby improving reuse potential.

Policy makers and PROs should consider combining structural enablers with robust behavioural strategies to optimise both the quantity and quality of collected e-waste. Future research should continue exploring the dynamics between behavioural determinants and classical lever, to better inform large-scale sustainable behavioural change interventions and help closing the loop of the Circular Economy.

Potential applications of these strategies to other pro-environmental or energy-related behaviours will be discussed.

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Motivation vs. Means: The influence of financial capability on homeowners' insulation decisions

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy renovation, Home insulation, Stages of change, Motivation, Context

Extended abstract

INTRODUCTION

The building sector significantly contributes to global greenhouse gas emissions, making energy renovations crucial for meeting climate targets [1]. To boost renovations, the EU introduced policies like the Renovation Wave Strategy and the Energy Performance of Buildings Directive [2], [3]. However, renovation rates remain low, around 1% annually in Europe - far below the 3% needed to reach 2050 goals [4], [5], [6].

Affordability is widely recognised as a major barrier [7], [8], [9], [10], [11]. For instance, a study in Flanders found about half of homeowners cannot afford the 2050 renovation standards [12]. While previous research has separately explored financial capacity and motivation, little is known about how these factors interact - particularly how financial situation influences homeowners' motivation for energy renovations. To address this gap, we apply the Attitude-Behaviour-Context (ABC) model, which suggests that behaviour results from the interaction of attitudes and external factors [13]. The ABC model is a socio-economic theory that explains behaviour as a function of both attitudes and contextual factors. It proposes that the link between attitude and behaviour is context-dependent: when a behaviour is difficult, costly, or inconvenient, a positive attitude alone may not lead to the corresponding behaviour. In this study, we specifically examine the interaction between financial comfort (contextual factor) and homeowners' personal norms related to home insulation.



METHOD

This study is part of the European Horizon project HouseInc and uses a cross-sectional online survey from eight countries: Flanders (Belgium), Czech Republic, Estonia, Finland, Germany, Italy, Romania, and the UK. A total of 14,254 respondents were recruited via a market research agency with quotas for age, gender, and region. Lower-income households were oversampled for better representation. For this study, a subsample of 7,656 homeowners who had not recently insulated their homes was retained. All participants were 18 or older.

The outcome variable was the self-reported stage of change regarding insulation decisions, including four stages: (1) not in decision mode, (2) deciding what to do, (3) deciding how to do it, and (4) deciding how to implement [14]. Personal norms were measured using three Likert-scale items, adapted from Van der Werff and Steg [15]. Financial comfort was assessed on a 5-point Likert scale. We included biospheric values and climate worry as psychological covariates, and controlled for a set of sociodemographic and dwelling-related covariates: age, gender, education, income, employment status, construction year, renovation history, perceived EPC rating, and country of residence. A multinomial logistic regression with interaction terms was performed. Given the large sample size, a significance threshold of $p < 0.01$ was applied. This study was preregistered on OSF: <https://osf.io/f7e9j>

RESULTS

The sample included 4,818 participants (62.93%) who stated they do not plan to improve their dwelling's insulation within the next three years (stage 1). Another 1,609 (20.94%) planned improvements and intended to explore measures (stage 2). A further 603 (7.88%) had decided on specific measures (stage 3), and 626 (8.18%) had concrete implementation plans (stage 4).

Two series of multinomial logistic regressions were conducted to examine the factors associated with advancing to later stages of insulation decision-making, with stage 1 as reference. Model 1 evaluated the main effects, while model 2 includes the interaction between financial comfort and personal norms related to insulation.

As for the psychological covariates in model 1, climate worry showed a significant negative association only with stage 4 (OR = 0.79, $p = 0.007$), but no significant effect of biospheric values was found. As for the sociodemographic and dwelling-related covariates, age was negatively associated with advancing to any of the subsequent stages. Higher age reduced the odds of being in stage 2 (odds ratio (OR) = 0.98, $p < 0.001$), stage 3 (OR = 0.98, $p = 0.001$), and stage 4 (OR = 0.98, $p = 0.007$), indicating that older respondents were less likely to progress beyond not being in a decision mode. Gender showed no significant association across any of the stages. Being not employed was associated with a lower probability of being in stage 2 (OR = 0.51, $p < 0.001$) and stage 3 (OR = 0.46, $p = 0.006$) compared to those who were in paid employment. No significant effect of education and OECD equivalised income was found.

The construction date of the dwelling revealed that respondents living in dwellings built between 1971 and 2006 (OR = 0.58, $p = 0.008$) and those built from 2007 onwards (OR = 0.45, $p = 0.009$) had lower odds of being in stage 4 compared to those living in dwellings built before 1940.

Regarding renovation history, with 'No renovations' as a reference category, participants who had carried out renovations between 2005 and 2009 (OR = 2.13, $p = 0.008$) and between 2010 and 2014 (OR = 2.16, $p = 0.005$) had higher odds of being in stage 3. Additionally, renovations conducted from 2020 onwards were associated with a greater likelihood of being in stage 4 (OR

= 1.97, $p = 0.003$). A better energy performance certificate (EPC) was linked to reduced odds of being in stage 2 (OR = 0.86, $p < 0.001$), but not to later stages.

Country of residence also played a role. Respondents from Estonia (stage 2: OR = 1.76, $p = 0.006$; stage 3: OR = 3.70, $p < 0.001$; stage 4: OR = 2.59, $p = 0.002$) and Romania (stage 2: OR = 1.92, $p = 0.002$; stage 3: OR = 3.88, $p < 0.001$) were more likely to be in later stages of decision-making than those in Belgium.

Regarding the ABC related factors, personal norms (attitudinal factor) were strongly and consistently linked to more advanced stages of decision-making. Respondents with stronger personal norms had higher odds of being in stage 2 (OR = 2.66, $p < 0.001$), stage 3 (OR = 2.76, $p < 0.001$), and stage 4 (OR = 3.97, $p < 0.001$). Financial comfort (contextual factor) was associated with reduced odds of being in stage 2 (OR = 0.78, $p < 0.001$).

Our second model only differed through the inclusion of the interaction between personal norms, and financial comfort. We found no changes compared to Model 1, suggesting that the effect of personal norms on insulation decision-making is not influenced by the level of financial comfort, or vice versa, within this model. It is worth noting that, for stage 2, the interaction between financial comfort and pro-environmental personal norms reached a p -value of 0.04 (OR = 1.14), which would have been considered significant under a conventional 0.05 threshold.

CONCLUSION

The findings did not support the hypothesised interaction effect related to the ABC model: financial comfort did not significantly moderate the impact of personal norms regarding insulation on decision-making stages. Nonetheless, stronger personal norms related to insulation were associated with a greater likelihood of advancing to later stages in the decision process, underlining their importance in motivating homeowners to take action. Interestingly, financial comfort was negatively associated with the early “deciding what to do” stage, suggesting that those who feel more financially secure may be less inclined to engage at this point. Overall, while personal norms clearly support progress in insulation decisions, the financial context plays a more limited and somewhat counterintuitive role, underscoring the need for policies that separately address motivational and economic barriers.

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The importance of including societal change in energy system modelling

Theme 6, sub-topic 6a); Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Extended abstract

1. INTRODUCTION

Energy system models are a valuable tool to inform policymakers about possible energy futures and could assist in strategic planning. Though they show a methodological weakness as they primarily examine how changes in techno-economic-environmental input assumptions affect the energy system, while largely neglecting the influence of energy-relevant human behavior ¹. Yet, this is of crucial importance, as political targets for the energy transition are becoming increasingly ambitious, while conflicting societal dynamics often hinder the necessary developments. In contrast, societal change processes can also be drivers for the necessary transformation of the energy system ². Hence, it can be stated that the transformation of the energy system is a societal process ³ and it is therefore vital to systematically understand the power of societal processes for the future transformation of the energy system.

However, the integration of societal change processes is challenging, as these processes are typically represented in the form of qualitative scenario narratives, which must be translated into quantitative input data for use in energy system analysis. There is, however, a lack of “advanced conversion techniques for quantifying storyline elements” ⁴. This shortcoming is addressed in this paper through the development of the Energy Service Demand Translation Tool (ESDT-tool), which translates societal change processes into quantitative energy service demands including modal shifts. Subsequently, the systemic impact of those changing energy service demands on the energy system is examined within this research using an energy system model.

The exploratory analysis using the ESDT-tool, combined with a soft-link to the model TIMES-SEDOS focuses on Germany in the year 2050 and on the passenger mobility sector. This sector has been chosen for analysis as it is especially challenging to decarbonize ⁵ and social factors strongly influence individual decisions within this sector ⁶. The functionality of the tool in connection with the TIMES-SEDOS model is demonstrated using two contrasting scenarios of societal change.

2. RELEVANCE AND METHODOLOGICAL APPROACH

Although recent literature emphasizes the importance of integrating societal change into energy system analysis ^{7,8}, there is a lack of advanced and transparent methods for quantitatively



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translating such changes into model inputs. For instance, the Ariadne project assumes behavioral shifts in the transport sectors but lacks transparency in their quantification⁹. Similar gaps exist in other recent studies focusing on behavioural shifts in personal mobility^{10–12}. This research seeks to address this methodological gap.

This research introduces the ESDT-tool, developed to quantify changes in energy service demands and modal split driven by societal change. The tool uses consistent societal pathway scenarios from the GeNESE project, derived via literature review and Cross-Impact Balance (CIB) analysis (see for a detailed description Prehofer et al., forthcoming¹³). The ESDT-tool translates these qualitative scenarios into quantitative energy service demand assumptions using multiple linear regression (OLS). Historical data from German official statistics informs the regression models, and future projections are based on CIB-derived assumptions—including pathways not yet observed but anticipated. This approach ensures transparent, model-based estimates of future energy service demands as inputs for energy system models. In a second step, the quantified energy service demands are integrated into the TIMES-SEDOS model to study the effects of changing demands on the energy system. The model is a cost-optimizing, techno-economic, bottom-up framework that minimizes system costs under constraints across sectors^{14,15}. TIMES-SEDOS is built on open-source data from the SEDOS project¹⁶, enabling a transparent and reproducible analysis of energy futures¹⁷.

3. SCENARIO DESCRIPTION AND RESULTS

The selected consistent scenarios (see Table 1) explore different societal behavior patterns under varying climate impacts, while sharing common framework conditions: high population growth until 2050, urban living, and a general tendency toward using environmentally friendly transport. Further, work patterns are similar, with most work remaining on-site.

Table 7: Selected CIB-Scenarios

	Scenario 1: Moderate climate impact	Scenario 2: Dramatic climate impact
Population	90.5 Mio	90.5 Mio
Spatial dispersion	Increasing Urbanization	Increasing Urbanization
Modal split	Ecomobility	Ecomobility
Leisure behaviour	Service-oriented	Service-oriented
Work patters	On-site	On-site
GDP/cap	Substantial increase (65 T€ ₂₀₂₁ /cap)	Postgrowth (stagnation at 40.5 T€ ₂₀₂₁ / cap)
Remote work	Low	High
Consumption patterns	Luxurious	Sufficiency
Decarbonization (target year of climate neutrality)	Slow (2050)	Fast (2040)
Public sector investment	Low	Moderate
CO ₂ -Pricing	BAU	High
Climate change impact	Moderate	Dramatic

The key difference between the scenarios lies in the pressure to act. Scenario 1 assumes moderate climate impacts, low CO₂ pricing, slow decarbonization, and stable behavior. Scenario 2, by contrast, features dramatic impacts of climate change, high CO₂ prices, rapid decarbonization. This drives more sustainable lifestyles, including sufficiency-oriented mobility, reduced air travel, and a modal shift enabled by major rail expansion. Quantified inputs for the ESDT tool and regression models are provided in the Annex.

Applying the ESDT-tool for translating the scenarios into changes in energy service demands by transport mode results in higher energy service demand under moderate climate impact than under dramatic climate change (see Fig. 1). The differences are within a 10% range and the modal split significantly differs between Scenario 1 (motorized individual travel (MIT): 58%, rail:12%, local public: 11%, air:8%, bike & pedestrian: 11%) and Scenario 2 MIT: 55%, rail:15%, local public: 14%, air:4%, bike & pedestrian: 12%).

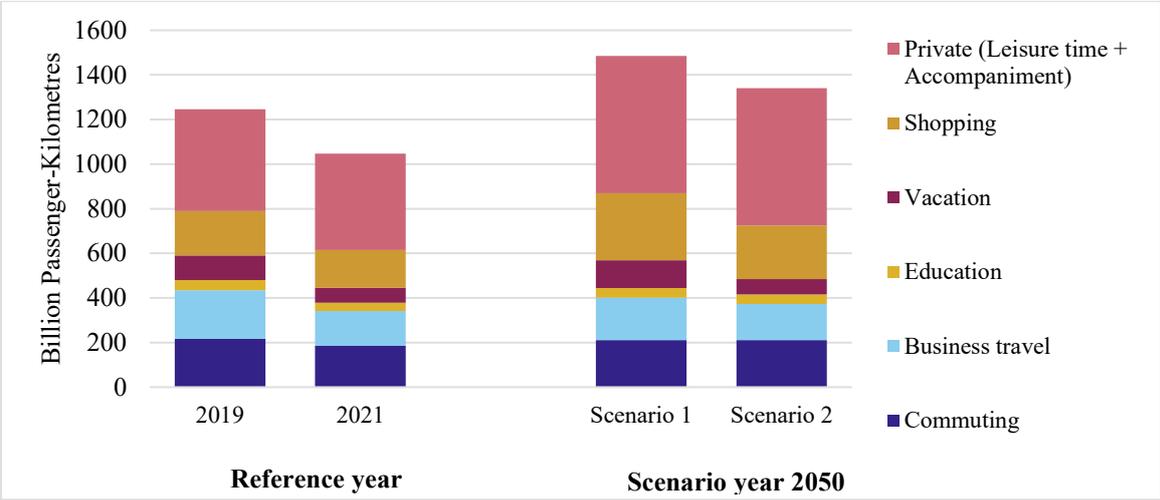


Figure 23 Energy service demands per scenario in 2050. Own illustration based on results from the ESDT-tool

In the second step of the analysis, the energy service demands by mode resulting from the ESDT-tool were used as inputs for the TIMES-SEDOS energy system model to examine the impact of societal change on the energy system. Assumptions about climate neutrality were set as framework conditions: the year 2050 for Scenario 1, and the year 2040, representing early decarbonization for Scenario 2. Results are plotted against the German projection report¹⁸ as reference.

The results (Figure 2) show that the decline in final energy demand between the two scenarios in 2050 amounts to 35%, primarily due to the different choices of transport modes. This indicates that a shift in final energy demand can be proportionally greater than the preceding change in energy service demand if a corresponding modal shift occurs.

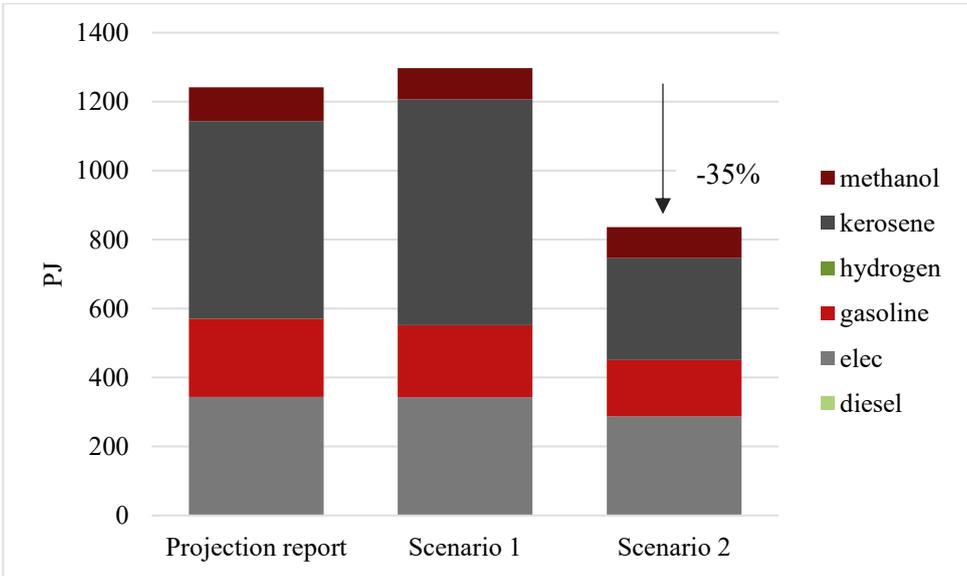


Figure 2 Final energy demand per scenario in 2050, own illustration based on results from the ESDT-tool and ¹⁸

4. DISCUSSION AND CONCLUSION

The results of the ESDT-tool analysis are consistent with the findings in the literature stating that behavioral measures can achieve a 10% reduction of personal mobility demand^{19,20}. This aligns with the results of Scenario 2, where a decline in air travel and a shift toward more sufficiency-oriented consumption lead to a decrease in energy service demand.

TIMES-SEDOS results likewise align with literature emphasizing the strong impact of modal shifts in passenger transport. ²¹for example identified a 30% reduction in final energy demand through mode shifts. Promoting sustainable modes can thus significantly support climate neutrality. Infrastructure, like the rail expansion in Scenario 2, is key, as it can shape transport behavior by defining the available options ²².In conclusion, politically set parameters such as the target year of climate neutrality and the infrastructure developments by the latter largely shape the context for more sustainable behavior.

On a methodological level, the presented expanded scenario space within this research demonstrates that integrating social change into energy system design is crucial for robust future assessments, which justifies the effort and further research needs to translate qualitative assumptions into quantitative inputs using advanced conversion methods.



ANNEX

Table 2: Composition of modes of transport.

Mode of transport	Description after Intraplan, Trimode, MWP, ETR 2024 (p.17)
	<i>Note: Included are transport services provided on the territory of Germany</i>
Motorized individual transport (MIT)	Motorised private transport (with cars including taxis and hire cars as well as motorcycles and mopeds)
Rail transport	Rail transport including suburban rail
Local public transport	Public road passenger transport, i.e. transport with buses (including long-distance buses), trams and underground trains
Air	Scheduled and charter air transport
Bike	-
Pedestrian	-

Table 3: Regression model results.

Model for Trip purpose	Number of observations with Cochrane-Orcutt estimator	adj. R2	F-statistic	Prob F-statistic
Commute	28	0.99	1.36E+04	6.98E-40
Education	21	1	2.97E+04	6.26E-34
Business	28	0.97	534.6	7.61E-22
Vacation	26	0.99	401.2	2.51E-17
Shopping	22	0.99	1.11E+04	5.15E-28
Leisure	26	0.97	331.7	3.28E-18

Note: Originally the data included 28 observation years. Since the data are time series data, they were analysed for autocorrelation (Durbin-Watson Test). Since autocorrelation occurred at a higher order, a Cochrane-Orcutt estimation was performed, resulting in a drop of observations.



Table 4: Regression models per trip purpose.

Commuting	
<i>Influencing pathway</i>	<i>Demographic change, Future work, Use of remote work, Commuting behavior, Spatial distribution of the population, Average weekly working hours</i>
Regression model ¹¹	$\text{Mobility Demand}_{\text{commuting}} = \beta_1 \times (\text{number of employed individuals}) + \beta_2 \times (\text{average frequency of commuting to work}) + \beta_3 \times (\text{average weekly working hours}) + \beta_4 \times \left(\frac{\text{average length of commute in kilometers}}{\text{rate of urbanization}} \right) + \varepsilon (1)$
Education	
<i>Influencing pathway</i>	<i>Commuting behavior, Spatial distribution of the population</i>
Regression model	$\text{Mobility Demand}_{\text{education}} = \beta_5 \times (\text{amount of people being in training}) + \beta_6 \times (\text{average length of journey for education purpose}) + \varepsilon (2)$
Business	
<i>Influencing pathway</i>	<i>Demographic change, Future work, Development of business meetings and business trips</i>
Regression model	$\text{Mobility Demand}_{\text{business travel}} = \beta_7 \times \left(\frac{\text{development of the amount of business meetings}}{\text{and business trips}} \right) + \beta_8 \times (\text{number of employed individuals}) + \varepsilon (3)$
Shopping	
<i>Influencing pathway</i>	<i>Demographic change, Consumption patterns, Spatial distribution of population, Commuting behaviour</i>
Regression model	$\text{Mobility Demand}_{\text{shopping}} = \beta_9 \times (\text{average private consumption expenditure}) + \beta_{10} \times (\text{number of consumers}) + \beta_{11} \times (\text{average distance to go shopping}) + \beta_{12} \times (\text{development of online shopping}) + \beta_{13} \times (\text{average weekly working hours}) + \beta_{14} \times (\text{frequency of commuting}) + \varepsilon (4)$
Vacation	
<i>Influencing pathway</i>	<i>Demographic change, Vacation behavior</i>
Regression model	$\text{Mobility Demand}_{\text{vacation}} = \beta_{15} \times \left(\frac{\text{number of holidaymakers}}{\text{number of holiday trips per holidaymaker}} \right) + \varepsilon (5)$
Leisure	
<i>Influencing pathway</i>	<i>Demographic change, Leisure activities, Average weekly working hours</i>
Regression model	$\text{Mobility Demand}_{\text{Leisure Time}} = \text{Adjustment Factor}_{\text{Leisure Activities}} \times \left(\beta_{16} \times (\text{average weekly working hours}) + \beta_{17} \times (\text{population size}) \right) + \varepsilon (6)$

¹¹ In the regression equations β is the regression coefficient and ε the error term.



Table 5. Translation of qualitative CIB assumptions into quantitative data to serve as input for the regression models of each trip purpose for the scenarios sc 1 and sc 2

Trip purpose	Relevant indicator for trip purpose	Descriptors comprising indicator	Unit	Sc1	Sc 2	Source
Commute	employed individuals	demographic change, future of work	millions	42.5	42.5	calculation based on Bundesinstitut für Bau-, Stadt- und Raumforschung (2024), Statistisches Bundesamt (2020), Statistisches Bundesamt (2022)
				16.7	16.7	calculation based on Nobis & Kuhnimhof (2018)
				4.5	4.5	calculation based on Kunze et al. (2021)
				29.2	29.2	calculation based on Allmendinger et al. (2024)
Education	amount of people being in training	demographic change	millions	1.461	1.461	calculation based on Kultusministerkonferenz (2023)
				0.84	0.84	calculation based on UN DESA (2018)
				7.15	7.15	calculation based on Nobis & Kuhnimhof (2018)
Business	employed individuals	demographic change, future of work	millions	42.5	42.5	calculation based on Bundesinstitut für Bau-, Stadt- und Raumforschung (2024),



Trip purpose	Relevant indicator for trip purpose	Descriptors comprising indicator	Unit	Sc1	Sc2	Source
Shopping	development of revenue in online shopping	development in online retail and delivery services	Billion €	124.0	88.6	calculation based on bevh (2025)
	average distance for shopping and errands	spatial distribution of the population	km	15.3	15.3	calculation based on Nobis & Kuhnhof (2018)
	number of consumers	demographic change	millions	75	75	calculation based on based on Bundesinstitut für Bau-, Stadt- und Raumforschung (2024)
	average private consumption expenditure	demographic change, consumption patterns and comfort behaviour	T€	24	18	calculation based on Statistisches Bundesamt (2023), Statistisches Bundesamt (Destatis), Wissenschaftszentrum Berlin für Sozialforschung (WZB), Bundesinstitut für Bevölkerungsforschung (2024)
Vacation	number of holidaymakers	demographic change, vacation behaviour	millions	65	41.3	calculation based on based on Bundesinstitut für Bau-, Stadt- und Raumforschung (2024), Statistisches Bundesamt (2022), FUR (2025a)
	number of holiday trips per holidaymaker	vacation behaviour	unit	1.3	1.1	calculation based on based on Bundesinstitut für Bau-, Stadt- und Raumforschung (2024)



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Addressing energy poverty for persons with disabilities: a policy tracking tool for inclusive transition in Mediterranean countries

Theme 2, sub-topic 2b), and Theme 1, sub-topic 1d)

☑ “Policy/practice contribution”

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Extended Abstract

Energy poverty is a multidimensional issue affecting vulnerable households that often struggle to access adequate, affordable, and reliable energy. Among the most affected groups are people with disabilities, who frequently require higher levels of energy consumption due to medical equipment, assistive technologies, and extended stays at home. Despite these higher needs, mainstream energy policies tend to overlook disability-specific challenges. Most support schemes are income-based and fail to account for the additional costs of living with a disability. This lack of knowledge and policy attention is a reflection of larger constraints in the effort to mitigate energy poverty.

To address this gap, a web-based analytical tool was developed to map and display national policies and financial measures related to energy poverty, with a specific emphasis on their accessibility and relevance for individuals with disabilities.. The analysis covers five countries: Greece, Cyprus, Italy, Spain, and France [1].

The Tracker includes the results of a comprehensive assessment and categorization of over 40 national-level schemes and support programs, regarding energy poverty mitigation and support to people with disabilities for the aforementioned countries. It aims to be a one-stop-shop of information, incorporating policy types ranging from electricity vouchers to photovoltaic (PV) adoption programs in urban environments [2].

Stakeholders can examine, filter, and compare policies using the tool's straightforward user interface, which aids in locating support gaps and accessibility obstacles. The goal is to enable municipalities, DPOs (Disabled People's Organizations), and policymakers to make inclusive, well-informed decisions [3].



The Tracker was co-developed through an iterative, participatory process involving stakeholders and experts to ensure that its structure, features, and usability reflect real-world needs and accessibility priorities

Policy relevance and integration

Findings from the underlying comparative research reinforce the need for such a tool. Despite the existence of general energy poverty alleviation schemes in all five countries, disability-specific dimensions are rarely considered. Most eligibility criteria are income-based, ignoring additional costs related to disability (e.g. medical equipment, temperature regulation, and in-home care). Moreover, application procedures are often complex or inaccessible [4].

Systemic fragmentation was found when more than 40 financial and regulatory measures were analyzed. For example, care allowances, mobility grants, and adaptation subsidies for individuals with disabilities are managed independently from energy schemes. These benefits only infrequently have indirect connections to energy consumption, like the "Independent Living Supplement" in France or the disability-related benefits provided in Greece through the national welfare and social solidarity agency. Because social protection and energy policy are not integrated, many vulnerable households are essentially invisible [5],[1].

To respond to these challenges, the Tracker offers a policy-mapping dashboard that allows users to explore inclusive measures across countries and governance levels. Rather than focusing solely on the existence of support schemes, the tool highlights aspects such as accessibility, disability relevance, and the degree of integration with broader social protection policies [6].

Justification of thematic selection

By concentrating on the unique vulnerabilities of individuals with disabilities, who are disproportionately impacted and frequently overlooked in policy frameworks, this work is in line with Theme 2b (Energy poverty and vulnerable consumers). Since it assesses the efficacy of financial and legal instruments' design, targeting, and implementation, it also fits with Theme 1d (Choice and Impact of Public Policies) [7]. Furthermore, the tool takes an intersectional approach, acknowledging that social and economic exclusion is exacerbated by disability and that customized, multi-sectoral solutions are necessary [8]. In order to meet the objectives of the European Green Deal and Sustainable Development Goal 7, which calls for universal access to affordable, sustainable energy, the Tracker assists national actors and municipalities in bridging the gaps between energy, social care, housing, and health [9].

Conclusion

The Energy Disability Policy Tracker is an innovative, evidence-based, and participatory instrument to support inclusive energy policymaking. It addresses a crucial policy gap in the nexus of energy poverty and disability. The tool makes vulnerable groups visible and allows for more focused, fair, and just policy responses through co-creation, field consultation, and comparative policy analysis. Future iterations will further enhance the tool's analytical capacity and expand its scope to facilitate institutional learning, policy alignment, and broader adoption across Europe.



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Bridging Individual and Social Identity Gaps: A Three-Level Identity Work Framework for Energy Transition

Theme 2, sub-topic a) / sub-topic c)

- “Academic contribution”
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Extended Abstract

Despite broad recognition of its urgency, the transition to sustainable energy continues to be a slow and complex process [1], [2]. While many stakeholders express strong intentions to support this transition, a range of constraints persistently hinder meaningful progress [3], [4]. To better understand these barriers, we conducted an interview study with key actors involved in a local energy transition initiative in a Dutch neighbourhood. The findings reveal multiple constraints, including conflicting stakeholder objectives, systemic and institutional barriers, and, perhaps most critically, identity-related challenges [5]. One example of an identity-related challenge involves differing expectations of the municipality's role. While municipal actors often view all stakeholders as equal and believe that an inclusive, collaborative approach best supports a sustainable energy transition, many other stakeholders expect municipalities to take a leading role [5]. As a result, municipalities are seen not as neutral facilitators, but as change agents expected to actively drive the transition [6]. While identity-related issues have received relatively limited attention in energy transition research, particularly when considering individual and social identity as distinct dimensions [7], [8], our study suggests that identity work is essential for bridging the gap between individual and social identity. This process plays a vital role in fostering collaboration, building trust, and enabling collective action. Understanding how individuals and organizations negotiate their roles and self-concepts within transition processes is fundamental for designing more inclusive and effective interventions.

Specifically, we conducted 18 interviews with key stakeholders, including municipal officials, housing corporations, owners' associations, sustainability foundations, network operators, and others involved in the local energy transition. The interviews revealed that identity-related challenges manifest in two key ways. First, while participating actors generally share some degree of values alignment on the importance of the energy transition and in broad lines wish for a systemic change, there is a lack of systematic articulation of a shared goal or vision. This absence impairs the development of a shared social identity within the energy transition space, which is essential for fostering cohesion, trust, and coordinated action. Second, this fragmentation and misalignment at the system level is mirrored at the actor level. There is often a lack of clarity regarding individual roles and responsibilities, leading to uncertainty



about how each actor contributes to the broader transition process. This ambiguity hampers collaboration and can contribute to inertia, as stakeholders struggle to position themselves meaningfully within the collective effort. Addressing these identity-related challenges is crucial for building the sense of joint ownership and aligned direction needed to accelerate progress.

To address these challenges, we argue that effective identity work is essential for bridging the gap between individual and social identity, enabling aligned intentions and coordinated action in the energy transition. We propose a three-level identity work framework to address these shortcomings and to support the process by guiding stakeholders through a structured reflection on shared values, clarified roles, and a common sense of purpose. The first level, *internal negotiation*, involves stakeholders engage in reflective processes to reconcile their own potentially competing values, priorities, and institutional logics that shape their engagement in the transition. This internal clarity forms the foundation for meaningful participation in broader collaborative efforts. The second level, *stakeholder negotiation*, focuses on interactions between actors. Here, identity work involves open dialogue and (re)ideation to surface and reshape divergent objectives, clarify expectations, and redefine roles in relation to one another. This process is essential for building mutual understanding and alignment across diverse stakeholder groups. Such as informational interventions can be a means to support value clarification and alignment for these two steps [9]. The third level, *collective identity reframing*, centres on the construction of a shared social identity, such as that of an “energy community” [10], [11]. Governmental bodies can facilitate this level of identity work through targeted policies and instruments [12]. This level of identity work fosters a sense of collective ownership, shared responsibility, and long-term commitment to the transition process. It encourages stakeholders to move beyond organizational boundaries and individual mandates to act as part of a cohesive, purpose-driven collective. Figure 1 below presents the framework outlining the three levels of identity work.

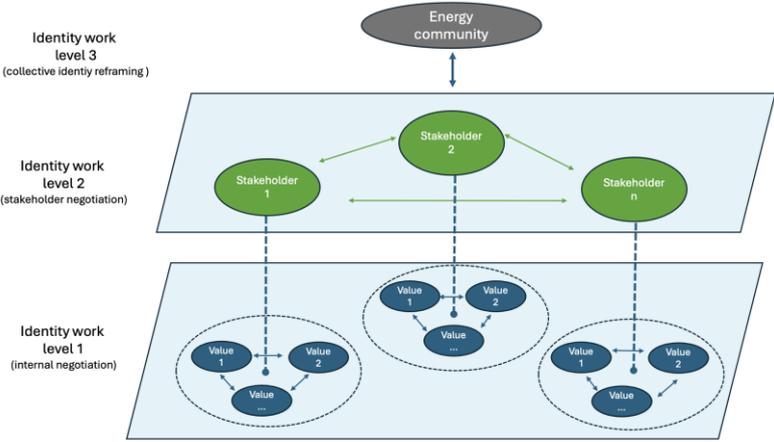


Figure 1: Three-level identity work framework

By introducing this framework, we emphasize identity work as a fundamental yet often underexplored aspect in energy transition efforts. This perspective shifts the prevailing focus from solely technological innovations and policy instruments to include the social and psychological processes that shape stakeholder behaviour and collaboration. Recognizing and addressing identity-related barriers can foster deeper cooperation among stakeholders, facilitate the alignment of diverse objectives, and support the formation of a shared sense of purpose. Ultimately, this can lead to a more cohesive and inclusive movement toward sustainable energy adoption. Our contribution is twofold: theoretically, we extend the discourse on identity work by situating it within the context of complex, multi-actor sustainability transitions; practically,

we offer a structured approach to navigating identity-related tensions and resistance, thereby supporting more effective engagement and implementation strategies within real-world transition processes.

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A typology of marginalized energy transition target groups through the lens of intersectionality

Theme 2, sub-topic 2b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Intersectionality, Energy justice, Energy equality, Energy equity, Cluster Analysis

Extended abstract

The energy transition, shaped by new technological and social innovations, is one of the major challenges of our time and offers significant potential for cities, municipalities, their residents, and businesses. However, these potentials are currently limited to a narrow segment of the population. Findings from recent research show that the energy transition has so far been predominantly driven by a specific demographic group – namely, “white, 35+, and male” [1]. For many people, active participation in or benefiting from the energy transition is simply not possible.

It is therefore crucial to involve users early in the development of new technologies and to consider the needs of the broader society, not only to advance technological innovations but also to ensure that they can be adopted and used by a broad segment of the population [2]. If a new technology is adopted only by a homogeneous group of early adopters, path dependencies may emerge that make later adjustments to diverse user needs more difficult [3],[4],[5]. This highlights the need to make the energy transition more inclusive. In particular, it is essential to consider existing heterogeneity, which – through the lens of intersectionality – is shaped by the intersection of diverse attributes and expressed in social inequalities, such as those related to gender, age, income, education, household characteristics, or social background. [6]. Considering intersectionality in the design of key technologies for the energy transition is key to promoting social justice; otherwise, marginalized groups risk being disadvantaged.

Gender alone already plays a significant role in how people interact with energy. The key technology *smart home* is more frequently used by employed men up to the age of 54 with higher levels of education. The lowest usage is documented among individuals who are exclusively responsible for household duties or are retired [7]. Furthermore, such systems



are often programmed based on a "male" learning style [8]. [9] point out that women, particularly those in lower socioeconomic strata, may face additional barriers to adopting smart home technologies due to traditional gender roles and household responsibilities.

In the context of the key technology *electromobility*, [10] show that there are significant gender differences in the use of (electric) vehicles. Men are more likely than women to own and use electric cars, tend to drive longer distances, and rely less on public transportation. Additionally, the "user experience" of (electric) cars is often tailored to men [11]. The review study by [12] identified demographic factors that influence electric vehicle acceptance behavior: men generally show a higher tendency to adopt electric vehicles; younger and middle-aged individuals, as well as those with higher income and education levels, demonstrate greater usage intentions. With respect to household characteristics, a higher number of vehicles in a household increases the likelihood of adopting electric cars.

However, gender-related differences are only one aspect of a multifaceted problem that becomes particularly evident in the key technology of *energy communities* [13]. The meta-analysis by [14] shows that individuals with higher income and education levels are significantly more likely to participate in an energy community. Moreover, people who own property are more frequently targeted by this key technology.

The current state of knowledge thus suggests that, for the key technologies *smart home*, *electromobility*, and *energy communities*, there are fundamental differences among target groups in terms of usage, access, and orientation of the technologies. In this paper, the overarching goal is to identify usage barriers posed by these key technologies with regard to social justice and intersectionality to ensure an inclusive technology development.

Therefore, a comprehensive quantitative survey is currently set up to uncover intersectional differences regarding user needs, attitudes, usage intentions, adoption, and actual use. This reveals barriers that prevent certain user groups from adopting and utilizing the key technologies smart homes, electromobility, and energy communities.

Therefore, a quantitative, nationwide survey (n~3000) is being designed, based on evidence-based indicators for identifying specific actions and motivations. This survey will assess behaviors and perceptions related to access to and use of the key technologies. The identified practices are intended to capture interactions between individuals and offerings of the key technologies, allowing for insights into both adopters and non-adopters. The survey is exploratory in nature and conducted in Austria, aiming to derive hypotheses regarding potential gender and intersectionality effects in the key technologies. Data analysis will be conducted using exploratory statistical methods such as cluster analysis.

Data collection and analysis will take place during the summer, ensuring that results are available in time for the conference and reflect the most up-to-date findings. The timely publication of results enables a current and well-informed discussion within the framework of the conference, which serves as an important consultation and participation measure for subsequent steps. This ensures effective feedback to relevant stakeholders to advance technological innovations such that they can be adopted and used by a broad segment of the population.

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Power of cities to act for cycle logistics

Theme 1. Instruments, interventions and evaluation of behaviour change and evolution in social practices in the field of energy and the environment, sub-topic 1d) Choice and impact of public policies

“Academic contribution”

“Policy/practice contribution”

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Keywords: Cycle logistics, cities, action levers, cargo bike

Extended abstract

Local authorities have considerable room for maneuver when it comes to supporting the local development of professional cargo bike uses, both in terms of land-use planning and support for economic players.

To help them, Boîtes à Vélo - France has published a [guide for them](https://lesboitesavelo.org/collectivites/) (<https://lesboitesavelo.org/collectivites/>). Produced with the support of the French Ministry of Transport, the guide aims not only to enhance local authorities' knowledge of professional cycle logistics, but also to inform them of all the available levers for action, and provide keys for prioritizing actions to be carried out according to the specific features of each territory. It is a toolbox for technicians and elected representatives wishing to take advantage of this virtuous mobility solution.

As part of the work on this guide, a research group from the Université Gustave Eiffel was commissioned to analyze and compare the implementation of different public action levers in terms of cost/benefit ratio on the development of cyclologistics activities and, more specifically, the distribution of 5 kg parcels. This research project has led to the design of a tool for modeling parcel distribution scenarios based on a number of parameters:

Type of delivery vehicle

- Bike-cargo with micro-hub
- Bike-cargo without micro-hub
- LCV diesel
- LCV electric
- Small HGV diesel
- Small HGV electric

Area density

- 200 inhab/km²
- 750 inhab/km²
- 2,500 inhab/km²



- 15,000 inhab/km²

The results of this study have been incorporated into analyses of the perceived impact and feasibility of the action levers included in the scope of the study, in particular :

- Long-term planning of traffic calming zones (delivery time zones, limited traffic zones, pedestrianization, etc.).), corresponding in this model to a 25% reduction in the speed of Light Commercial Vehicles (LCVs) and Heavy Goods Vehicles (HGVs)
- Extending the cycle network (continuous, secure, permeable, signposted) in line with anticipated traffic flows, and in a way that is adapted to the size of cargo bikes, corresponding in this model to a 20% increase in the speed of cycles and a 15% reduction in distances covered by cargo bikes.
- Securing and making available public land for bicycle businesses (conventional warehouses, requalified public parking lots, sites in transition, parking spaces for cyclologistics operations), illustrated by the payment of a subsidy of up to 50% of micro-hub rents.

The impact of the levers analyzed corresponds to their influence on the Total Cost of Ownership* of the cyclologistics solution based on the use of a micro-hub compared with the costs of solutions with other modes of transport over a 5-year period, for parcel delivery, in different contexts of population density.



Sufficiency policies in the Global South: What predicts support for a public transport subsidy in Mumbai and Delhi?

Theme 3, sub-topic 3a) OR Theme 5, sub-topic 5d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: India, Sufficiency, Policy Support, Transport, Carbon Footprint

Extended abstract

Scope and objective

The transport sector is one of the major emitters around the globe [1]. The carbon footprint based on transportation differs between countries, between the global north and the global south, between urban and rural areas and between various social groups. The same may apply for the support of sufficiency policies in the transport sector. To reduce carbon emissions and simultaneously contribute to societal wellbeing, sufficiency policies and their support are key. Especially in areas with high carbon footprints regarding transportation, a shift to sustainable transport is necessary and may be enhanced by related policies.

For this paper, we use the definition of sufficiency from the European Horizon project FULFILL. Hence, we define sufficiency as creating the social, infrastructural, and regulatory conditions for changing individual and collective lifestyles in a way that reduces energy demand and greenhouse gas emissions to remain within planetary boundaries and simultaneously contributing to societal wellbeing [2].

Due to the global need to reduce CO₂ emissions from transport and to identify avenues for sustainable change, we aim to look into predictors of transportation policy support in India. Specifically, the objective of this paper is to present levels and differences among Indian citizens regarding support of a sufficiency policy. Our research questions are (1) to what extent are sufficiency policies in the transport sector supported by the population in India and (2) what factors predict the (lack of) support of sufficiency policies. To examine these two research questions, we used a case, i.e., we selected two major cities in India and one sufficiency policy



in the transport sector. Further details on the study's design are presented in the following methodology section.

Methodology

The quantitative data collection took place between April and May 2024 as part of the European Horizon project FULFILL. The project aimed to determine the extent to which people are living sufficiently and to examine what may support individuals, what challenges they face and what are potential barriers to overcome for living sufficiently in daily life.

We selected two major cities in India due to various reasons: For instance, we aimed to collect data in the Global South but to limit the vast diversity in India, we focused on two megacities, namely Mumbai and Delhi. Moreover, the specific cities were selected based on their location and to keep some variety regarding social and climatic factors. Delhi is located in the North of India (without a coastal line). It is a state city and the capital of India; hence, it does not have high poverty rates. In contrast, Mumbai is located on the Arabian Sea in the West of India with a very humid and hot climate and a medium poverty rate [3].

Data was collected by a market research institute which conducted face-to-face interviews to achieve a representative sample in both major cities. The survey contained several parts: for instance, one part focused on participants' carbon footprint, another one asked participants to what extent they support various sufficiency policies. One of these sufficiency policies will be the focus of the present paper. Based on the survey data from about 1000 participants from Delhi ($n = 494$) and Mumbai ($n = 483$), we analyze the predictors of support for a sufficiency policy in Indian megacities. Specifically, we asked respondents to rate perceived justice, personal affectedness, and acceptability on a five-point Likert scale to a sufficiency policy. The selected and presented sufficiency policy was the result of a group discussion with three experts who were born or lived in India. The policy for this paper is a subsidized ticket for public transport in Mumbai and Delhi, respectively, that was presented to the participants as part of the face-to-face interview.

Results

To present descriptive statistics of support of the sufficiency policy, we calculated one policy support index (including the three questions on perceived justice, personal affectedness and acceptability; Cronbach's alpha in Mumbai = .82 and in Delhi = .92). The mean of the policy support differs between the two megacities (see Figure 1). In Mumbai, the support is slightly above the scale's midpoint with $M = 3.83$ ($SD = 0.56$), whereas in Delhi, the support is significantly higher than in Mumbai with $M = 4.23$ ($SD = 0.52$). This difference is statistically significant, $t(975) = -11.30$, $p < .001$, 95%CI [-0.46; -0.33].



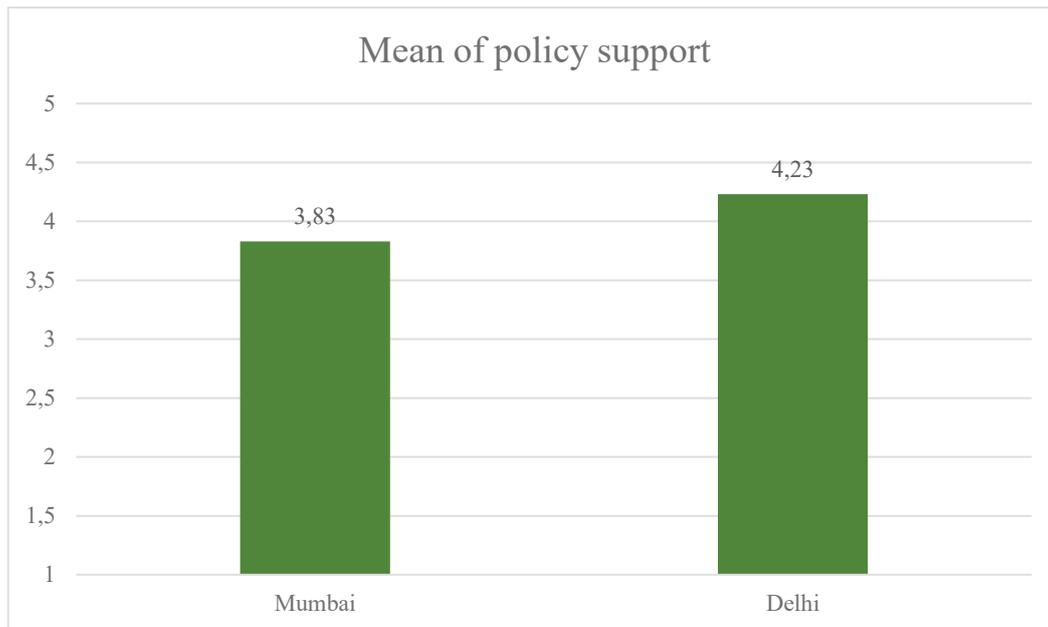


Figure 1. Average support of the public transport subsidy in Mumbai and Delhi with possible answers ranging from 1 to 5 showing a statistically significant difference.

Moreover, we performed two regression analyses – one for Mumbai and one for Delhi – to analyze what predicts support of the sufficiency policy, i.e. the public transport subsidy. As predicting variables, we included socio-demographic variables (gender, age, having children or not, subjective income), transport variables (having a car and two-wheeler in the household, regular use of public transport) and sufficiency-related variables (sufficiency orientation and respondent’s carbon footprint). Results are presented in Table 1 and indicate differences between the cities. In Mumbai, support of the reduced price of public transport is explained by three variables: Policy support is higher if respondents are sufficiency-orientated, if they have no two-wheelers in their household and if they have no children. In Delhi, results are similar but also show differences. Specifically, in Delhi, policy support is related to four variables: respondents who regularly use public transport, who have two-wheelers in their household, who have lower income (subjectively) and a higher sufficiency orientation support the public transport subsidy more than their counterparts. Notably, the variables in Delhi explain 27% of the variation in policy support, whereas in Mumbai, only 4% are explained. The result regarding public transport in Delhi is intuitive, the variation in results regarding having a two-wheeler in the household requires further examination.

	Mumbai	Delhi
gender	beta = -.05, p = .308	beta = .03, p = .495
age	beta = -.01, p = .920	beta = -.05, p = .232
children (1 = yes)	beta = -.10, p = .033	beta = -.04, p = .331
income (subjective)	beta = .07, p = .140	beta = -.14, p = .003
no car (1 = yes)	beta = .02, p = .668	beta = -.04, p = .436
no two-wheeler (1 = yes)	beta = .14, p = .007	beta = -.35, p < .001
public transport (1 = regular use)	beta = -.04, p = .409	beta = .27, p < .001
sufficiency orientation	beta = .15, p = .001	beta = -.14, p = .001
carbon footprint	beta = .06, p = .223	beta = .06, p = .292
Adjusted R ²	0.044	0.269
	F(9, 461) = 3.40, p < .001	F(9, 481) = 21.06, p < .001

Table 1. Results of the regression analyses indicating predictors of policy support.

Conclusions

The present paper aimed to examine the support of a sufficiency policy in the transport sector from a perspective of the Global South; hence, we presented results from face-to-face interviews of about 1000 respondents from two major cities in India (Mumbai and Delhi). We find a significant difference in support of the sufficiency policy between the cities. Specifically, the support of a public transport subsidy is larger in Delhi than in Mumbai. Further regression analyses reveal that socio-demographic (i.e., income and having children) as well as transport-related (i.e., having two-wheelers and regular use of public transport) and sufficiency-related (i.e., sufficiency orientation) factors predict policy support and should be considered when promoting sufficiency policies. Hence, we recommend a detailed communication strategy to inform various groups about sufficiency policies and to reach a large share of the wider public. In addition, our analyses show that regional features should be considered when introducing sufficiency policy. A limitation of the study is that the presented sufficiency policy is a soft measure which usually leads to higher levels of support than more restrictive policy measures [4]. Since the latter is usually more successful in reducing CO₂ emissions (than soft policy measures), the comparison of the presented results to policy support of more restrictive policy measures may be discussed.

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Electric vehicle smart charging: consumer behaviours and message development

3) Acceptability and ownership of energy and environmental policies, b) Stakeholder and public acceptability and ownership of low-carbon projects and technologies

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Behaviour, flexibility, demand response, electric vehicles, transport, fleet

Extended abstract

Introduction

As the number of electric vehicles (EVs) increases in the U.K., it has become clear that uncoordinated charging could strain the electricity grid, especially during times of peak demand. With advancements in technology and the proliferation of smart meters, the concept of dynamic smart charging has emerged. This type of charging allows for real-time adjustments to charging patterns based on grid conditions, renewable energy availability, and electricity prices. From an end user perspective, smart charging offers EV drivers a more cost-effective way to charge their vehicles, by taking advantage of dynamic charging schedules and charging when energy demand is low and/or availability is high. Energy Saving Trust was commissioned by the Department of Energy Security and Net Zero to conduct research to explore the barriers and levers for smart charging amongst both consumers and fleet managers, and to develop and test messages to help build consumer awareness and encourage uptake of smart charging.

Method

The objective for the first phase of research was to understand UK consumers’ and fleet managers’ knowledge and behaviour around smart charging. We conducted a rapid evidence assessment, followed by 30 qualitative interviews with current and prospective EV drivers, and fleet managers who had either switched some of their vehicles to EVs or were planning to.

In the second phase of the research, we conducted 6 co-design focus groups to develop a set of guiding principles for message development to promote smart charging.

Key findings

Understanding of, and attitudes towards, smart charging



Understanding of smart charging terminology was mixed, with some misconceptions around the phrase ‘smart charging’. However, when explained, participants understood and were familiar with the concept. Discussion of different types of tariffs helped to clarify the idea of charging while demand was low, or when supply was in excess.

Overall, attitudes towards smart charging were positive; with participants identifying that cost savings and environmental benefits were worthwhile. A small minority were more sceptical of smart technology, including smart meters, which extended to negative opinions of smart charging.

Different tariff options were discussed, with *time of use tariffs* (where rates are cheaper during certain hours, particularly overnight) being well-known and perceived positively. *Dynamic tariffs* (where the supplier takes control of the charging schedule) were less well known by research participants. Participants were generally not against idea of the supplier having control of the charging, (though some had reservations) as long as they were confident that they would have enough charge when they needed it.

Current behaviour, levers and barriers

Smart charging was widely used by domestic participants who charged at home; with charging overnight on time-of-use tariffs the most common. Prospective owners were also planning to smart charge; as cost saving was a key motivation for buying an EV and they wanted to maximise this. Participants also noted that environmental benefits and convenience were levers to smart charging. The main barrier was habit; participants sometimes forgot to plug the vehicle in, leading to use of the override function or public charging facilities.

Smart charging in the workplace was not widely used, due to lack of chargepoint functionality (research suggests only around 12% of those who charge at work are able to schedule their own charging¹²), timing of shifts and logistics of number of cars to chargepoints.

A number of fleet managers perceived that smart charging would not work with their schedules; stating that vehicles were not static for long enough to charge slowly; or that they were only at depots during peak grid hours. Fleets where the drivers took the vehicles home at the end of shifts, might have had the potential to smart charge, but fleet managers were reticent to interfere with what tariffs the drivers should be on, and noted that many did not have off-street parking.

Fleet managers were motivated by cost, so there is potential to leverage this benefit, along with the benefit of smart charging to the environment and thus meeting ESG (environmental, social, and governance) targets or net zero policy goals.

Consumer needs

Key needs to enable smart charging behaviour for the consumer groups were:

- Cheap prices
- Clear information provision on how it works
- Confidence about reliability (knowing they would have enough charge for when they need it), and convenience (not adding extra “burden” to their charging routine). This was especially true for prospective drivers (those who were considering the purchase of their first EV), who needed more assurance that they would not be left without adequate range.

For **fleet managers**, other needs were:

¹² Electric Vehicle Smart Chargepoint Survey 2022 (publishing.service.gov.uk)



- Efficiency (ensuring time was not wasted in the charging process)
- Reliability (knowing the vehicles would have enough charge to complete a shift).
- Support understanding how to overcome logistical difficulties

Phase 2: Message development

Six focus groups were conducted to test various messages across five themes, which were developed after Phase 1; based on user needs, barriers and levers.

- Messages explaining “how smart charging works ” were essential for understanding, which allowed participants to engage better with the subsequent messages. Presenting different tariff options helped aid understanding, and participants found this to be a key area where they would want more information on which tariff might suit them best.
- Messages around cost savings were motivational, and relative savings compared to non-smart charging were more effective than giving absolute figures, which were met with some scepticism.
- Messages highlighting environmental benefits were motivating, especially if combined with cost-saving messages (i.e. a ‘win-win’).
- Messages highlighting the ease and reliability of smart charging, including having enough charge for emergencies, were key for reassuring participants that their needs would be met.
- Messages that were too long, and messages with fluffy or “cheesy” language were not as well received. Participants found having a large block of text intimidating and found messages that were broken up by bullet points easier to digest.

Conclusions and recommendations

Smart charging as a concept was generally well supported by participants across all groups, although more difficult to action in workplace and fleet settings. The main misconceptions around smart charging stemmed from lack of understanding of the principles and technology, leading participants to worry about the effort involved and the reliability of smart charging. As such, messages highlighting the ease and convenience were well received. Previous research¹³ has shown that the greater the understanding of smart charging, the greater the appeal, which was also demonstrated during our message testing focus groups.

Energy suppliers were seen to be the most effective messenger, as tariffs were seen as an integral part of the smart charging process. Other trusted messengers would include government, independent advice organisations and comparison websites, as well as trusted friends and family and trusted online forums.

There is potential to maximise smart charging amongst fleets, where current levels of smart charging were found to be low. As fleets operate so differently, providing a range of advice and options for different types of fleets could be effective, whilst also highlighting the cost benefits and reassuring fleet managers that smart charging is easy and reliable. Case studies showing how smart charging could work for their specific fleet type would be useful to increase understanding of the different types of smart charging and could empower fleet managers to explore the options.

¹³ <https://delta.lcp.com/podcasts/smart-ev-charging/>



The Energy Behaviour Forum

Theme 1, sub-topic 1a) 1d) 1e), Theme 2, sub-topic 1a) 1c) 1d)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Behavioural campaigns, Local actors, Knowledge sharing, Capacity training, Digital platform

Extended abstract: The Energy Behaviour Forum [1] supports local and regional authorities on strong consumer behaviour regarding energy efficiency. DG Energy initiated this EU-wide project in spring 2025, involving 13 partner organizations coordinated by VITO, with activities planned to run through winter 2027. Behavioural measures have long been part of EU and national energy-saving strategies, with various initiatives supporting local and regional implementation. In recent years, behaviour change has gained stronger recognition as essential to reducing energy use to sustainable levels.

The Energy Behaviour Forum will serve as a knowledge sharing platform where local and regional authorities can exchange experiences related to energy efficiency projects and awareness campaigns. It will provide tools, good practices and capacity training for local and regional authorities to build effective short-term, medium-term, and long-term strategies, initiatives, and projects. These initiatives specifically target the engagement with citizens and private sector stakeholders to boost energy efficient behaviour and thus overall energy efficiency. The platform is developed in close cooperation with both local and regional authorities as well as behavioural and energy efficiency experts. The figure below shows the various types of hands-on and interactive support provided by the Energy Behaviour Forum.



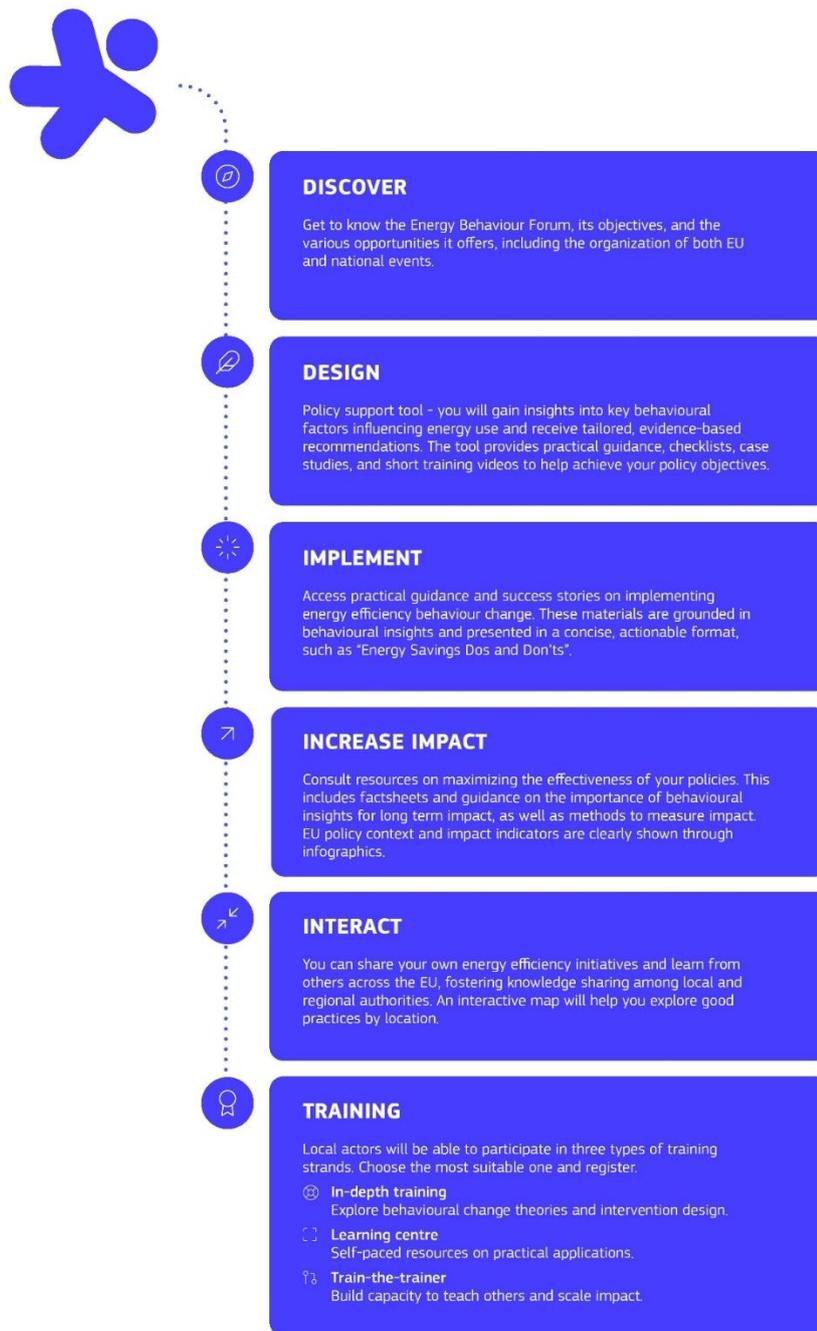


Figure 1: What can users expect from the Energy Behaviour Forum?

Specific expert guidance available for users

Behavioural insights are critical in understanding the underlying factors that influence energy consumption and the potential for behavioural measures to enhance energy efficiency. These insights delve into the psychological, social, and contextual factors that drive energy-related behaviours [2]. By understanding barriers such as ingrained habits, misaligned incentives, and socio-cultural norms, and identifying levers—specific strategies or stimuli that promote energy-saving actions—more effective energy-saving campaigns can be designed [3-4].

Conducting impact assessments for these campaigns is essential to measure their effectiveness. This involves defining clear campaign objectives, collecting baseline data, and using metrics like kilowatt-hours saved, reduced carbon emissions, and cost savings for



quantitative evaluation. Integrating control groups and continuous monitoring helps track the impact over time, considering external factors such as weather and economic conditions [5]. Ensuring the long-term sustainability of behavioural changes is another critical aspect. While behavioural interventions can initiate short-term shifts in energy consumption, maintaining these changes requires addressing factors like the "rebound effect," where individuals revert to old habits over time. Reinforcement mechanisms are necessary to sustain desired behaviours, as short-term incentives or reminders may lack the longevity needed for lasting impact [6]. Evaluating the long-term effects involves rigorous methodologies, to provide reliable evidence of success.

Despite the promising advancements in behavioural insights, there are notable gaps in the existing case studies and interventions from which local and regional authorities can learn [7]. For instance, many collections are unsystematic and lack comprehensive coverage across different countries. Additionally, there is often a lack of detailed information or analysis of the behavioural aspects, limiting opportunities for learning and knowledge transfer. Practical limitations such as language barriers and difficulty in searching through long lists of initiatives also hinder the effectiveness of these repositories [8].

Interactive trainings and tools on boosting energy savings behaviour

Recognizing these challenges, the Energy Behaviour Forum aims to bridge these gaps by offering interactive trainings and tools on boosting energy savings behaviour. Starting from these needs and behavioural insights, the knowledge sharing hub will feature EU-wide case studies, an interactive policy support tool, next to guidance documents, as shown in *Figure 1*. It promotes knowledge exchange, ensuring users can share experiences and access up-to-date information. The training hub offers online capacity-building materials and courses for addressing local and regional behaviour change challenges. The communications hub provides information about promotional events and meetings in their country, helping stakeholders stay connected with ongoing projects and the Energy Behaviour Forum's efforts. Hereto, stakeholders can become member of the Friends of the Energy Behaviour Forum offering networking opportunities, access to exclusive information, and promotional support for initiatives.

The Energy Behaviour Forum will offer participants tools and knowledge to implement behavioural insights effectively. Through interactive trainings, case studies, and short guidances, participants will learn how to design, measure, and sustain energy-saving initiatives in their local contexts. Local actors and other stakeholders will be able to participate in three types of training strands, namely '*in-depth training*', '*learning centre*', and '*train-the-trainer*' strand. The 'in-depth training' component will serve as a platform for selected participants to engage in peer learning, gain valuable insights, and acquire practical tools for designing measures that promote energy efficiency behaviour. These participants will also act as mentors or supporters – often referred to as '*replication actors*' - to assist other local and regional authorities with similar initiatives. On the other hand, the '*learning centre*' segment offers flexible, self-paced learning through a Massive Open Online Course (MOOC) covering the fundamentals of behavioural change activities. Lastly, the '*train-the-trainer*' component is designed to enhance the knowledge of experts in the field of behavioural science in energy efficiency, such as competence centres and behavioural teams supporting local and regional authorities' work.

Participants will gain practical guidance and benefit from best practices shared through the policy and knowledge-sharing tool. Guest speakers and trainers will lead discussions on lessons learned from current initiatives and offer insights from behavioural science in the



field of energy efficiency. Training sessions and workshops will be scheduled to align with relevant EU-wide and national events whenever possible. These events will also help promote the programme and attract participants from across all 27 EU Member States. To support this, the Energy Behaviour Forum will coordinate a range of promotional and engagement activities, making it easy for local stakeholders to discover and access our training opportunities.

In short, the Energy Behaviour Forum offers tailored trainings and materials from across EU countries, including guidance on designing, implementing, and monitoring energy-saving campaigns effectively.

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Sunny, Flexible or Fast? Flexible Charging of Electric Vehicles in Public

Theme 1, sub-topic 1b) Behavioural solutions in companies

“Academic contribution”

“Policy/practice contribution”

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Keywords: Electric vehicles, Public charging, Flexible charging, Energy design

1. INTRODUCTION

Road transportation accounts for approximately 16% of global energy-related CO₂ emissions, and electric vehicles (EVs) are one alternative with less impact [1]. However, EV charging can impose significant peak loads on already stressed distribution grids [2,3], and integrating renewable energy sources, often intermittent, adds further complexity. Flexible charging, which involves aligning EV charging with periods of high electricity production or low demand, has been proposed as a solution. It may also alleviate capacity shortages in transmission networks [4].

While flexible charging at home has been extensively studied [5,6], public charging remains underexplored. This is critical, as not all EV users have access to private chargers or park at home during the day, when solar generation typically peaks. Public charging includes both urgent charging (e.g., during long-distance travel) [7] and destination charging [8].

Beyond technical feasibility, user acceptance and behaviour are key to the success of flexible public charging. This study presents a field trial involving a custom-designed app and pricing model aimed at enabling and encouraging flexible public EV charging. The objective was to explore how users respond to a digital solution that aligns charging with electricity supply conditions.

2. DESIGN OF APP AND PRICE MODEL

The design of the app for flexible charging was build on previously performed interviews [9] about flexible charging at home and in public, previous studies of flexible charging in public [e.g. 10] and a benchmark of existing charging solutions for home charging and charging in public. These insights were compiled into the following design requirements:

- adaptable to **different charging scenarios** - **easy to understand** for users
- provide some sort of **predictability** for users
- **easy to use**
- perceived as **fair**



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- make flexible charging **meaningful**
- **bold** enough to challenge the current ideas about flexible EV charging
- have a **V2G-compatible logic**

The design and development of the test app followed an iterative process, incorporating user testing throughout. The design was created with the intention to be able to be used by municipal parking companies, and the design process included feedback from this company as well. The final version (see Figure 1) featured three charging modes, each with a distinct price. In Sunny mode (€0.04/kWh), charging occurred only when local solar power was available. In Flexible mode (€0.13/kWh), charging was allowed only when the local grid was not under strain. In Fast mode (€0.40/kWh), charging was guaranteed regardless of conditions. Although payment functionality was not implemented, each registered user received a preloaded account with €45. The app also displayed real-time and three-hour forecasts for solar power availability and grid load.

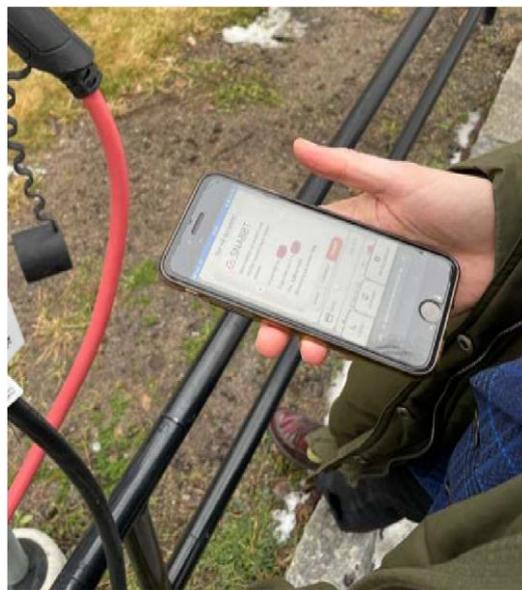


Figure 1a. The app used in the trial.

3. TEST OF THE APP

The app was tested over three winter months at a public charger with two charging spots located on the university campus in Uppsala, Sweden (see Figure 2). Access was open, and 149 users registered accounts, each completing between one and 70 charging sessions. The collected data were analysed descriptively and to identify potential correlations.





Figure 2. The public charger used in the trial.

Fast mode was the most frequently selected charging option during the trial (see Figure 3) and had a significantly longer average session duration compared to other modes. This difference was statistically significant, indicating a correlation between charging mode and session length. Charging mode choice also correlated with solar power availability and local grid load, suggesting that users may have opted for the lower-cost Solar or Flexible modes only when confident their vehicle would receive at least some charge.

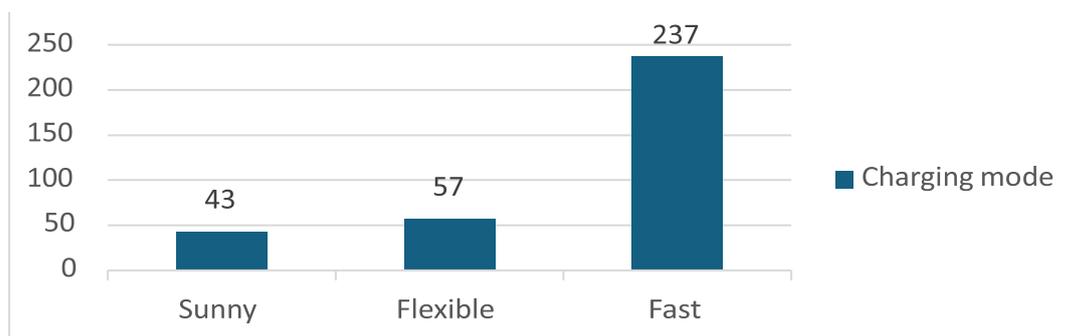


Figure 3. Frequency of charging options during the trial.

4. DISCUSSION AND CONCLUSION

The predominance of Fast charging mode in this study could not be definitively explained, but several plausible factors emerge from the data. One key observation is that Fast mode was frequently selected when power availability was low, suggesting that users preferred to ensure at least minimal charging upon plug-in. This behavior aligns with typical user expectations, as connecting a vehicle without receiving any charge is unfamiliar and may not align with established charging routines. Moreover, participants in this trial did not incur actual costs for charging, which may have influenced their willingness to experiment with different modes.

Another contributing factor may be the perceived scarcity of charging infrastructure. Many EV drivers consider it unacceptable to occupy a charger without actively charging, especially when stations are limited. The two chargers used in this trial were often occupied, potentially reinforcing a reluctance to use Sunny or Flexible modes when they did not immediately deliver power.

Additionally, some users may have misinterpreted the functionality of Sunny or Flexible modes, assuming they were malfunctioning when no power was delivered—an understandable assumption given the common experience of encountering faulty chargers.

Interestingly, the data also suggest “gaming” of charging: Flexible mode was more frequently used when power availability was high, and Sunny mode when solar availability was high. This indicates that users may have attempted to optimise charging costs while minimising the risk of leaving with an insufficient state-of-charge.

Despite the dominance of Fast mode, the use of Sunny and Flexible modes, despite the absence of direct financial incentives, suggests a willingness among users to engage with alternative charging strategies. This supports the notion that public charging infrastructure should accommodate diverse charging needs, ranging from urgent charging to destination charging, and everything in-between.

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Unraveling the hassle factor as a psychological barrier to demand flexibility for Dutch households through survey-based research

Theme 1, sub-topic 1a

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Hassle factor, demand flexibility, household behaviour, survey research

Extended abstract

1. INTRODUCTION

The transition to a sustainable energy system is central to mitigating climate change. Electrification however, while necessary, brings new challenges, particularly for electricity grids under increasing pressure. One vital solution is demand flexibility, where energy users adjust their consumption patterns to relieve grid congestion. Dutch households are increasingly recognized as crucial actors in this system, not only by reducing total energy use or adopting solar panels, but also by shifting the timing of energy-intensive activities like laundry, dishwashing, and electric vehicle (EV) charging.

Recent Dutch policy initiatives reflect a growing awareness of the need for such behavioural adaptations [e.g. 1]. The phasing out of the net metering schedule and the launch of campaigns like ‘*Zet de Knop Om*’ signal a push toward household-level flexibility. However, while information campaigns and economic incentives (e.g. time-of-use tariffs) are common [e.g. 2], evidence suggests that these interventions often overestimate the role of motivation and underestimate psychological barriers to behaviour change [3, 4].

This study focuses on hassle as a potentially critical but empirically understudied barrier to household load shifting. The goal is to identify, typologize, and quantify how hassle influences



households' willingness and ability to shift energy use, and how hassle interacts with habit strength and stress in daily life.

2. PROBLEM STATEMENT

Traditional approaches to encouraging household demand flexibility tend to rely on financial or informational interventions [e.g. 5, 6]. However, their limited effectiveness suggests the need to examine deeper behavioural constraints [e.g. 7]. Recent behavioural research, including the proposed barrier-first approach [4], argues that environmental motivation is often present, but unrealized due to the behavioural cost of action such as hassle [8].

Hassle is multifaceted. In economics it manifests as transaction costs [e.g. 9]; in behavioural economics as friction or sludge [e.g. 10]; and in psychology as mental strain or cognitive load [e.g. 11]. Hassle is a micro-stressor that inhibits simple but non-automated behaviours such as shifting appliance usage to off-peak hours [12]. Despite widespread anecdotal evidence in the Dutch context, empirical investigations into hassle as a barrier to load shifting are nearly absent.

The central problem addressed in this paper is the lack of empirical understanding of hassle-related barriers and how they affect three key household load-shifting behaviours: doing laundry, doing dishes, and charging EVs.

3. OBJECTIVES

This research scientifically aims to a) map and categorize the types of hassle described in literature, b) measure the extent to which Dutch households experience hassle as a barrier, c) develop a typology of external and psychological hassle, and d) investigate how habit strength and stress in life correlate with perceived hassle. Ultimately, the goal is to inform more effective behavioural interventions and demand flexibility policies by spotlighting the underexplored role of hassle.

4. METHODOLOGY

We explore the topic by a structured literature review, supplementing it with four large-scale survey studies. The structured literature review entails a systematic search of the Scopus database and snowballing techniques to identify relevant studies on hassle in relation to laundry, dishwashing, and EV charging. Subsequently, we conduct four surveys targeting Dutch households:

1. Study 1 (n = 3200): Eneco customers with solar PV, assessing hassle in manually programming appliances to run during sunny hours.
2. Study 2 (n = 350): Technical university students, focusing on a developing a habit-strength scale for laundry habits.
3. Study 3 (n = 250): Solar PV-owning households targeted through two Dutch municipality newsletters, assessing multiple hassle factors for dishwashing and laundry shifts to sunny hours.
4. Study 4 (n = ~8000): General population (with and without PV) from a national panel, assessing hassle factors for laundry, dishwashing and EV-charge shifts (this survey is in preparation and will be conducted in October 2025).

Each survey includes both standardized and context-specific measures of hassle, habit strength (based on the habit strength scale in [13]), and stress in life (based on daily hassles and uplift measurement scale in [14]). Hassle was operationalized with items addressing both several external (practical) and psychological (cognitive/emotional) barriers. Examples are "it is a hassle that dishes are piling up" and "It's too complicated to program the appliance."

5. RESULTS



Literature review. The review revealed sparse but suggestive evidence of hassle as a barrier to demand flexibility [15]. Common factors include technical complexity, perceived effort, coordination difficulties, and time demands. Notably, most studies aggregated demand behaviours and did not isolate laundry, dishwashing, or EV charging. Hassle is often implicitly present in concepts like “effort expectancy” [16] or “ability” [17], but rarely measured directly.

Survey studies. Across all studies (excluding study 4, which is in preparation), hassle is commonly reported as a barrier. Over 60% of PV owners in Study 1 agreed that programming appliances was “not worth the hassle.” In Study 2, a majority of students found shifting laundry to off-peak hours inconvenient. Mentioned hassles are piling laundry baskets and coordination with household members. Study 3 revealed similar results: coordination with household members was reported as a major hassle, especially for dishes.

Factor analyses across studies 2 and 3 uncovered four recurring dimensions of hassle:

- a) Technical complexity (e.g., timer setup, app usage)
- b) Social coordination (e.g., sharing appliances)
- c) Routine disruption (e.g., needing to remember new times)
- d) Perceived inefficiency (e.g., half-full machines)

Role of Habit Strength and Stress. Habit strength was positively correlated with perceived hassle across all behaviours (study 2 and 3). Stress in life also intensifies the perception of hassle (study 3). Regression models confirmed that both variables significantly predict lower likelihood of (self-reported) shifting behaviours, even after controlling for demographics.

6. DISCUSSION

This research extends the behavioural literature on demand-side flexibility by systematically exploring the hassle factor. Unlike most previous studies that focus on price signals, we adopt a psychological lens to understand why even motivated households may fail to adopt flexibility-enhancing behaviours. Our typology of hassle adds granularity to the concept and opens the door for tailored interventions. For example, households with high habit strength and life stress may benefit from automation tools (like Home Energy Management Systems) that reduce decision-making effort. However, current smart systems often introduce new hassles due to poor design [18], illustrating the importance of behavioural insights in technology development.

7. CONCLUSION & RECOMMENDATIONS

This study confirms that hassles are a meaningful and measurable barrier to household load shifting. We recommend that a) policymakers incorporate hassle-reduction strategies into demand flexibility programs, b) energy providers test interventions that simplify or automate load shifting (e.g., default appliance settings, user-friendly apps) and c) researchers build on this work by developing impact-oriented, behaviourally-informed policy experiments.

Removing hassle can unlock the latent motivation among households and accelerate the energy transition by making flexibility easier, not harder.

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Welfare and behavioural effects of energy transition in homes: Impact assessment using 2 million individual linked data of Dutch households

Theme 1, sub-topic 1c) and 1d) (12 font size)

- “Academic contribution”
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Keywords: Energy transition, Public housing, Effect evaluation, Poverty, Health, Wider welfare benefits

Extended abstract

Background: Governments around the world subsidize insulation and heating upgrades of older energy-inefficient homes to reduce CO₂ emissions. In the EU alone, 35 million homes are to be renovated by 2030. While these upgrades primarily aim to reduce fossil fuel dependence and improve environmental outcomes, they also have a profound impact on the residents, affecting their behaviour, lifestyle, energy bill, comfort, health. These wider welfare effects can differ significantly across groups of residents, potentially introducing inequalities. Quantifying and predicting these impacts is essential to make the energy transition inclusive and just. In this contribution we report on the results of a six-year research program BEL—Behaviour, Energy transition, Low income, in the Netherlands. BEL designed and applied novel methods and models to assess and predict behavioural and welfare impacts of energy-efficient interventions in Dutch public housing, leveraging big data, smart technologies and behavioral economic modelling.

Methods:



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We performed large-scale causal analyses of the welfare effects of energy-efficient housing upgrades—insulation and ventilation, heat pumps installations—on energy use, environmental footprint, poverty, comfort, and health of residents. We used Dutch public housing as a case study, as the sector is large with 2.2 million homes, has undergone a significant energy transition in the past decade and offers a unique institutional setting for the impact assessment.

We made use of the sample of residents living in houses that qualified for home upgrades over 2012-2021 (two million residents during 10 years, approximately 12 million person-years). Starting in 2012, a covenant required most public housing providers to gradually retrofit their older, poorly insulated dwellings. Over 1 million homes were eligible, but, due to logistic constraints, only part of these could be retrofitted by 2021. The retrofit treatment assignment was based on technical factors, uncorrelated to tenants' socio-economics. Further, by law tenants could not opt out, eliminating self-selection. As a result, the setting approximated a natural experiment: many comparable individuals experience the treatment at different times, not by choice.

We linked individual administrative records of households to house-level records on energy-efficiency upgrades over 10 years. We exploited economic, econometric and machine learning models to study how behavioural and welfare impacts of home upgrades vary across population groups. Up to now the research program delivered three studies, evaluating wider welfare effects of home insulation—a primary energy transition measure that is a prerequisite for many other energy upgrades.

Research findings

The first study [1] analyzed the differences in post-insulation energy savings, combining econometrics and machine learning techniques. We found a large variation ranging from 10% to 30% reduction in natural gas use. The savings varied by house type, renovation size, population group and tenants' behaviour. For example, pre-retrofit heating demand was an important predictor of savings: large energy users reduced gas use the most, not only in absolute but also in relative terms. Economically disadvantaged households, on the other hand, saved less gas than average. From a policy perspective, these results stress the importance of tailored and targeted energy-efficiency interventions.

The second study [2] further investigated behavioural responses and comfort improvement after home upgrades. Insulation lowers the cost of thermal comfort, leading households to raise indoor temperatures. This behaviour—known as rebound—reduces energy and CO₂ savings. We built and trained a novel computable consumer model to show that comfort benefits are substantial, especially for the lowest income households, reaching up to 20% of total benefits of insulation. We also found that, for this group, the rebound was associated with substantially lower gas savings—one third lower than average. From a policy perspective, this reveals an important trade-off: energy-efficiency policies aimed at reducing (energy) poverty improve well-being and comfort, but come at the cost of lower CO₂ savings.

The third study [3] focused on the health impacts. Older homes often present health hazards, but insulation and ventilation upgrades eliminate them. Using individual data from health insurers, we found a 4% reduction in asthma and allergy complaints among children after home upgrades. In monetary terms (willingness-to-pay), these benefits are substantial—their order of magnitude is comparable to the energy bill savings. Children's health improvements are particularly impactful, providing lifetime benefits. From a policy perspective, the estimated health benefits could substantially alter the cost-benefit calculus of retrofitting programs, especially when energy savings alone often do not cover renovation costs.



From research results to actionable policy

To make the above reported research results actionable for the policy makers, our research program delivered several decision support tools that help prioritize and optimize energy-efficiency renovations. One of these is a prototype web platform Prioritize—an optimization algorithm that allows public housing providers to optimize between competing policy goals, such as e.g. energy poverty reduction and environmental savings. As discussed above and shown in [2], these two goals can conflict.

Figure 1 illustrates the working of the platform. The user (e.g. social housing provider) uploads their housing stock, selects the percentage of stock to be renovated, and assigns weights to policy goals (in this version: climate impact versus poverty reduction). The algorithm based on [2] then calculates which homes best meet these criteria and assigns renovation priorities. Figures 1a and 1b illustrate different outcomes: in 1a, the main goal was poverty reduction and the properties to the North of the area were selected for renovation; in 1b, climate impact was the goal, resulting in prioritizing the southern part of the area. Note that due to privacy concerns, the tool operates on aggregated data—such as six-digit postcode areas, not individual homes.

Discussion

A key takeaway from the BEL research program is that energy-efficient home retrofits have a wide variety of important societal and behavioural effects, including reduced energy bills, improved comfort, better health, poverty reduction. These wider welfare benefits vary substantially across population groups. For example, lower-income tenants often prioritize increased comfort over direct energy savings after insulation, resulting in lower gas savings and environmental gains. Children, on the other hand, benefit in terms of improved respiratory health.

These insights underscore the importance of welfare-centred and tailored interventions to ensure equitable outcomes in energy transition. Our research provided new knowledge, methods and tools for this purpose. To successfully apply these innovations, it is essential that policymakers and housing providers are explicit about their policy goals and can prioritize these, as some of the goals may conflict.



(a) Policy goal energy poverty reduction

Prioritize by:

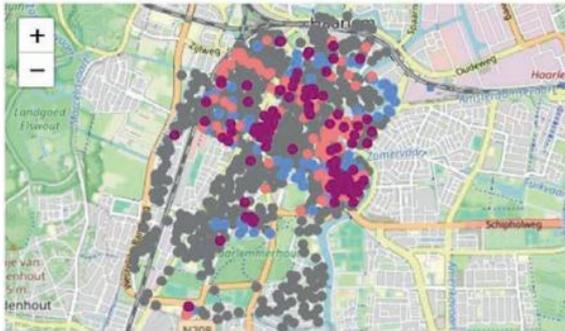
Environment

Poverty reduction

Renovation priority:

First priority Third priority

Second priority None



(b) Policy goal maximal environmental savings

Prioritize by:

Environment

Poverty reduction

Renovation priority:

First priority Third priority

Second priority None



Figure 1. Proof-of-concept web platform Prioritize. Source: [1].

Equally important is the development of robust, representative datasets that can support reliable policy analysis and decision-making. For instance, ongoing research in BEL analyses the wider welfare effects of switching from natural gas heating to heat pumps. Unfortunately, so far we were unable to replicate this research for district heating—another widely discussed policy option for phasing out natural gas. Reason is the lack of a comprehensive, longitudinal dataset on household heat consumption.

Overall, we conclude that the wider social and behavioural effects of energy transition in homes are substantial. Accounting for them can alter the cost-benefit analyses of energy transition policies, the effectiveness of which is now widely debated ([4]). At the same time, trade-offs between environmental savings and social impacts may present a challenge for effective and equitable renovation policies. Our research contributed to solving these policy challenges by providing actionable new insights based on large-scale policy evaluations and by translating these insight into hands-on decision support tools.

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Guidelines for just participation in energy social housing renovations

Theme 2, sub-topic 1a)

- “Academic contribution”
- “Policy/practice contribution”

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Keywords: just and inclusive residents’ participation, energy social housing renovations, feedback loops, reciprocity, capability

Extended abstract

The Dutch energy transition aims to achieve a carbon-neutral built environment by 2050. However, nearly 41% of homes lack an energy label, and about 31% of labelled homes are rated C or lower [1]. This situation requires urgent action in the housing renovation sector. According to the 70% rule, any renovation plan must be approved by at least 70% of residents [2] yet participation indicators focus predominantly on technical or economic criteria, neglecting social needs.

This paper presents a design research project conducted in collaboration with an SME that supports housing associations in sustainable renovations. The project explores how resident participation can become more inclusive and representative, placing people’s values at the core of decision-making. We propose a framework grounded in energy justice that aims to improve agreement, trust, and satisfaction among residents while maintaining technical and financial feasibility.

The following sub-sections will first provide a description of the challenges around just participation that were observed between the stakeholders, indicating tensions between trust, comfort, safety and flexibility from the residents’ side and efficient, programmatic, financially and technically constraints from the housing association’s side. Secondly, a just participation framework is introduced operationalising concepts of reciprocity, feedback loops, and capabilities is. Thirdly, design guidelines are presented exploring mechanisms of flexibility, reciprocity, and responsiveness. Finally, a brief discussion and conclusion highlights the impact that justice can make in the shift from efficient to just indicators for participation.

Methodology

The research takes place within a five-year renovation project involving 5.000 apartments. Design research activities—ethnography, co-design workshops, and stakeholder interviews—were conducted in collaboration with internal stakeholders from the SME, housing associations, and community support organizations to co-developing a justice-based participation framework.

Challenges to just participation



The SME's programmatic renovation approach supports housing corporations in delivering technically feasible, financially viable, and desirable plans. Their clients—typically social housing associations—manage large building stocks and highly diverse resident populations. The goal is to efficiently reach agreement with residents while operating within tight budgetary and scheduling constraints. However, meaningful participation proves challenging. Residents vary widely in language, literacy, financial stability, and household structure. Many are migrants or lower-income individuals, with both long-term and short-term tenures. Their lived experiences include discomfort (cold drafts, overheating, noise), safety concerns (e.g. theft, neighbour conflict), and institutional distrust, often rooted in prior negative interactions with housing authorities.

Current participation processes inform on technical, environmental, and financial metrics. The first step typically includes:

- A digital survey (self-reporting conditions and preferences)
- An information booklet on the renovation plan
- Permission requests for energy label assessments
- An invitation to participate in a sounding board

Yet participation is limited. Residents often don't relate these materials to their lived experiences. Internally, project teams synthesize resident feedback with technical and financial data into a final renovation report for voting. But by then, much of the social input has been filtered out.

This structured and linear process overlooks the nuances of real community life. As a result, only the most vocal or active residents participate, while the majority remain passive. The resulting agreement—though legally sufficient—is socially shallow, reducing resident satisfaction and institutional trust. In xx main tensions between the institutions implementing the programmatic process and residents are illustrated.

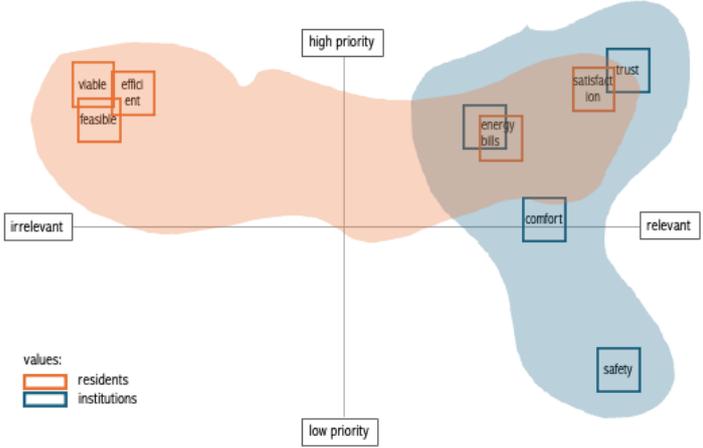


Figure 24. Tensions maps based on values of residents and institutions

A framework for just participation

To address this, we developed a design framework grounded in two energy justice tenets: **procedural justice** (fairness in the process) and **recognition justice** (acknowledging diverse values and identities). These tenets are based on literature exploring the interdependencies between participation, power, and justice [3]. The framework is operationalized through three guiding mechanisms: capability, reciprocity and feedback loops (see Table 1).

Mechanism	Aim	Example strategies
Capability [4]	Support residents' ability to participate	Early-stage coaching, simplified materials

Reciprocity [5],[6]	Create mutual value in participation	Recognition of input, flexible incentives
Feedback loops [7]	Establish visible, two-way communication	Resident-facing updates, participatory decision logs

Table 8. Framework for just participations

These mechanisms aim to shift engagement from transactional to relational, fostering trust and inclusivity.

Design guidelines

The framework informed a series of design interventions across four key participation dimensions: flexible participation, framing through residents’ eyes, responsive processes, and reciprocity to build trust.

Flexible participation. The involvement of residents is an unstructured process that starts by listening. A streamlined approach that assumes participation as an efficient and sequential process creates gaps for inclusive and diversity in participation. The design space lies in developing flexible participation formats that can be adapted according to capabilities and needs of residents and project developers. Examples:

- Reworking soundboards into low-threshold drop-in sessions
- Using pictorial or multilingual formats for surveys and booklets
- Recognizing and rewarding different types of resident engagement and input

Framing through residents’ eyes. The need for project efficiency and standardisation means that the degree of customisation possible for individual residents is limited. Once values of residents are identified it is hard to embed them in a programmatic process where several disciplines are working on a structured and linear approach. Translating channels can help connect the technical aspects of renovation to residents’ values by reframing the benefits of renovation in terms of what matters most to them. Examples:

- Model homes redesigned with experienced-base walkthroughs (noise, airflow)
- Booklets rewritten to highlight lived experiences (“no more cold drafts”)
- Infographics that show impact on monthly energy bills

Responsive processes. Given the limited organisational capacity, participation must support responsiveness and representativity. The challenge lies in ensuring that participation leaves visible traces in decision-making and is not just performative. Residents need to see how their input shaped the renovation plan. Examples:

- Feedback dashboards that track suggestions and responses
- Mini "What we heard" reports sent after meetings
- Trained ambassadors sharing updates through informal networks

Reciprocity to build trust. In practice, risks, power dynamics, and imbalance of efforts damage long term relations in participation. Even small acts of recognition can transform the dynamic between institutions and residents. Examples:

- Public appreciation of “resident ambassadors”
- Personalised thank-you notes or digital badges for involvement
- Adjusted construction schedules to meet community needs



Discussion

This project shows that just participation is not about adding layers of complexity, it is about redesigning existing processes to be more equitable and meaningful. Current methods are often efficient but not effective. By embedding recognition and procedural fairness into the early stages of decision-making, the participation process can reflect what truly matters to residents. While flexibility, reciprocity, and responsiveness may require additional effort, they lead to greater satisfaction, higher quality agreements, and long-term resilience. In return, housing corporations may benefit from fewer delays, better communication, and more stable tenant relationships. Ultimately, justice is not a burden to the renovation process, it is a lever for making it work better for everyone.

Conclusion

While the justice-based framework may require an initial investment in participation, it supports a fundamental shift from efficiency-based to effectiveness-based indicators. Renovation programs grounded in procedural and recognition justice are more likely to secure trust, enhance resident satisfaction, and result in shared ownership of sustainability transitions. As the Netherlands scales up its energy renovation ambitions, these participatory approaches offer a pathway to socially grounded, scalable solutions.

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Hidden Energy Users: Who Are They And Why Are They Hidden?

Theme 2, sub-topic 2 b) d)

“Academic contribution”

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Keywords: Hidden Energy Poverty, Energy Justice, Behaviour, Community Engagement, Hard-to-Reach Energy Users

Extended abstract

The Hard-to-Reach Energy Users Task (HTR Task) by the Users-Centred Energy Systems Technology Collaboration Programme (Users TCP) by the International Energy Agency (IEA) has been characterising hard-to-reach (HTR) energy users since early 2019. Several reports, culminating in a seminal e-Book reviewing over 1000 publications [1], explored this topic [2,3,4,5].

Taking the HTR energy users characterisation and estimation that at least 2/3 of global energy users fall into this broad definition by [1] further, [6] used Eurostat data for the EU-27 to compile a basket of indicators relevant to each of 13 proposed HTR profiles. Many authors, reviewed by [1,6], acknowledge issues with the HTR terminology, particularly with regards to heterogeneity and intersectionality, lack of standardised indicators and frameworks, and energy justice considerations.

One of the main issues with HTR terminology is that most energy policy makers and programme managers simply regard them as low-income households (e.g., [4,7]). However, as research has made clear, “only” being low-income, does not mean an energy user is also hard-to-reach [1,4,5]. To further hone in to the complex issue of intersectionalities, vulnerabilities and heterogeneity of this user base, we decided to focus on “hidden energy user” segments (see Figure 1) in Phase 2 of the HTR Task. This abstract is part literature review, and partly based on mixed methods field research insights.



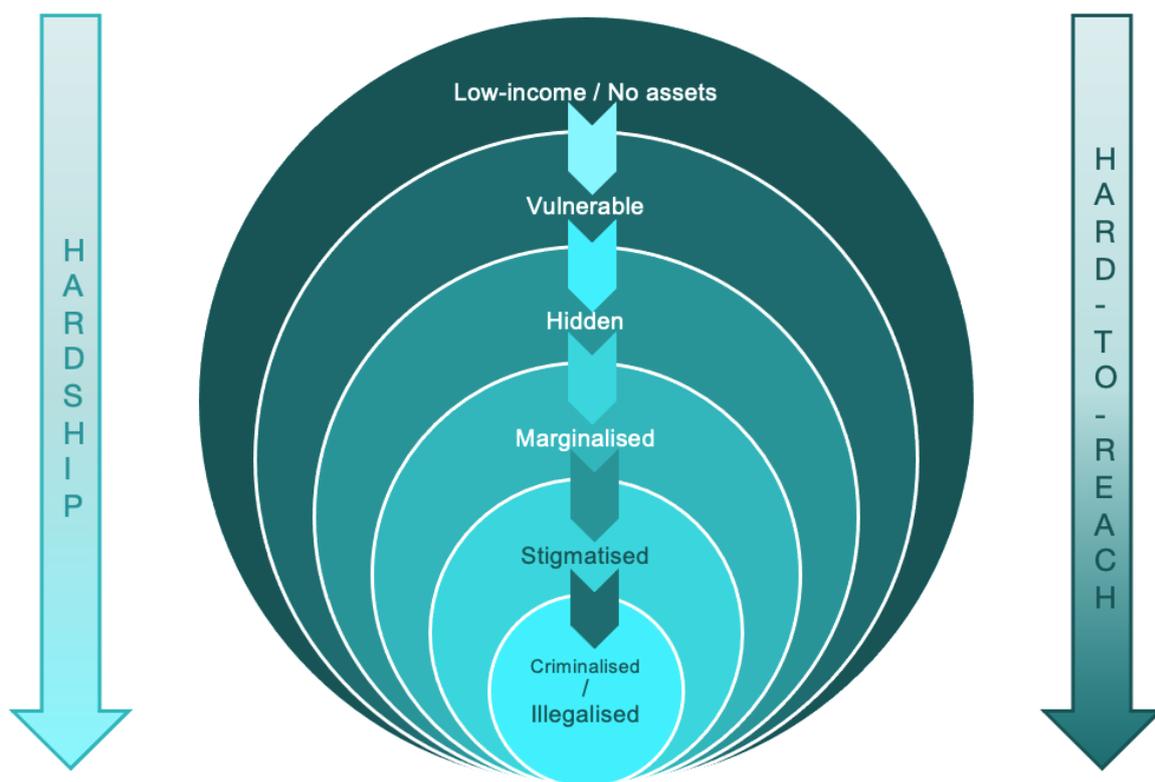


Figure 1: Diagram showing different segments of HTR Energy Users, including increasing hardship and hard-to-reach-ness.

Within low-income households (especially those having no assets, such as renters), compounding and intersecting vulnerabilities (such as related to age, gender, health, minority status, or types of isolation) will tip them into a “hidden” status, where they are either misrecognised, deprioritised, or choose to remain invisible. In this diagram and extended abstract, we focus on energy users living in hidden hardship [8,9]. However, there are other hidden segments, such as high-income / sumptuous spenders in the residential, or small businesses in the commercial sectors [1,6,12].

Academic literature refers to hidden energy users usually in the context of hidden energy poverty (e.g., [10-13]) and/or hidden geographies (e.g., [14-16]). Most of the literature examines hidden energy poverty (HEP) in highly-developed [8, 13], but largely European countries (e.g., [10-12; 14-16; 19-20]), with some from middle-development countries [7, 17], and none that we could find from Sub-Saharan Africa. Some of the literature mentions specific types of hidden audiences, and some the reasons for why they may be hidden (see Table 1). Several papers delve into developing multidimensional (beyond income-based, also taking into account limiting energy behaviours and intersecting vulnerabilities) HEP indicators, sometimes also called the “energy equity gap” [7,10,12,17,18,19,20].

One of the major problems with current (mostly income- or disproportionate energy expenditure-based) standardised energy poverty metrics is that they don’t account for behavioural underconsumption by comparing households’ actual energy expenditures with their required ones [12]. However, some households also under-consume (e.g., for frugal or environmental reasons) without living in hidden hardship [11,12]. In addition, building characteristics, location, household demographics, psychographics and consumption patterns, are crucial elements to determine required energy consumption [12]. Several papers calculate

HEP numbers as around 25% of the population, in Spain [12] and 11 other Central and Eastern European nations [19], although in Belgium it was only reported as 5% [20].

While income poverty can often be quantified through straightforward financial metrics, HEP encompasses a range of underlying factors, making it more complex to identify and address [19]. This complexity arises from the interplay of economic, social, and environmental variables that affect households differently, further complicated by geographic heterogeneity. As Figure 1 attempts to show, there is both an increasing hardship as well as hiddenness that comes with more intersecting and compounding vulnerabilities. Table 1 identifies some of the intractable complexities around reasons and motivations why energy users may live in hidden hardship - some extrinsic, some intrinsic, some voluntary, some involuntary.

Table 1. Examples of Hidden Energy Users, Reasons Why They May be Hidden, and References.

Examples of hidden energy users	Reasons why they may be hidden	REF
Low income plus other vulnerabilities (see below)	Lack of capital to retrofit / purchase EE, behavioural underconsumption	[1][7][10] [12][15]
Transitory homeless, home-based micro-businesses, welfare recipients	Deprioritised / mis-recognised or disrespected by decision makers	[1][12][13] [23]
(Bereaved) elderly, recent immigrants & refugees	Do not want to be a burden on society, physiological habits & traditions, incidental masking	[1][7][8] [12][13] [15][19]
Rural remote (Indigenous), elderly, disabled, lonely or single	Geographically, technologically or socially isolated	[1][2][5] [9][16][19]
Non-native speakers, mentally disabled, carers / single parents	Inability to engage with time-consuming interventions	[1][8][15]
“Squeezed middle” without assets	Stigma or pride, lack of perception they are the “working poor”	[8][13][19] [20]
Overcrowded households (e.g., student flatters, Pasifika, children)	Only the customer (bill payer) is known	[8][9][10] [15]
Renters, social housing and MFA tenants, informal dwellings	Split incentive issue, Principal Agent Problem, illegal utility meters	[1][2][7] [12]
Global South, using traditional energy sources like biomass	Reliability, affordability & cleanliness of energy services	[17][22]



Indigenous, refugees, those with bad historic experiences from e.g., being debt collected or in government care	Multigenerational trauma, lack of trust in the system	[1][8][9]
Travellers, illegal overstayers, homeless, sex workers, addicts, recently released from prison	Being illegalised or criminalised means they voluntarily remain hidden	[1][8][9] [12]

Vulnerable populations we engaged with our field research [8,9] have clearly told us that they don't like being regarded as such, nor do they appreciate being pigeonholed into scientific or statistical audience characteristics. However, in order to engage them in co-designing tailored interventions that actually suit their needs and overcome specific barriers and reasons why they are hidden, we have to find relevant local and community intermediaries (“Navigators”) that can help identify and recruit them - something most authors researching HEP recommend [1,2,4,5,7,13,17,20,21,22]. However, these Navigators often distrust our motives.

To build trust, particular attention should be given to non-economic indicators and the subjective lived experiences (such as comfort levels, health implications, psychological well-being, and family dynamics) of vulnerable households in policy formulation [7]. However, most energy policy makers operate from a Western, male, and engineering or economics-dominated mindset which causes significant blind spots and often, unfortunate unintended consequences [1,15,21,22,23].

Recommendations

1. Ensuring that equitable participation begins with recognising the legitimacy of different values and experiences that hidden groups bring to the conversation - elevate them to “priority voices” to ensure a just transition.
2. Mitigating measures should consider the multifaceted nature of energy hardship, and go beyond economic metrics.
3. Undertake mixed methods research, triangulating quantitative with qualitative insights, especially including demographic and psychographic (including behavioural) indicators.
4. Improve energy literacy across the population, but especially by engaging with and training frontline and community providers that can help identify hidden hardship.
5. Improve energy efficiency of building stock, especially in vulnerable (e.g., renters, remote rural, older, overcrowded, minority, mentally or physically disabled) groups.
6. Local interventions are crucial, in combination with national funding and targeted policies.

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Quality over Quantity: Investigating the macroeconomic impacts of quality-oriented consumption as a sufficiency lever

Theme 5, sub-topic 5c)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Longevity, Durable goods, Quality consumption, Macroeconomic impacts

Extended abstract

As efficiency improvements alone are insufficient to deliver the emission reductions required to meet climate targets, sufficiency strategies are increasingly recognised as essential complements to technological innovation (Creutzig et al., 2016; Mundaca et al., 2019; Rogelj et al., 2018). Among these, extending the lifespan of durable goods represents a promising lever (Sandberg, 2021).

However, transitioning from a quantity-based to a quality-oriented consumption paradigm raises significant socio-economic questions. From an environmental perspective, the adoption of longer-lasting goods may induce rebound effects in other consumption domains, potentially offsetting environmental gains (Cooper, 2005, 2016). Such transitions may also generate adverse effects on employment, income distribution, or fiscal balances.

These socio-economic outcomes are strongly shaped by the economic characteristics associated with quality production. Depending on the sector and product type, quality production structures often include features beyond longevity (Cooper, 2012; Park, 2016). These may involve greater labour intensity due to more time-consuming manufacturing processes, a stronger reliance on skilled and better-paid workers, better working conditions or business models based on premium pricing and increased service components such as personalisation, after-sales service, or repairability.

This paper examines the socio-economic and environmental implications of a quantity-to-quality consumption shift, with a particular focus on how different conceptualisations of quality affect these dynamics.

While the issue of product lifetimes has been largely addressed at the microeconomic or business level (Gossen et al., 2024), macroeconomic perspectives remain underexplored. Notably, (Monserand, 2022) highlights the role of planned obsolescence in exacerbating inequality through post-Keynesian stock-flow consistent (SFC) models.

Building on this approach, we develop a stylised SFC model following the methodology of (Godley & Lavoie, 2012) to capture the macroeconomic feedbacks of a shift in consumption



composition towards higher-quality equipment goods. The model represents a closed economy composed of a representative household, a firm producing both high- and low-quality equipment goods as well as a disposable good, and a public sector ensuring monetary consistency. Households are required to maintain a constant stock of equipment goods, replacing depreciated items and allocating the remainder of their income to disposable goods. We simulate an exogenous increase in the share of high-quality goods purchased, driven by changes in consumer preferences or policy incentives.

For each characteristic of quality production—higher labour intensity, increased wages, shorter working hours, or higher profits are investigated in this study—we analyse the short- and long-term macroeconomic effects of the transition. The model is roughly calibrated using stylised European data.

MAIN FINDINGS

The shift to longer-lasting goods initially reduces the frequency of purchases until a new equilibrium is reached, where consumption of each good aligns with their depreciation rate. This reduction in equipment consumption frees up income for disposable goods ("report effect") but simultaneously lowers overall income due to reduced employment in equipment production ("income effect"). These dynamics are reinforced by a feedback loop driven by increased employment in disposable goods production and balanced by another loop stemming from changes in savings, ultimately driving the long-term economic equilibrium. Here total output remains constant, but its composition changes from equipment to disposables. This serves as the baseline scenario.

When quality also entails higher labour intensity, the additional employment mitigates income losses but also raises prices, reducing the report effect. If labour intensity increases more than depreciation decreases, long-run disposable consumption falls below its pre-transition level. Variants involving higher wages or reduced working hours further alter income and report effects, influencing public budgets and long-run equilibria.

KEY CONCLUSIONS AND POLICY RECOMMENDATIONS

First, our study highlights that the socio-economic and environmental outcomes of a quantity-to-quality transition depend critically on the specific characteristics embedded in the concept of "quality". These characteristics can be linked to sectors and product types, offering a better understanding of the dynamics of a real-world quality transition.

Second, if quality is defined solely by longevity, significant rebound effects may arise, limiting environmental gains. These effects are mitigated when quality also involves higher costs through increased labour intensity or wages.

Third, policy design should account for the structural features of quality production. Targeted subsidies, worker retraining programs, or public investments may be necessary to support the transition while preserving employment and purchasing power. Transitions are socially and economically smoother in sectors where quality involves more labour input.

Finally, if quality increases output but reduces employment, income inequality may worsen. Redistribution measures and access policies, such as subsidies for quality goods for low-income households, are essential to ensure that sufficiency does not become a new vector of exclusion.

In conclusion, this paper offers a structured macroeconomic framework for assessing sufficiency transitions through the lens of quality-oriented consumption. This paper analyses



separately the macroeconomic effects of different interpretations of quality. By systematically varying the economic characteristics associated with each, we show that the socio-economic and environmental impacts of a sufficiency transition are highly sensitive to context. Targeted, sector- and product-specific analyses are therefore essential to guide effective policy design.

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Community Acceptance and Rejection of Sustainable Energy Infrastructure Projects in the Province of Ontario, Canada: Insights from Macro- and Micro-Investigations

Theme 3, sub-topic 3b)

“Academic contribution”

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Keywords: Canada, energy storage, renewable energy, social acceptance

Extended abstract: The means by which individuals and communities around the world secure access to energy services is unsustainable: amongst other required changes, increased use of renewable energy – through greater electrification and other means – is critical. Such expansion, however, must work in concert with other sustainability priorities, including improving local economic and social livelihoods. As such, greater understanding of the ways in which communities evaluate – and eventually decide to accept, reject, and/or modify – renewable and sustainable energy projects is vital. The purpose of this paper is to contribute to such understanding by analyzing current activity across multiple municipalities in the province of Ontario in the country of Canada.

Ontario, home to 16 million people, is Canada’s most populous and industrialized province. Powering its mixed economy is a 30 GW (capacity) / 150 TWh (energy) electricity system that must – by virtue of increasing electrification of mobility and heating as well as growth in data centres and green manufacturing – expand by 75% over the coming 25 years [1]. To achieve this, the largest electricity procurement process in the province’s history is currently underway, with the Independent Electricity System Operator (IESO) pursuing supply and storage options across a range of resources and technologies, including renewables. This activity has served to catalyze a rush of activity in the sustainable energy space in Ontario (after, it should be noted, five years of virtual silence on the issue), with multiple companies engaging numerous communities, to consider hosting of varied sustainable energy infrastructure projects. With the IESO being told by the government that a ‘municipal support resolution’ must be part of any executed contract, engagement on the issue is widespread across Ontario [2].

While increased use of renewable resources in electricity supply – for instance, solar and wind – brings many benefits, like lowering carbon emissions, it can also bring many costs, like landscape disruptions. As a result, there can be substantial debates – with varied perspectives – regarding the desirability of hosting such projects, locally. Such debates have occurred in many parts of the world – Ontario included, particularly during the last decade [3] – and a literature has arisen that aims to explain pathways to successful sustainable energy infrastructure deployment (e.g., [4] [5] [6] [7]). That literature is reviewed in order to generate a range of



variables that guide the data collection process. These variables relate to issues of distributive justice (e.g., community benefit agreements, local environmental and economic impacts, safety concerns), procedural justice (e.g., early, full, and frank consultations), and situational factors (e.g., policy entrepreneurs, veto intervenors, networks, structural considerations).

Methodologically, the aim is to develop an inventory of sustainable energy infrastructure projects (projects that were focused upon either solar, wind, hydropower, or energy storage) in the Province of Ontario and that were ‘active’ for at least one day between 1 January 2023 and 31 December 2024. By ‘active’, we mean at least one of the following conditions was satisfied:

- An active decision to ‘accept’ the project (e.g., a municipal support resolution was passed or otherwise obtained) took place during this two-year period.
- An active decision to ‘reject’ the project (e.g., a municipal decision to not support the project was made) took place during this two-year period.
- There is evidence that this project was ‘alive’ – actively under consideration – but that it was not clear whether it would be proceed or not (e.g., a community open house was held; an article about it, with ‘current’ quotes from proponents and/or opponents, was published) for at least one day during this two-year period.

A mixed methods approach was used: searches of publicly-available information across known lists (e.g., the IESO’s lists of successful and unsuccessful applicants to its different procurement competitions), media databases (e.g., Factiva and Google News), company websites (particularly those companies that had taken part in the IESO’s public consultations), and web-based searching more broadly.

Thirty-six sustainable energy infrastructure projects were identified, characterized, and placed into tabular and spatial databases. As Figure 1 shows, these projects are located primarily in southern Ontario (32/36 or 89%) and for the most part were battery energy storage systems (27/36 or 75%); additionally, the majority were predominantly accepted (20 accepted and nine rejected; the remainder are ‘ongoing’ or ‘conditional acceptance’).

Following the ‘macro-investigations’ – that is, reflecting upon the sample of 36 as a whole – a search for patterns that emerged from these Ontario experiences was undertaken. More specifically, four areas for further investigation emerge:

- *Technology-specific trends*: While the dominance of battery energy storage systems (noted above) mean that all other technologies are particularly ‘small-n’, the sheer presence or not of particular technologies is suggestive of broader societal perceptions and priorities. The rejection of the three wind projects that were attempted to be established is particularly noteworthy.
- *Spatial proximity of accepted and rejected projects*: Some of the accepted projects clustered around two parts of Ontario – namely, the Greater Toronto and Hamilton Area; and the Ottawa-Kingston Corridor – while some of the rejected projects clustered within parts of the Chatham-Kent and Windsor municipalities and Prince Edward County.
- *Politization of acceptance and rejection*: While the majority of all projects that have had a final decision made (24/30 or 80%) were located within areas that had Progressive Conservative (PC) members of the provincial legislature, it is still noteworthy that all nine projects that were rejected were located within areas represented by PC members.
- *Land and communities*: Map overlays of renewable resources (e.g., solar radiation and wind speeds), land quality and use (i.e., agricultural land, or not), and population



densities and sizes (i.e., rural or urban areas) allow reflections upon the extent to which conflicts between groups of peoples regarding alternative values might be at the root of distinctive acceptance/rejection outcomes.

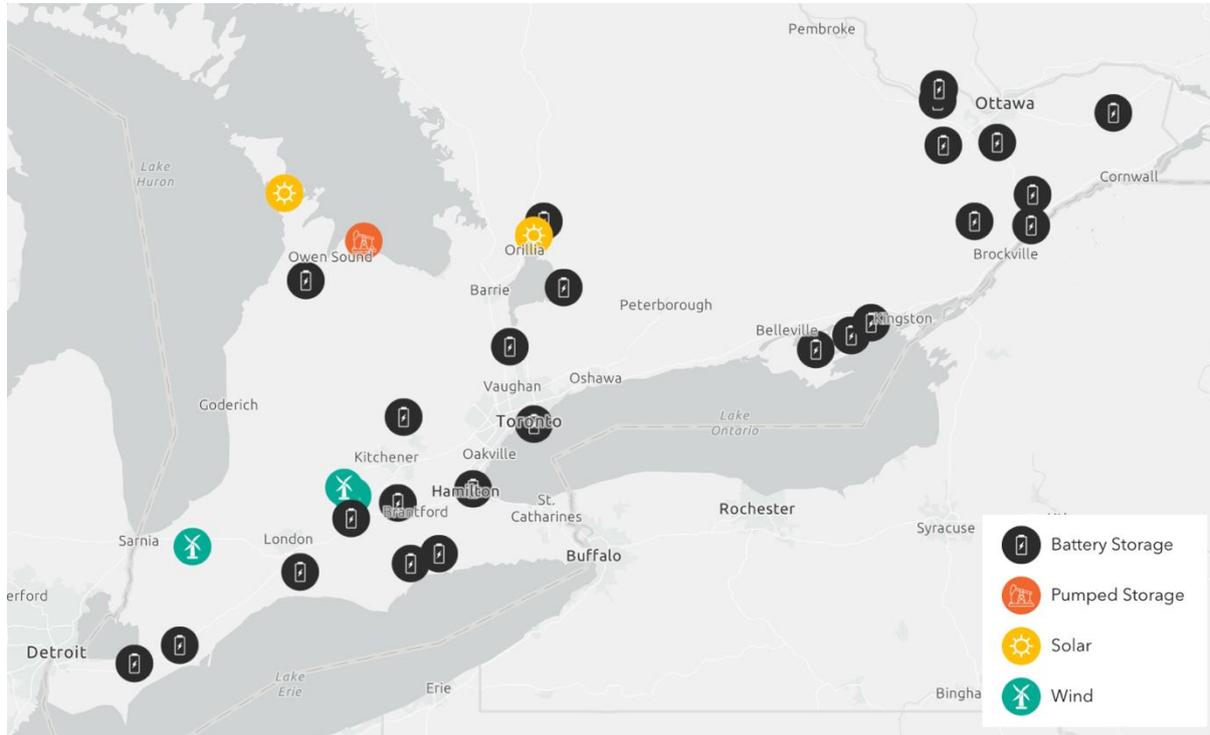


Figure 1. Locations and technologies of southern Ontario-located projects under investigation

‘Micro-investigations’ allows ‘deeper dives’ to be taken on particular cases that appear comparable for further insight. The presence of contiguous battery energy storage systems projects in eastern Ontario that, in turn, accepted and rejected offers (Edwardsburgh Cardinal and Elizabethtown-Kitley, respectively) invites further investigation into the impact of individual factors, including local champions, ownership representatives, and entrepreneurial officials. And when a technology has only one project in the sample (i.e., pumped storage hydropower, specifically Meaford), additional considerations – potentially unique to the particular technology – enter into consideration.

Through macro- and micro-investigations, greater understanding of the ways in which sustainable energy infrastructure might be deployed in Ontario (and elsewhere) in the future is advanced. By reflecting across 36 cases – and by more detailed investigations of subsets of this sample – insights are developed to help to ensure that the ‘best’ sustainable energy transition infrastructure projects can be sited, completed, and brought online efficiently, expeditiously, and in an environmentally-sound manner, while leaving no one behind.

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FAIRlagern – Transforming Mobility through Situational Behavioural Interventions in Rural Communities

Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Behavioural interventions, rural mobility, situational communication, low-cost strategies, sustainable transport, social inclusion

Extended abstract

Achieving a modal shift towards sustainable mobility remains a complex challenge in rural communities. Despite having options such as micro-public transport, walking, or cycling, private cars dominate short-distance travel under five kilometres. The problem is not always infrastructure-related; habitual patterns, low visibility of alternatives, and a default reliance on the car often drive behaviour.

FAIRlagern was designed to address this challenge with a behaviourally informed, communication-based approach. Implemented in 2024 in three municipalities in Burgenland, Austria, the project introduced a situational focus: instead of categorising people by age or socio-economic group, FAIRlagern targeted specific moments of mobility decision-making – such as the school run, a doctor visit, or quick errands. This micro-targeting enables more relevant, practical messaging, reducing cognitive barriers and making sustainable choices easier.

Objectives and Core Challenge

The overarching aim was to promote climate-friendly mobility for short trips by changing everyday decisions rather than attitudes alone. To achieve this, the project set three objectives:

- Interrupt habitual car use in situations where alternatives are practical.
- Provide municipalities with low-cost, adaptable tools for sustainable mobility promotion.
- Ensure accessibility and inclusivity, so interventions reach diverse age and social groups.

Key barriers identified were [1]:



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- Lack of salience for sustainable options in daily routines.
- Strong habits reinforced by perceived convenience.
- Resource constraints in small municipalities limiting campaign scope.

Behavioural Framework

The design was grounded in COM-B and Nudge Theory [2] [3] [4] [5]:

- Capability: FAIRlagern ensured people knew about alternatives, using simple, clear communication materials.
- Opportunity: Measures placed visible cues in everyday environments – child-friendly brochures for schools and information on beer coasters in restaurants.
- Motivation: Incentives (e.g., reward-based sticker collection), social norms (local role models), and emotional appeal made sustainable choices attractive.

Nudge principles were used through:

- Salience: Positioning mobility messages where decisions happen (e.g., when parents plan school routes or visit local cafés).
- Social proof: Featuring community figures like pharmacists to model behaviour.
- Small incentives: The school mobility pass rewarded repeated active travel, reinforcing the behaviour loop.

The project also created habit disruption moments, such as the start of the school year, leveraging natural breaks in routines to introduce alternatives.

Implementation Design

FAIRlagern was built on modular actions that municipalities could easily adapt to local conditions. The measures combined analog and digital formats to ensure accessibility for all age groups and digital literacy levels. Key components included:

1. School Route Action – Mobility Collection Pass and “School Route Detectives”
Children were encouraged to actively participate in observing and documenting their daily school routes while using climate-friendly transport modes such as walking, cycling, or public transport. Each successful trip was marked in a reward-based collection pass, turning sustainable mobility into a playful and motivating experience for children and families. This approach created conversations within households and schools, making active travel a shared commitment.
2. Situational Social Media Nudges:
Digital communication focused on real-life contexts, such as quick errands or doctor visits, using short posts and videos. To increase trust and identification, the messages featured well-known local figures, for example, pharmacists or other community members. Posts were placed at times when related mobility decisions were likely to occur, making them timely and relevant.
3. Everyday Prompts in Local Environments:
Information on local mobility options was brought into familiar community spaces, such as cafés and schools. Examples included beer coasters with micro public transport details in restaurants and simple information materials in schools. These low-threshold



cues ensured visibility of mobility alternatives in daily life and at decision-making points.

To ensure scalability, all measures were documented in a step-by-step communication guide [6]. This guide includes templates, language recommendations, and instructions for campaign timing, enabling municipalities with limited staff or expertise to implement similar actions.

Results and Impact

The pilots demonstrated significant behavioural and awareness changes:

- In Neufeld, the “School Route Detective” action increased active school travel by 28.3% on the benchmark day.
- In Güssing, visibility of the demand-responsive service BAST improved after interventions such as beer coaster prompts and local campaign posts.
- In Eisenstadt, situational social media posts generated over 70,000 impressions and reached more than 50,000 people with a spend of only €140 – showing the high cost-efficiency of locally resonant messaging.

Beyond numbers, the project created social value: actions sparked conversations among families and in local businesses, strengthened community identity, and encouraged spontaneous adoption by schools and local actors outside the project scope.

Accessibility and Inclusion

FAIRlagern integrated barrier-free design principles from the outset. Measures were:

- Analog-first, ensuring people without digital access could participate;
- Written in clear, simple language;
- Distributed in everyday spaces like cafés, schools, and clinics;
- Complemented by social media for extra reach, without excluding non-digital users.

This inclusive design allowed engagement across age groups, education levels, and digital competencies, addressing mobility as a shared, community-wide issue.

Scalability and Replicability

The project demonstrates how municipalities can promote behavioural change without heavy investment. FAIRlagern’s toolkit requires minimal cost and staff capacity and is flexible for different local contexts. Since early 2025, the guide has been available publicly, and initial feedback from municipalities confirms strong interest in replicating the approach.

Conclusions

FAIRlagern shows that situational, behaviourally informed communication can significantly influence mobility choices in rural areas. By focusing on where and when decisions occur, applying COM-B and Nudge principles, and leveraging local identity, small communities can disrupt car-use habits and encourage low-carbon alternatives – without building new infrastructure.



The success of FAIRlagern confirms that behavioural change is key for sustainable mobility, especially in resource-constrained settings. Municipalities can adopt this approach as part of their climate strategies to deliver real-world impact quickly and affordably.

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PUBLIC ACCEPTABILITY OF DIGITAL PERSONAL CARBON TRADING: A TECHNOLOGY ACCEPTANCE PERSPECTIVE FROM UK HOUSEHOLDS

Theme 3, sub-topic 3a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: domestic energy use, low-carbon behaviour, carbon budgeting, household acceptance, technology acceptance model

Extended abstract

Introduction

To achieve climate targets, deep decarbonization across all energy demand sectors is required. In the UK, the domestic sector accounted for 26% of total final energy demand in 2023, with residential buildings emitting around 50 Mt_{CO₂e} annually [1,2]. Addressing household emissions is therefore essential to meet emission reduction targets.

Personal carbon trading (PCT) has long been discussed as a policy instrument to incentivise low-carbon behaviour by making individual emissions visible and tradable [3]. The concept has been explored mainly during the early 2010s, and few schemes have progressed beyond the conceptual stage, citing costs, technical complexity, and political sensitivity as key barriers to implementation [4].

However, recent technological and societal developments warrant a re-examination of PCT's feasibility. Digital infrastructures could enable fully integrated platforms for carbon accounting and trading via smart meters, smartphone apps, and web interfaces. While some prototype applications for personal carbon allowances already exist, these typically lack real trading functionalities. Nonetheless, such digital systems offer the potential for real-time feedback and user interaction at significantly lower cost than earlier proposals based on banking infrastructure and physical card systems [5]. Moreover, public responses to COVID-19 and the 2021–2023 energy crisis have demonstrated a collective willingness to accept behavioural constraints and digital monitoring when framed around societal benefit [5].



This study revisits the PCT policy proposition by examining the acceptability of a digitally mediated scheme in everyday life. In doing so, we update the evidence base on PCT and offer empirical insights into the socio-technical conditions under which such schemes might gain public traction.

Methodology

This study is based on semi-structured interviews conducted with 22 households and overall 32 participants in and around Oxford, UK. The aim was to explore the social acceptability of a digitally implemented PCT scheme, using the Technology Acceptance Model (TAM) as the guiding theoretical framework. Each interview followed a three-phase structure, as summarised in Table 1.

Table 1. Interview structure.

Phase	Content
1. Introduction to PCT	Brief explanation of PCT & digital tracking
2. Core questions	TAM based questions (see Table 2)
3. Optional reflection	Overall willingness to participate (voluntary vs. mandatory)

To support comprehension of the abstract concept of PCT, participants were shown a handout (Figure 1) illustrating key scheme components, including annual carbon allowances, behavioural impacts on the budget, and trading mechanisms. The visual provided a clear reference point for discussion and was particularly useful for engaging all household members, including minors.

The core of the interview drew on TAM constructs to investigate how participants evaluated a potential digital carbon tracking system. TAM postulates that people are more likely to adopt a new technology if they perceive it as useful and easy to use [6]. Figure 2 presents an extended version of TAM, adapted to investigate the acceptability of a digital PCT scheme. In addition to the core TAM constructs, such as perceived usefulness, perceived ease of use, attitude toward use, and behavioural intention, the model incorporates three key extensions: (1) External variables, such as environmental attitude, technophilia, access to visualisation tools, and online ability influence perceived usefulness and ease of use. (2) Concerns and perceived barriers, which may negatively affect perceived usefulness and attitude towards use. (3) Contextual moderators (marked with an asterisk) to qualify the strength and direction of relationships between constructs, such as links between attitude and intention of use.



How personal carbon trading works for households

"Every household/person gets a free carbon credit"

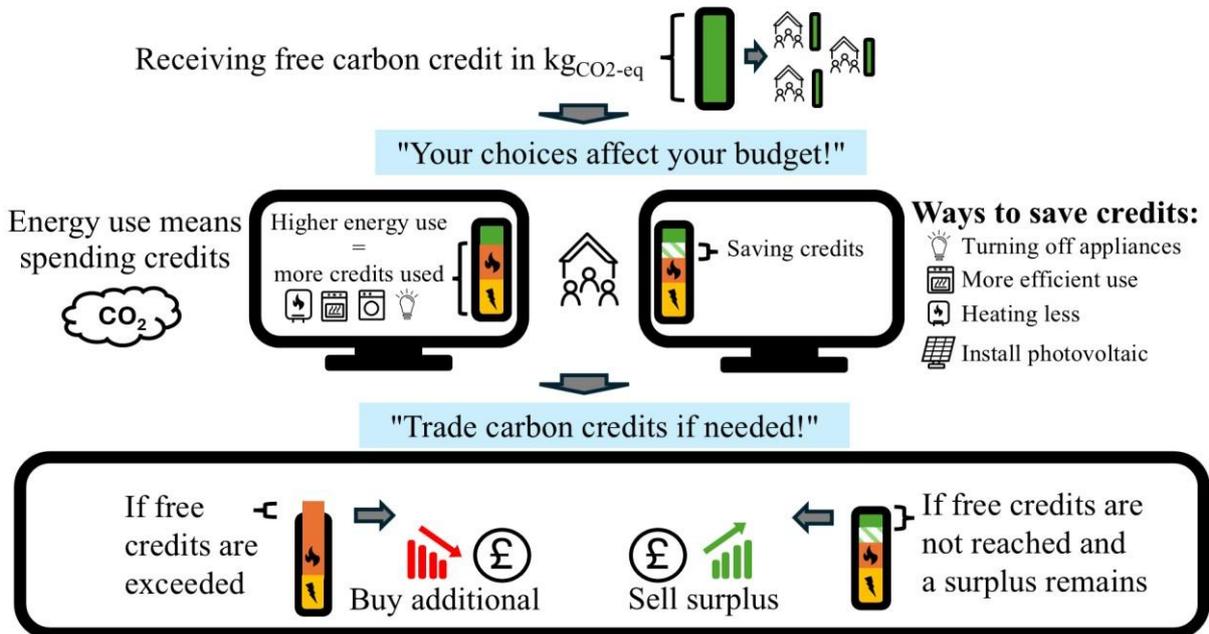


Figure 1. Visualisation to introduce the concept of personal carbon trading to the interview participants.

Among these contextual moderators, we also include voluntariness of use, which was identified by Venkatesh et al. (2003) as a key moderating variable in TAM. This reflects the policyrelevant distinction between voluntary participation and mandatory implementation, which is expected to moderate the relationship between perceived usefulness and behavioural intention to use [7].

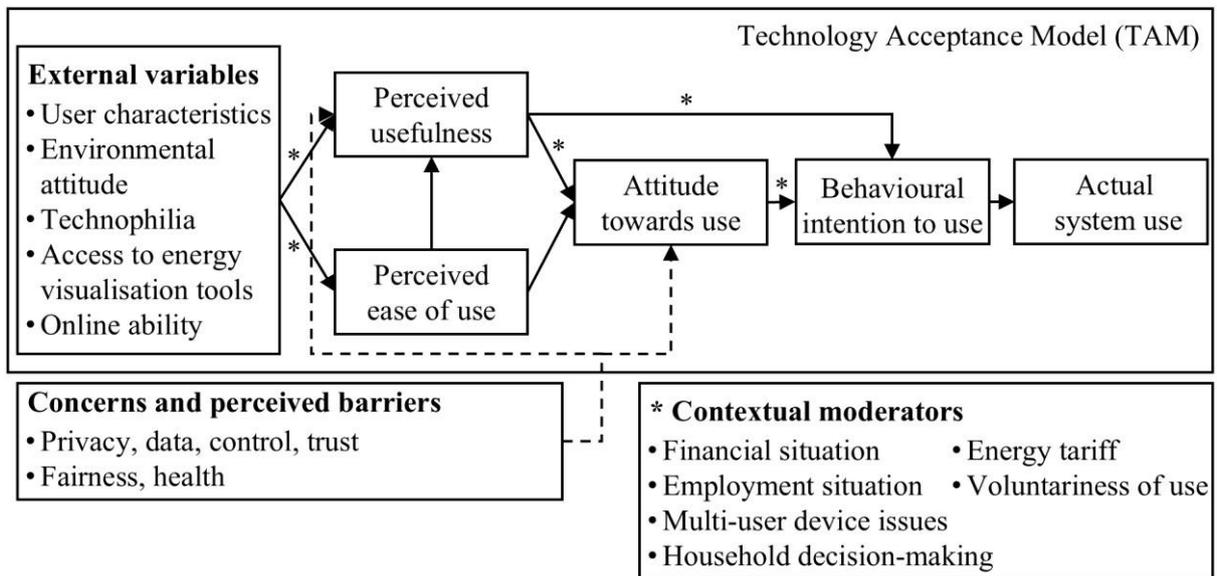


Figure 2. Theoretical framework of this study. The Technology Acceptance Model (TAM) extended for concerns and perceived barriers, and contextual moderators.

Questions targeted perceived usefulness, ease of use, user attitudes, and behavioural intentions. An additional question addressed concerns and barriers, including privacy and digital trust. The full question set is shown in Table 2.

Table 2. Core Interview Questions (TAM-Based) and optional questions to reflect on overall acceptability of personal carbon trading.

	Interview question
TAM category	
Perceived Usefulness	If you could track your carbon budget through an app or website, do you think it would help you use less energy at home? Why or why not?
Perceived Ease of Use	What would make a carbon tracking app or website easy or difficult for you to use?
Attitude Toward Use	Would you enjoy checking your carbon budget on an app or website, or would you rather get automated updates (e.g., push-notifications on the phone, emails, or no updates at all)? Why?
Behavioural Intention	Since the system automatically tracks your carbon emissions, how often do you think you would actively check your carbon budget? Daily, weekly, or only when needed?
Concerns & Barriers	Do you have any concerns about using a digital carbon tracker? (For example, privacy, difficulty using it, or sharing data with energy providers?)
Overall acceptability	
PCT Acceptability	Would you be open to participating in a Personal Carbon Trading (PCT) scheme voluntarily, or would you only consider it if it were mandatory? Why?

Participants were recruited from a larger living lab of households as part of the ‘iDODDLE’ project and represented a range of demographic and housing characteristics [8]. Interviews were conducted online or in person with all willing household members to gain intra-household perspectives. The interviews were audio-recorded and transcribed verbatim. Transcripts were analysed using qualitative content analysis. The coding framework was developed iteratively and aligned with the TAM constructs, while also capturing emergent themes related to digital trust, design preferences, and PCT acceptability. Supplementary survey and interview data from previous living lab activities was added as external variables or contextual moderators to support interpretation and triangulation e.g., participants’ technology affinity and environmental attitudes, and their financial and employment situation.

Results

Participants largely supported the idea of digitally tracking personal carbon budgets, with 62% finding it potentially useful and improved energy literacy cited as a key motivator. Ease of use centred on the need for clear visualisations and simple feedback, with many participants valuing suggestions or alerts tailored to specific devices or personal usage patterns. Performance comparisons over time (e.g., monthly or annual energy use) were also frequently mentioned, while features such as AI-driven insights, gamification, and financial feedback came up, but less often.

Attitudes toward use showed a clear preference for active engagement: of around 80% who would interact with such a system, 68% preferred checking the interface regularly, 12% favoured regular prompts, 12% prompts and checking, and 8% prompts for unusual consumption or being close to exceeding the cap. Of all participants who would check the interface, around 80% said they would check the interface daily; while 20% preferred weekly or monthly use. Fairness (n=15) was the most frequently raised concern, with many fearing that wealthier individuals would be unaffected while lower-income households could be disproportionately impacted (n=7). Participants also highlighted inequalities linked to age (n=4), family status (n=5), disabilities (n=3), tenancy (n=2), and work-from-home

arrangements (n=2). Another major concern related to potential mental and physical health effects (n=9), including anxiety from constant monitoring or risks from underheating homes.

Additional concerns included data privacy (n=6), perceived loss of personal control (n=6), and methods of carbon allocation (n=7).

Behavioural intention varied strongly with policy framing, between mandatory and voluntary participation. 53% of all participants were willing to take part in a voluntary scheme. Support dropped notably under a mandatory framing, with 88% opposed to compulsory participation, while 6% did not clarify their intentions on these points. Overall acceptability was supported by 56% of participants, 38% opposed the scheme, and 6% did not answer. While this analysis focuses on core TAM dimensions, the influence of additional external variables and contextual moderators will be examined in more detail in subsequent analyses.

Discussion and Conclusion

Overall, digital carbon tracking was viewed as useful and acceptable by the majority of the participants, particularly under a voluntary scheme. Designing PCT tools with actionable, comparative, and personalised feedback could help sustain consumer engagement, but must also balance transparency with minimal cognitive burden.

These findings align with TAM. Perceived usefulness was reflected in motivations like energy literacy and perceived ease of use in preferences for simplicity and visual clarity. Attitude toward use was generally positive, with most participants preferring to engage regularly and check their performance themselves, and behavioural intention varied significantly based on voluntariness of use, underscoring the relevance of contextual framing.

Concerns around fairness, privacy, and mental wellbeing remain. Future research should explore whether explicitly integrating and communicating safeguards within PCT prototypes can help address these concerns, build public trust, and examine how these prototypes could be tested in real-world pilot studies.

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Lifestyle change modelling for climate change mitigation: complementary strengths, policy support, and research avenues

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Keywords

Climate-friendly lifestyles, climate policy, model comparison, model coupling, interdisciplinarity

Extended abstract

Abstract

Lifestyle changes are an essential, complementary measure for reducing greenhouse gas emissions and, therefore, also an important ingredient to climate policy. Computational models of lifestyle changes and their contribution to climate change mitigation can provide valuable insights in support of policymaking. Each modelling approach provides useful, albeit partial, insights into lifestyle changes. The identified challenges call for both continual refinements within individual model frameworks and hybrid methods that bridge their respective strengths and allow for representing lifestyle changes more comprehensively. Ultimately, cross-disciplinary collaboration will be key to designing lifestyle-focused policies that are both impactful and acceptable.

Introduction and problem definition

In our complex world, computational models have the potential to support policy processes regarding lifestyle changes. They can have a place throughout the different policy stages, such as policy design through target setting and exploration of policy options, as well as evaluation of implemented policies through impact assessment^{1,2}. Accordingly, models can support policymaking both prospectively (ex-ante) or retrospectively (ex-post). By enabling experiments in a virtual world, they offer several advantages over running “real-world experiments” or policy pilots: they save time and costs, avoid irreversibility, allow to explore several alternatives under otherwise equal conditions or the same policy under different



contexts, avoid ethical issues of administering a beneficial policy to some individuals but not others, and allow to examine possible futures¹. However, lifestyle change has so far been represented in models only to a limited extent, hindering our understanding of the potential and scope of lifestyle change to support climate policy.

Methodology

Here we examine four distinct and widely used model families relevant to emulating anticipated impacts of climate-friendly lifestyle changes: input-output analysis (IOA), life cycle assessment (LCA), integrated assessment models (IAMs), and agent-based models (ABMs). IOA and LCA are empirically grounded matrix algebra methods, while IAMs and ABMs are models that dynamically iterate over the studied time horizon. One of each operates on a large scale (IOA and IAMs), while the others operate on a smaller but more detailed scale (LCA and ABMs). We perform a literature review on the fields of application of these models, and by doing so we extend previous articles that have qualitatively compared different sets of model families for different scopes.

Results and discussion

In our literature review we analyse how the four model families can support climate policymaking across four critical dimensions: theoretical mitigation potential, behavioural plasticity, policy feasibility, and policy effectiveness:

- For **theoretical mitigation potential**, IAMs estimate carbon budgets and explore overshoot pathways³, while IOA enables detailed emissions accounting and fair burden-sharing across regions⁴. IOA also captures financial rebound effects⁵. ABMs are less suited for quantifying mitigation potential.
- **Behavioural plasticity**, or the likelihood of individuals adopting lifestyle shifts, is best represented through ABMs, which simulate social influence and agent-level decisions^{6,7}. IAMs aggregate behavioural assumptions, while IOA and LCA treat them as external inputs⁸.
- **Policy feasibility** hinges on public and institutional support. ABMs incorporate political preferences and negotiation dynamics^{9,10}, while IAMs assess feasibility through aggregate system metrics¹¹. Participatory modelling enhances trust and relevance.
- **Policy effectiveness** requires integrating all dimensions. IAMs and ABMs assess future policy impacts and heterogeneity¹², while IOA and LCA support retrospective validation^{13,14}. Combining methods strengthens policy design¹⁵.

Drawing from the experience from all authors, and taking the attributes of effective scientific advice into consideration (utilizing the paradigm of Cash et al.¹⁶, representing credibility, salience and legitimacy):

- **Credibility via reusability of lifestyle models:** Credibility of lifestyle models rests on scientific adequacy and transparency. Despite challenges in validating unobservable outcomes¹⁷, credibility can be enhanced through uncertainty assessments^{18,19}, structured evaluation protocols^{20,21}, and open science practices²²⁻²⁴. ABMs benefit from standardized documentation²⁵ and open libraries²⁶, while IAMs are advancing openness via initiatives like the IAM Wiki²⁷.
- **Saliency via model coupling and learning across representations:** Hybrid approaches—e.g., IOA-LCA²⁸, IOA-IAM²⁹, or ABM-LCA^{15,30}—address respective limitations and improve comprehensiveness. ABMs add agent-level behavioural dynamics, enriching prospective scenarios^{3,31}.



- **Legitimacy via potential contributions of theoretical and empirical social sciences to modelling lifestyles:** Legitimacy depends on integrating social science theory and empirical insights. Behavioural models benefit from psychology³², political science³³, and participatory research³⁴. Challenges remain in theory selection, operationalisation, and parameterisation^{35,36}, which cross-disciplinary collaboration can help overcome^{37,38}.

Conclusions

As underscored throughout our analysis, lifestyle representations are analyzed across multiple research fields. There is hardly any doubt that lifestyle change can be an effective measure in combating climate change³⁹; however, the scientific field is still far from holistically addressing lifestyle change. Snippets of its driving force or effects can be obtained from specific modelling paradigms and scientific disciplines, though these empirical bases are still very much in development as a science and in their practice. In general, it is understood that knowledge of causation and correlation can be drawn from historical phenomena, expert elicitation or surveys, though such empirical evidence may not immediately find further application in models on impact assessment yet. Further experimentation and integration are therefore of utmost importance to better understand these fundamental mechanisms that motivate personal choice over time and space and what that means for the global socio-ecological and socio-economic systems. Interdisciplinary collaboration is still not the standard – disciplinary evaluation criteria disincentivize the various schools from more thoroughly collaborating, and difficulties due to different languages and working styles may reduce productivity. However, sharing common goals and showing mutual trust and respect can increase the group’s effectiveness and lead to innovative research⁴⁰ capable of addressing complex sustainability challenges such as climate-friendly lifestyles more holistically.

The literature on lifestyle change can contribute to many facets relevant to a more systemic societal change. However, as outlined above, recent efforts appear to have mostly evolved around improving credibility and legitimacy, making it a rather isolated scientific endeavour of modelling and social science communities. Considering also the tension between translating knowledge to actual action⁴¹, engaging more with stakeholders and decision-makers in scoping and developing knowledge can improve the salience of the research field. Such more holistic assessments may offer greater value for agents of change and those in positions of power.

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Operationalising the Energy Efficiency First Principle through Local Campaigns: Insights from SaveEnergyTogether

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy Efficiency First principle, behavioural change, local campaigns, public engagement

Extended abstract

Achieving carbon neutrality requires not only behavioural nudges but also the widespread adoption of more structural energy efficiency measures, such as building renovations, heating system upgrades, and insulation. This reflects the *Energy Efficiency First Principle*, a central EU policy priority which states that energy demand should be reduced wherever cost-effective before supply-side investments are made [1]. While low-cost behavioural interventions have become increasingly well understood and are often promoted in campaigns and policy design, the communication of more complex and structural actions continues to pose a significant challenge – particularly in socio-economically diverse and institutionally fragmented contexts [2].

This paper presents practical insights from the EU LIFE project *SaveEnergyTogether*, which is currently designing and rolling out modular, locally tailored energy campaigns in five European pilot regions: Austria, Germany, Lithuania, Portugal, and Slovenia [3]. The campaigns focus on promoting simple Energy Efficiency Interventions (sEEIs), such as adjusting heating settings, reducing hot water use, or switching to LED lighting. Although many of these actions are minor and low-cost, they are framed as potential gateways to more ambitious measures like insulation, heating system replacement, and comprehensive building renovations [4]. In this way, the campaigns aim to not only encourage immediate energy savings but also lay the foundation for deeper and longer-term energy transformation.

By integrating behavioural messaging with local engagement formats and practical support tools, the campaigns are contributing to the implementation of the Energy Efficiency First principle. The actions promoted are low-threshold and highly contextualised but carry messages and structures that can catalyse wider change. Even simple acts – like a heating check or participation in a home energy event – are being used to spark interest in more structural improvements. The campaigns are embedded in local institutions, tailored to the needs of their



respective communities, and delivered through trusted actors to maximise both reach and resonance [5].

Methodological approach

In each pilot region, campaigns have been or are being co-developed through Campaign Implementation Groups (CIGs), which include municipal authorities, technical experts, energy advisors, civil society organisations, and researchers. These groups ensure that campaigns are locally relevant, inclusive, and aligned with existing initiatives such as climate plans, renovation strategies, or social housing programmes. The collaborative approach also fosters ownership, legitimacy, and scalability.

Evaluation of the campaigns follows a mixed-methods strategy that allows for learning during implementation. Quantitative data are being gathered through feedback forms at campaign events such as workshops, DIY sessions, or home visits. Qualitative data come from structured interviews with key stakeholders, including campaign leads, municipal energy managers, and intermediaries.

This combination of data collection and local feedback loops enables an iterative process. Campaigns are not static: they are adjusted based on early results and peer learning across the five regions. A full impact analysis is not foreseen, but the practical evidence gathered provides valuable insights into how energy communication can influence both behaviour and readiness for structural change.

Regional implementation

Each pilot region is developing a campaign tailored to its specific socio-economic conditions, energy systems, and institutional capacities. Despite their differences, all campaigns aim to lower entry barriers for energy action while building momentum for larger changes.

In Austria (Tyrol), heating system checks in public and private buildings are being used as a conversation starter about energy system renewal. Municipalities conduct these checks as part of broader energy routines embedded in the e5 network. The campaign combines technical guidance with funding advice and targeted materials to spark discussions around heat source replacement.

In Germany (Allgäu), the campaign relies heavily on social learning formats. “House Viewing Days” and DIY renovation workshops allow citizens to see real-life examples of renovations and ask questions in a relaxed, peer-to-peer environment. These events are supported by local energy managers, craftspeople, and community organisations, reinforcing credibility and local knowledge.

In Lithuania (Vilnius and Tauragė), the campaign focuses on visualisation and demonstration. A mobile “smart home” booth is touring both urban and rural areas, using interactive exhibits to explain energy savings. Energy marathons and gamified school sessions complement this effort. The campaign pays particular attention to energy poverty and includes messaging on comfort and affordability.

In Portugal (Braga), the campaign works closely with social housing residents, focusing on energy literacy and basic efficiency measures. Campaign messages are aligned with the



municipality's renovation strategy and delivered through schools, tenant associations, and a one-stop-shop for energy advice. Highly visual, accessible materials support inclusive outreach.

In Slovenia, a national-level approach is being combined with local adaptations. Campaigns involve seasonal print materials, digital content, and public workshops. Topics range from heating to appliance use and are integrated into school outreach and collaborations with consumer protection organisations.

Cross-cutting insights

Several lessons are already emerging from these regional experiences for practitioners seeking to design communication strategies that support structural energy change.

Campaigns must bridge the gap between simple and structural actions. Even seemingly minor interventions – such as lowering room temperatures or switching light bulbs – can initiate deeper engagement if they are paired with compelling narratives, relatable examples, and guidance on next steps. Where follow-up support is available, such as funding consultations or access to renovation services, participants are more likely to pursue further action.

Local anchoring is essential. Campaigns delivered through trusted intermediaries such as municipalities, schools, or tenant associations enjoy greater credibility and reach. Embedding efforts within existing networks and programmes not only ensures continuity but also helps avoid duplication and fatigue.

Visual and hands-on formats are particularly effective. Abstract or technical concepts such as insulation or heating systems become tangible when demonstrated through physical exhibits, home visits, or interactive displays. These formats are proving especially powerful in engaging households that might otherwise feel excluded from policy discussions.

Tailoring makes a difference. Energy prices, housing stock, and institutional maturity vary widely across the regions. Campaign content and tone must therefore be adapted accordingly. In energy-poor areas, for instance, messages about comfort and health have more traction than purely economic arguments.

Behavioural change is a process. One-off events provide an entry point, but meaningful transformation depends on sustained engagement. Several regions are experimenting with follow-up materials, seasonal messaging, or recurring formats (e.g., school workshops) to keep energy issues present in daily life.

Framing and language matter. Energy efficiency can be associated with a wide range of outcomes — from cost savings to climate protection or improved comfort. Campaigns using positive, specific, and relatable messages are more successful in activating change than those relying on technical or abstract arguments.

These early insights demonstrate how the Energy Efficiency First Principle can be put into practice not through technology alone, but through socially grounded, well-communicated, and community-led interventions.

Recommendations



The contribution will include practical recommendations for policymakers, municipalities, and implementers working to align communication with energy transition goals. These include: designing campaigns that link behavioural and structural messages within a clear, motivating narrative; using trusted local actors and networks to ensure legitimacy and accessibility; investing in engaging and visual formats that help people understand and relate to energy issues; tailoring messaging to local needs, and planning for long-term, relationship-based engagement.

These insights highlight the transformative potential of local energy campaigns. Rather than prescribing solutions, they support people and communities in taking the next feasible step – a key condition for scaling up energy efficiency in a just and inclusive way.

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The Interplay of Fear Appeals and Policy Framing in Shaping Climate Policy Support

3a) Acceptability and ownership of public policies by stakeholders and the public (e.g. energy laws, taxes, subsidies, infrastructure changes, system changes, ...)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Policy Support, Fear Appeal, Collective Efficacy, Framing

Extended abstract

Addressing climate change and moving toward a sustainable society remain among the most urgent challenges of our time **Erreur ! Source du renvoi introuvable.** In line with international agreements, The Netherlands has set climate targets in the Dutch Climate Agreement (2019) and the Climate Act (2023), aiming for a climate-neutral society by 2050 [1][3]. To achieve these targets, effective climate policies **Erreur ! Source du renvoi introuvable.** and sufficient public support for these policies are needed **Erreur ! Source du renvoi introuvable.** Without such support, climate measures may be met with resistance and low compliance **Erreur ! Source du renvoi introuvable.** **Erreur ! Source du renvoi introuvable.** [7]. Although a majority of the Dutch population is concerned about climate change [9][10], support for climate policies remains fragmented. Citizens’ policy preferences vary considerably depending on the type of measure being proposed [11][12]. For instance, while higher taxes on airline tickets receive widespread support, meat or dairy taxes are met with more resistance [13][14]. This variation suggests that concern about climate change does not automatically translate into support for all policy measures equally.

Communication plays a crucial role in shaping attitudes toward climate policies and action [15][16]. Several studies suggest ‘framing’ to be an effective communication technique to increase climate policy support [17][18][19][20][21]. Here, framing refers to the strategic presentation of information to emphasize particular aspects of an issue. Among various types of framing, fear appeals have attracted substantial interest [22][23]. Messages with fear appeals highlight the severity and urgency of climate risks to motivate behaviour change [16][21][24][25][26]. However, at the same time, those ‘doom and gloom’ messages are also



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found to backfire, provoking denial, apathy, or disengagement, especially when individuals feel powerless to act [16][27][28].

A widely accepted theoretical model that addresses these mixed effects of fear appeals is the Extended Parallel Process Model (EPPM) [26]. **Erreur ! Source du renvoi introuvable.** According to the EPPM, fear appeals can lead to either adaptive or maladaptive responses to a message, depending on whether individuals perceive high levels of efficacy (i.e., the belief that one has the ability and/or capacity to take meaningful action to reduce the threat). Without perceived efficacy, fear-inducing messages are likely to backfire and lead to message rejection [29]. In line with this, studies have shown that fear appeals are only effective in promoting a message or action when paired with efficacy information [21][30][31]. For example, [32][32][32][32] found that messages combining threat and efficacy information were more effective in promoting climate-friendly behaviours than those that focused on threat or efficacy alone. Based on these findings, we expect a fear-based message (without efficacy) to lead to lower policy support than a message without fear appeal (H1). In line with the findings of [32], we further expect the combination of a fear appeal with a policy framing to lead to higher policy support than when presenting only a policy framing (H2).

To be more specific, different forms of efficacy have been found to play a role in engagement, policy support, and intentions to act [33][34][35][36]. **Erreur ! Source du renvoi introuvable.** **Erreur ! Source du renvoi introuvable.** Given that climate change is a collective challenge, emphasizing collective efficacy – the belief that a group (e.g., a group of citizens, a nation, or the EU) – may be particularly impactful [37]. **Erreur ! Source du renvoi introuvable.** **Erreur ! Source du renvoi introuvable.** Research shows that higher collective efficacy is associated with greater support for climate policies and increased participation in public-sphere climate actions [34][36]. Furthermore, messages emphasizing collective agency (e.g., “together we can solve this”) are found to be more persuasive than individualistic appeals [38][39]. **Erreur ! Source du renvoi introuvable.** **Erreur ! Source du renvoi introuvable.** It is assumed that people believe that broader collaborations, like those at the European level, have a higher chance of successfully mitigating climate problems [5][40]. In addition, individuals tend to feel more efficacious when acting as part of a collective, such as a community or political alliance [37][41][42].

Until now, only a few studies have systematically compared different levels of policy framing, such as emphasizing policies at the national versus the European level [43][44]. Those studies suggest that communicating about larger collective units, like the EU, may foster greater policy support and pro-environmental behaviour intentions than more localized or individual framings. This may be because people see international cooperation as more likely to bring meaningful change, hence the scale of the measurement increases and therefore shows more impact. We therefore hypothesize that policy support varies by level of framing: European policy framing will lead to the highest policy support, followed by Dutch policy framing, individual framing, and no framing (H3). We further expect European policy framing to lead to the highest levels of collective efficacy, followed by Dutch policy framing, individual framing, and no policy framing (H4). Finally, we expect that the combination of a fear appeal and European policy framing will lead to the highest levels of collective efficacy (H5).

The current study investigates how communication strategies, specifically different combinations of fear appeal and policy framings, affect collective efficacy and public support



for climate measures. Recognizing that policy support often depends on the specific nature of the proposed measure, we assessed participants' responses to three distinct policies from different domains: (1) road pricing (transport), (2) an increase in the meat tax (dietary), and (3) a ban of free return shipments of online purchases (consumption). The study employed a 2 (fear appeal: present vs. absent) × 4 (framing: individual, national, European, no framing) between-subjects design. Participants (N = 2,069), recruited via a representative Dutch online panel, were randomly assigned to one of eight experimental conditions.

Half of the participants read a brief description of climate change risks (fear appeal). This was followed by descriptions of the three policy measures framed at one of the four levels (individual, national, European, or no framing). Participants then evaluated the three proposed policies and answered questions about their collective efficacy. To enable further exploratory analyses, we also collected data on self-efficacy, climate change worry, trust in the European Union and Dutch government, political orientation, perceived fairness, effectiveness, and personal impact of the policy measures, as well as intention to change. Data analysis is currently conducted.

Our findings will offer actionable insights for climate communicators, NGOs, and policymakers aiming to increase public support of ambitious climate measures. They will also contribute to theoretical debates on climate communication and collective efficacy. The results of this study (if accepted) will be presented at the BEHAVE 2025 Conference in Paris.

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Walking a tightrope: Acceptance and preferences for communicating self-restraint and sufficiency

Theme 5, sub-topic 5b, 6c

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, Willingness to Sacrifice, Self-Restraint, Behavior Change, Communication, Verzicht

Extended abstract

The urgent need for direct climate protection has brought the lifestyle changes towards sufficiency and, thereby, the concept of self-restraint¹⁴ to the forefront of environmental discourse. Widespread self-restraint and sufficiency in areas with high per capita CO₂ emissions like car use, air travel, or diet, could yield substantial climate benefits [2–4].

However, communicating about self-restraint is challenging. While there is a wealth of research on effective climate communication [5–7], the specific concept of climate-related self-restraint is yet understudied. In Germany, the term "Verzicht"¹ has been politically exploited in politics, leading to a negative connotation in discussions surrounding sustainable politics [8]. A recent media analysis reveals a polarized representation of self-restraint in German newspapers and indicates that the current media discourse does not align with established recommendations for climate-related communication [9]. This highlights the necessity of exploring effective ways to communicate about self-restraint. To address this research gap, we pose several research questions:

- *How can media messages promoting self-restraint be crafted to enhance acceptance and motivation?*
- *What factors are most critical in designing compelling messages?*

Utilizing a Choice-Based Conjoint (CBC) approach, we assess public preferences regarding message design by presenting participants with summarized newspaper clippings that advocate self-restraint. Instead of unrealistic evaluations of abstract communication details,

¹⁴ We translated the German term "Verzicht" to self-restraint / to forgo, as it has no direct equivalent in English. "Verzicht" refers to the conscious, voluntary act of refraining from an action or consumption, even though the opportunity or desire to do so exists. "Verzicht" is therefore associated with a feeling of restriction or deprivation [1].



this method allows participants to express preferences for realistic newspaper articles. Through this research, we aim to contribute valuable insights into effective communication strategies that can foster greater acceptance and willingness to forgo on the way to sufficiency.

METHOD

Five key factors relevant to message design on self-restraint were identified in the literature and included into the CBC (cf. Figure 1).

Which of these articles motivates you the most to forgo for the environment and climate?

Who is speaking? (Communicator)	A politician from a party you like states: (Politician)	A well-known climate activist states: (Activist)	A scientist states: (Scientist)
How vehement is the call to forgo? (Vehemence)	Everyone must forgo (Command)	Everyone should forgo (Demand)	Everyone could consider forgoing (Suggestion)
How are the consequences of forgoing behaviour described? (Framing)	because this way we do something good for the environment and climate. (Gain-positive)	because this way we can prevent worse impacts on the environment and climate. (Gain-negative)	because our behaviour would otherwise have serious consequences for the environment and climate. (Loss-negative)
How is the forgoing behaviour motivated? (TPB)	Forgoing behaviour is necessary and sensible and also has positive effects for you personally (e.g. health or happiness). (Attitude)	Your family and friends support forgoing behaviour or even forgo themselves. The community can motivate you and you can be a role model for others. (Subjective Norm)	In everyday life there are many alternatives , and everyone (including you) has the ability and resources to forgo. (Perceived behaviour control)
	Select	Select	Select
Would the article selected above actually motivate you to forgo for the environment and climate?			
Yes			
No			

Figure 1. Example choice task and overview over factors and factor levels.

1. The **communicator**, particularly trust in the communicator, has been identified as an important factor in climate communication [10–12].
2. Based on the findings of a recent media analysis [9] and the importance of wording in climate change communication [13,14], we included the **vehemence** of calls for selfrestraint on a word level.



- Furthermore, we varied the **framing** of the messages according to the goal framing approach by [15], focusing on the outcome of the climate-related self-restraint.
- The Theory of Planned Behavior (TPB) [16] is one of the fundamental theories to describe the relation between attitudes and actions and has been applied and validated to study environmental behaviors [17,18]. Based on these influences, we developed **motivational arguments** that focus on either of the three main influences on behavioral intention postulated in the TPB: attitude, subjective norm, and perceived behavioral control (PBC).

Questionnaire: Participants completed eight choice tasks where they chose which of three summarized newspaper articles was most motivating (cf. Figure 1). A Dual-Response None option allowed participants to indicate whether the chosen message would motivate them to forgo. The CBC was part of an online survey that gathered socio-demographic data and assessed political attitudes [19], environmental awareness [20] and willingness to sacrifice [21].

Data Cleaning and Analysis: We excluded incomplete responses, failed quality checks, and speeders. Reliability of psychometric scales was verified with Cronbach's alpha ($> .7$). Hierarchical Bayes Analysis was used for conjoint analysis.

Sample: We recruited a convenience sample from Germany through social circles. The acquisition of participants is ongoing at abstract submission. Currently, our sample includes 136 participants who are predominantly young and higher educated than the German population (see Figure 2).

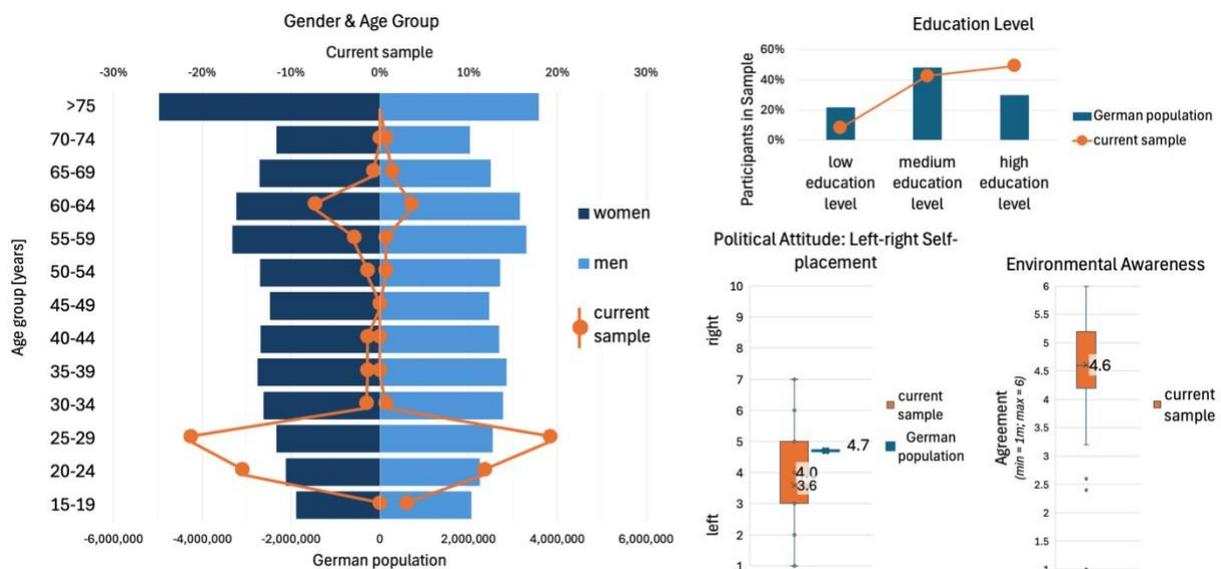


Figure 2. Sample Description (n = 136).

RESULTS

Figure 3 depicts the key results. As most significant factor for a motivating newspaper article, the vehemence of the call for self-restraint emerged, followed closely by the communicator. The motivational argument and framing of climate consequences are less influential.

Thereby, *demands to forgo* are most favored, while *commands* are least motivating. *Scientists* are the most motivating communicators, whereas *activists* and *politicians* are least effective. The most preferred motivational argument highlights the benefits of self-restraint (based on *attitude*), followed by emphasis of social support (based on *subjective norm*). Arguments

focusing on individual capability to forgo were least motivating (based on *PBC*). Framing consequences in a *gain-positive frame* was least motivating, while *gain-negative framing* proved most effective. However, the differentiation between the frames is comparably limited in its importance for a motivating newspaper article. Overall, many articles were not perceived as motivating (c.f. utility of the *none-option*) despite a moderate willingness to forgo observed in our sample.

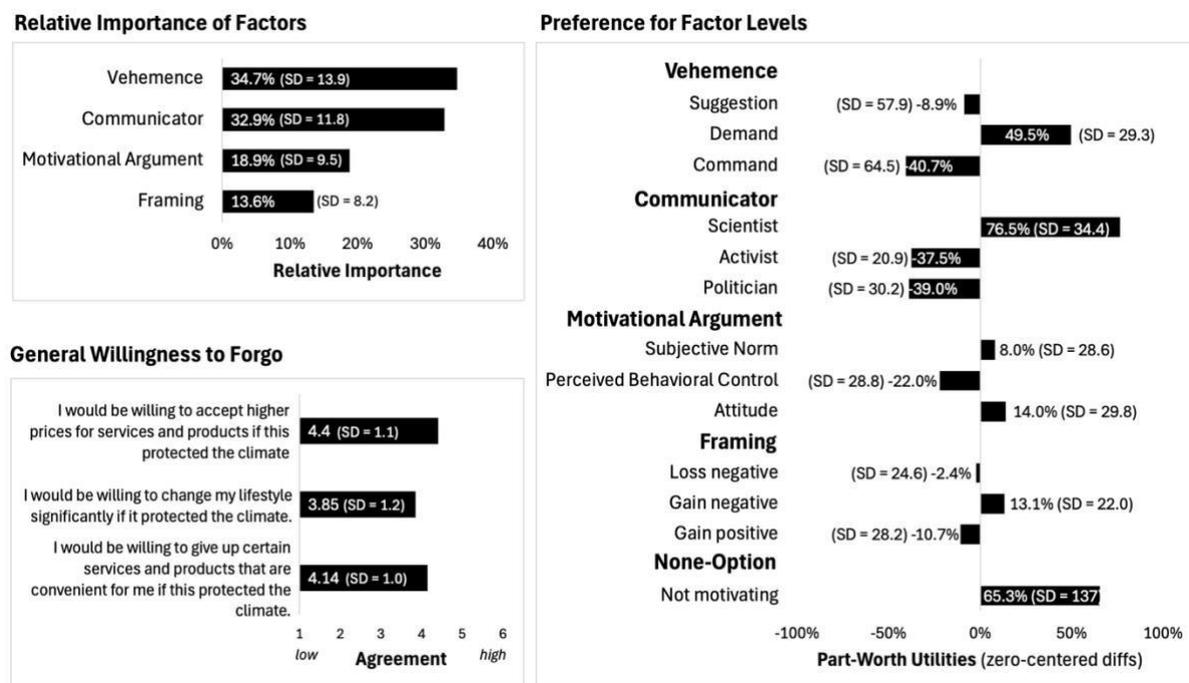


Figure 3. Results (n = 136).

DISCUSSION AND CONCLUSION

Despite that one in two people in Germany consider individual consumption reduction to be an effective measure against climate change [22], action is often not take [23]. Communicating self-restraint is particularly challenging, as the concept is intrinsically linked to costs [1] and is politically and emotionally charged. This is also reflected in the moderate willingness to forgo in our study and the low motivational impact of the newspaper articles.

Our results on self-restraint mirror findings on climate communication, like the importance of the communicator [10,12,24], with a strong preference for scientists and a less trustworthy image of politicians [12,25], and the motivational effectiveness of gain-negative framing [15,26]. That the TPB arguments are only moderately relevant and PBC shows the least motivating effect seems contradictory to previous research [27] but may be explained by the shortened arguments in the study and the hypothesis that PBC cannot be conveyed well in a newspaper article. The high importance of the vehemence is an intuitive result, however, the preference for *demands* which may be perceived as moralizing and preachy needs to be handled with care. While *demands* may be most motivating according to our research questions, they may still not be the best way to communicate about self-restraint as this may trigger reactance and resistance to the whole cause [24].

The results offer valuable insights into effective communication strategies to motivate selfrestraint. Looking at the best-case, messages are most motivating when they include scientists' demands, specifically address the advantages of self-restraint and use gain-negative

framing. Particularly, the message tone needs to walk the tightrope between unmotivating suggestions and reactance-promoting commands.

Still, the analysis to date is limited by the small, imbalanced sample. Through further acquisition, a larger and, particularly, more balanced sample is targeted for the conference, enabling analysis of user diversity, as previous findings show that social groups differ greatly in their willingness to forgo [28,29]. The innovative conjoint approach to message design enabled a more realistic choice for participants than, for instance, rating scales on abstract message characteristics. However, the formatting and the very short sentences still could not reflect realistic newspaper clippings.

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Shifting the gaze: An assessment of children experiencing energy poverty in the Netherlands

Theme 2, sub-topic 2b)
Policy/practice contribution

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KEYWORDS: Children, energy poverty, energy home injustice, policy

Extended abstract

Energy poverty – defined as the inability to secure adequate warmth, cooling, lighting, and energy to power appliances at an affordable cost – has traditionally been analyzed through the lens of adult experiences and at the household level. Although a growing body of scientific literature has begun to consider individual household members[1], this paper shifts the research and policy focus to children as distinct stakeholders within the home. By doing so, we aim to call for a better understanding of the specific energy needs of children and the consequences when these needs are shift the policy focus towards a demographic group largely devoid of political agency.

The paper, therefore, sets out to achieve three things: (1) to contextualize the issue of children experiencing energy poverty in the Netherlands, (2) to offer a descriptive statistical estimate of the number of affected children and their demographics, and (3) to call for further research and targeted policy action. To our knowledge, this is the first study in Europe to present a robust estimate of the national number of children experiencing energy poverty.

Literature review

In Dutch policy, child poverty and energy poverty are addressed as two separate domains. With child poverty being considered as poverty experienced by children and young people and energy poverty as household with a low-income and a high energy cost or/and a low energetic quality. However, the implications of experiencing energy poverty as a child and how this influences a child's upbringing, remain underexplored and under addressed. Academic evidence suggests that experiencing energy poverty could increase respiratory disease [2] chronic illnesses [3] household spending on health care[4], decrease mental health and school performance[5]. Although child poverty is an established policy field in the Netherlands a strong connection to the build environment, a child's energy needs, and the health effects of children experiencing energy poverty is lacking.

On a European level, literature confirms that children are disproportionately affected yet systematically overlooked in policy design [6]. While most national statistics measure energy poverty at the household level, this approach gives us little to no insight into the specific ways in which children experience, internalize, and respond to energy poverty. For instance, households with children tend to have higher energy needs, due to more frequent use of heating, lighting, and hot water, but are less flexible in cutting back on usage without compromising children's health or educational performance[7,8].

Methodology



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This study bases itself on statistical data of all households in the Netherlands, provided by the Dutch Central Bureau of Statistics, from the period 2019-2023. The data was used to calculate descriptive statistics on the number of children experiencing energy poverty in the Netherlands. In accordance with Dutch research on energy poverty, indicators combining a low income and a high energy bill and/or a low-energy efficient home were used. Further demographics were added to provide insight in the household characteristics in which the children live.

Results

First, we show that approximately 9% of children in the Netherlands experience some form of energy poverty in 2023. We show that there is a declining trend of children experiencing energy poverty since 2019, which has decreased from 22%. This steep decline can be explained due to the fact that the Dutch government has focused on the one hand improving the building stock, while on the other supporting households with subsidies. The data further reveals that children experiencing energy poverty are more likely to live in single-parent households, often with a female main earner, and more frequently have a 26 migration background. Additionally, they are disproportionately represented in rental housing, homes built before 1965, and dwellings with low energy efficiency.

Discussion

We argue that energy poverty in the Netherlands is not only an issue of economic hardship and housing inefficiency, but also a profound social injustice that shapes children's lives. Comparing child poverty rates with children experiencing energy poverty data shows the scale of the issue: in 2023, around 4% of Dutch children lived in poverty [9] whereas nearly 8.7% experienced energy poverty. This suggests that child energy poverty is a much broader problem than child poverty, and although the steep decline suggests that housing conditions are increasingly improving, it is unclear how and if deprivation might continue.

Our findings thus underscore the need to further investigate the energy needs of children experiencing energy poverty, particularly health, education, and social equity. Furthermore, to effectively combat home energy injustices faced by children, we must begin by understanding their specific energy needs and how these evolve over time. Lastly, we should ensure that children are able to participate within the political arena as recognized energy citizens.

Policy recommendations

Based on the findings stated above, we have formulated some policy recommendations. Responses to energy poverty in the Netherlands have focused on financial relief by lump sums of money and quick-fix energy support. While these are necessary emergency measures, they do not address the energy needs children may have, how they change over time, and how they shape their lives. We therefore call for both research and policy to focus on the lived experience of children and embed energy equity within child welfare, education, and housing strategies.

Specifically, the article proposes a policy framework that incorporates (1) the recognition of children as distinct stakeholders in household energy systems, (2) integration of energy vulnerability into child- and energy poverty programs, (3) participatory policymaking that includes children and families.

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Beyond Technical Solutions: Integrating Social Data to Reduce Inequality in Urban Energy Transitions

Themes 1 & 2, sub-topic 1c) & 2b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Building retrofit strategy, Energy transition, Mediation analysis, Energy behaviour

Extended abstract

1. Introduction

Our project, DE-CIST¹⁵, developed a physics-based, AI-driven simulator predicting household gas and electricity demand by integrating building characteristics with local social and behavioural data. Focusing on Rotterdam, we show how factors such as socio-economic status, demographics, and neighbourhood dynamics shape residential energy use. This was our first step towards nuanced ‘energy-profiles’ for use in the AI tool, using granular secondary data to untangle complex relationships and strengthen energy-use profiles based on social and demographic attributes. By bridging technical and sociological dimensions, our work fills a gap in existing energy modelling [5],[6],[7]; moving beyond data-driven interventions focused only on physical or financial factors, and supporting effective, socially and spatially-aware policy. The results presented here informed a further cluster analysis, and alongside qualitative insights from the project, the creation of more in-depth area energy-use profiles in further research.

2. Analysis

Our analysis used 100 by 100m² grid data [8] and aggregated neighbourhood data [9]. The theory behind household energy use is broad, ranging from behavioural economics [1] to relational sociology [3], [4]. Using a cross-sectional, multi-level design, we tested relationships between literature-identified variables and household gas and electricity use, as well as among the variables themselves, unifying some variable domains identified by different parts of the literature.

We selected socio-economic (property-value, ownership/tenure type [10],[11]); demographic (migration background, age [2],[12]); household composition variables (household size, children, single-parents [2],[3],[4]), and one built fabric variable (build year [13],[14]). At the neighbourhood level, we selected variables representing social cohesiveness, as the literature shows it is important for energy behaviour [3],[4].

¹⁵ DE-CIST: Developing Energy Communities with Intelligent and Sustainable Technologies



Initial modelling revealed nearly all variables had non-linear relationships with gas and electricity-use (to differing extents). We accounted for this, using centred linear and quadratic terms in subsequent models where appropriate. Because gas and electricity use share unobserved influences, we first estimated a seemingly-unrelated regression (SUR). The SUR results indicated (i) shared hidden variation and (ii) whether a neighbourhood-level random intercept was needed in the subsequent multilevel models. Next, we fitted a series of regression models checking for confounders. We then added mediators to outcome models to decompose each variable's total association into (i) indirect paths through mediators and (ii) direct paths, disentangling complex associative pathways suggested by theory (e.g. [1],[3]). We then added interaction terms to test associations in different contexts, i.e., how built forms and tenure interact for higher or lower energy use.

Finally, to capture multivariate associations and unmeasured spatial effects, we ran a random intercept multilevel model, including both linear and quadratic coefficients. We then checked the remaining residuals for spatial clustering to check if our estimates hold when neighbourhood structure is accounted for. Analysis was done in *R 4.5.0* [15] using packages *dplyr* [16], *systemfit* [17], *Lme4* [18] and *mediation* [19].

3. Results and Discussion

Multilevel Model

Table 1: Results for multilevel modelling on both gas and electricity use DVs, accounting for non-linear effects.

Predictor† (z-scaled)	Gas-use β (CI, 95%)	Shape	Electricity-use β (CI, 95%)	Shape
% children (0-15 yr)	-47.8*** (-60.50, -35.02)	concave \downarrow ($\beta^2 = -25.5***$)	-93.1*** (-107.98, -78.18)	concave \downarrow ($\beta^2 = -33.8***$)
% elderly (65+ yr)	-20.6** (-34.54, -6.61)	\approx linear (β^2 n.s.)	-59.5*** (-75.88, -43.22)	slight convex ($\beta^2 = +5.1$, $p = .09$)
Mean HH size	+50.3*** (+30.27, +70.34)	inverted-U ($\beta^2 = -15.8***$)	+261.3*** (+237.84, +284.68)	convex \uparrow ($\beta^2 = +20.5***$)
% single-parent hh	-19.7* (-36.20, -3.19)	U-shape ($\beta^2 = +9.1**$)	+1.6 n.s. (-17.70, +20.90)	concave \downarrow ($\beta^2 = -9.3**$)
Mean WOZ value	+322.9*** (+297.20, +348.65)	weak concave \uparrow (β^2 n.s.)	+650.6*** (+620.68, +680.55)	concave \uparrow ($\beta^2 = -37.6***$)
% rental dwellings	+16.5* (+3.07, +29.97)	convex \uparrow ($\beta^2 = +21.0**$)	-53.8*** (-69.54, -38.09)	weak U (β^2 n.s.)
% flats	-79.7*** (-97.29, -62.03)	concave \downarrow ($\beta^2 = -38.0***$)	-50.9*** (-71.41, -30.31)	U-shape ($\beta^2 = +27.4**$)



% non-W. migrants	-2.1 n.s. (-17.22, +13.02)	U-shape ($\beta^2 = +27.9^{***}$)	-12.9 n.s. (-30.53, +4.77)	trend concave ($\beta^2 = -10.5, p = .07$)
Median build year	-215.2*** (-226.10, -204.22)	concave \downarrow ($\beta^2 = -93.0^{***}$)	-30.4*** (-43.17, -17.62)	concave \downarrow ($\beta^2 = -17.6^{**}$)

All covariates are centred and scaled (SD = 1). Gas-use = m³ per dwelling · yr; Electricity-use = kWh per dwelling · yr. CI = 95% confidence interval. Significance: ***p < .001, **p < .01, *p < .05. n.s = non-significant. “Shape” refers to the joint linear + quadratic pattern: concave \downarrow = falling at an increasing rate, convex \uparrow = rising at an increasing rate, inverted-U = peak, U-shape = trough.

Our multilevel regressions show that grid-level socio-demographics and housing stock features are joint - often non-linear - associates of energy demand. Gas-use is consistently negatively linked with newer build years (-215 m³ SD⁻¹; concave), flat shares (-80 m³ SD⁻¹; concave) and elderly or child populations, but rises at a diminishing rate with property value and rental share. Electricity-use shows similar trends, though the directions sometimes invert. Rental share is negative (-54 kWh SD⁻¹) while household size and property value are positive and large (+602 kWh SD⁻¹, +651 kWh SD⁻¹). In terms of confidence intervals, point estimates for high rental areas, new build years, flats, and high property values are tightest and consistently predict energy use. Demographic predictors are less certain. Child and elderly share CIs are moderate, whereas single-parent and migrant shares show wide intervals that span or brush zero in at least one model; the associative weight of these latter effects should be considered with caution.

The fit measures show that the neighbourhood structure matters: 44 % of the explainable variance in gas-use and 34 % in electricity-use within grid-squares lies between the 66 neighbourhoods in which they are nested (adjusted ICCs = 0.44 and 0.34). Model fit is acceptable with negative singularity checks indicating stable variance-component estimation¹⁶.

Both models suggest energy-use profiles; owner-occupied, high value, detached-housing areas use the most, whereas rental, flat-dominated areas use less. The moderation and mediation analysis below explores in more detail the inter-associations between built-form, occupancy and demographics.

Mediation/Moderation Analysis

Table 2: Most meaningful/significant moderation/mediation results

Pathway	Effect	Type
% single-parent households → Flats → Gas-use	-42.9 m ³ (indirect); -41.3 m ³ (direct)	Mediation
% single-parent households → Renters → Gas-use	-79.2 m ³ (indirect); -5.1 m ³ (direct, n.s.)	Mediation

¹⁶ Intraclass correlation coefficient (ICC) partitions variance: an ICC = 0.44 (gas) or 0.34 (electricity) means 44 % and 34 % of the total explainable variance sits at the neighbourhood level rather than within grids. *Singularity checks* test whether estimated variance components collapse to zero; “no” implies random-intercept variance is identifiable and the model is not over-parameterised.



% residents \geq 65 y \rightarrow %Flats \rightarrow Gas-use	-16.2 m ³ (indirect); +4.9 m ³ (direct, n.s.)	Mediation (weak)
% non-Western migrants \rightarrow Renters \rightarrow Gas-use	-55.6 m ³ (indirect); -101.9 m ³ (direct)	Mediation
%Flats \times HH-size \rightarrow Gas-use	+75.9 m ³ per SD	Moderation
% Flats \times HH-size \rightarrow Electricity-use	-144.7 kWh per SD	Moderation
% Flats \times median build year \rightarrow Electricity-use	-72.2 kWh per SD	Moderation
Median build year \times % rental \rightarrow Gas-use	+79.6 m ³ per SD	Moderation
Median build year \times % rental \rightarrow Electricity-use	-38.3 kWh per SD	Moderation
Median build year \times WOZ value \rightarrow Gas-use	-31.3 m ³ per SD	Moderation
Median build year \times WOZ value \rightarrow Electricity-use	+73.9 kWh per SD	Moderation
% residents 0 to 15 \times HH size \rightarrow Gas-use	-71 m ³ per SD	Moderation

Mediation tests explain why some main associations change direction between gas and electricity use. A higher share of single-parent households sees lower gas-use directly (-41 m³) and indirectly via associations with flat proportions (-43 m³) and rentals (-79 m³). Likewise, neighbourhoods with larger elderly populations see lower gas-use through a smaller positive link with flat density (-16 m³). A high concentration of non-Western migrants is linked to lower gas-use directly (-102 m³) and via rental-proportion (-56 m³); tenure is constitutive rather than overwhelming. Together, these relationships show that built-form and tenure carry demographic associations with energy use. Moderation analyses suggest fuel-specific interactions complicating the above. First, the impact of flat prevalence depends on household size; increased flat share raises gas-use by +75.9 m³ for larger households but reduces electricity-use by -144.7 kWh. This suggests higher-occupancy apartments are electricity-efficient but less efficient in gas-based heating or cooking. Second, build year interacts with rental concentration; newer rental stock is linked to lower electricity-use (-38.3 kWh SD⁻¹) but higher gas-use (+79.6 m³ SD⁻¹). Both results seem counter-intuitive; newer buildings generally have lower energy use, but not in these contexts, pointing to structural inefficiencies or behaviours associated with non-ownership. A similar inverted asymmetry appears when interacting build year and property value (-31 m³ vs +74 kWh), suggesting wealthier areas with newer housing stock have better insulation but higher electricity usage. Wealthier households likely have more appliances. Finally, testing the strong negative association of area child density with energy use, child proportion moderated the household-size effect on gas-use (-71 m³ SD⁻¹). This suggests larger



families economise on energy use, consistent with non-linear associations in the multilevel model.

From these relationships, we suggest three tentative energy-use profile areas. (i) areas characterised by high percentages of flats, rentals, migrants, and single-parent populations with low gas-use, inverted under certain conditions. This could reflect social structures or behaviours related to non-ownership or shared utilities. (ii) neighbourhoods with larger households, higher child densities, mid-range property values, and 1960–1990 housing stock show the highest, most non-linear gas-use and moderate electricity-use, tied to child-share. Defining factors here are likely single-family homes with children. (iii) owner-occupied areas built after 2000 with high property values, relatively low gas-use, but higher electricity-use. These properties are likely well-insulated, but higher electricity-use could reflect expensive appliances or EV charging.

4. Conclusion

Together, these findings demonstrate that social factors - household composition, tenure mix, demographic make-up - shape in different ways the association of built form with energy demand under varying conditions. Accounting for this complexity in data-driven public outreach and intervention strategies will better reflect the complex social realities of urban communities. We have also made a first attempt at creating granular, energy-use area profiles, to be expanded in later work using clustering methods alongside qualitative inquiry. Finally, this is a strong first step toward synthesising a more social understanding of energy-behaviour mechanisms with data-driven policy tools, enabling not only more successful energy interventions but also more inclusive policymaking.

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Minimum viable energy - Perceived minimum electricity needs in energy crisis scenarios

Theme 6, subtopic 6b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: energy crises, essential energy needs, emergency demand reduction, public perceptions

Extended abstract

Introduction and Study aim

Human-driven climate change is intensifying extreme weather events, such as heatwaves, heavy rainfall, and droughts [1], with serious consequences for health, infrastructure, and power supply [2], [3], [4], [5]. As climate-related disruptions and geopolitical tensions grow, the risk of electricity disruptions in Europe is becoming more urgent. Examples of large-scale impacts of weather extremes are the storms Gudrun (2005), Dagmar (2011), and Ivar (2013) causing widespread blackouts and telecommunication failures in Scandinavia [6], [7], [8], and the recent heat wave (June 2025) resulting in peak electricity prices across Europe [9].

Temporarily reducing residential electricity consumption, either via load rationing or via emergency demand response programs [10], [11], [12], can help reduce risk of blackouts during times of emergencies or crises [12], though the success of such programs relies on consumer



uptake of such programs, as well as public willingness and ability to reduce consumption. In severe crises, authorities may decide to issue warnings or appeals to all civilians to cut consumption to help maintain grid stability and protect critical services. Even when most people are willing to comply to public appeals [13], little is known about how much electricity households can realistically forgo, and are willing to forego, during emergencies. In other words, the boundary between what is perceived to be “essential” and “expendable” electricity use under crisis conditions remains largely uncharted.

A further challenge is that people often lack accurate mental models of how much electricity common appliances consume, and therefore what would be most beneficial to reduce. Research suggests that individuals tend to underestimate the usage of high-consuming appliances while overestimating the impact of low-consuming ones [14], [15], [16]. This results in the risk of households exerting effort into changing behaviours and routines to reduce appliances with low effect on the electricity grid, while not changing high-impact appliances. It remains unclear how these misconceptions play out in emergency contexts, where time, stress, and uncertainty may further distort perceptions of what can and ought to be reduced.

This study investigates how Swedish households perceive their minimum necessary electricity use during emergencies, focussing on the difference between households’ baseline appliance use and perceived essential need of appliances in emergencies. Participants are presented with one of two crisis scenarios: one involving large-scale, unpredictable blackouts, and another involving short, scheduled outages. By comparing baseline and crisis-time estimates of electricity needs per appliance, the study aims to assess how far voluntary reductions could realistically extend under emergency conditions. It also provides insights for communication strategies, such as identifying which appliances are commonly viewed as expendable versus essential, which can guide public appeals and educational efforts prior to and during future crises.

Methods

A sample of 800 Swedish adults will be recruited in an online survey panel, with stratified quotas to ensure demographic representation in terms of age, gender and region of residence. Respondents are subsequently randomly assigned to one of two emergency scenarios. In both scenarios, the scenario puts Sweden in a hypothetical time of sabotage and cyberattacks. In both scenarios, respondents are shown a public announcement where civilians are warned that electricity supplies are unstable and where large-scale reduction of electricity consumption is required to avoid negative outcomes. In the severe scenario, the negative consequences concern unplanned widespread blackouts for unknown periods of time, limiting even access to water and heating and digital communication. The mild scenario instead concerns consequences like planned outages (i.e., load shedding) for short periods of time.

Respondents assess their household’s appliance use per common device (e.g., number of fridges, use of stove or microwave, laundries run per week), after which they are presented with one of the two above-described scenarios. Subsequently, they are asked to assess items measuring perceived severity, self and response efficacy and willingness to comply with the request, as well as indicate, per appliance, what the minimum use of the device would be under the presented scenario. The answers to these appliance-level questions, both from baseline and from crisis-scenario, will be converted to approximate household consumption, using pre-existing average appliance-level consumption data. In addition to these main measures, the survey collects data on household composition (e.g., number of residents,



presence of children), housing type (apartment, single-family home), urbanicity, and regional location. These data allow for subgroup comparisons to assess whether perceived essential needs differ depending on household structure or context.

Results and Implications

Results will illustrate the degree to which Swedish households perceive they need to use electrical appliances during a crisis, and how much this perceived need differs from their typical consumption. The study will also identify which appliances are seen as more essential versus more expendable, offering insight into what types of electricity use are considered negotiable under emergency conditions. Furthermore, we will examine whether perceived minimum requirements vary depending on the severity of the crisis scenario. Finally, we will explore whether these responses differ across household types (e.g., urban vs rural, family composition) and how they covary with psychological factors such as perceived risk severity and self-efficacy.

These insights have practical implications for both technical and policy domains. The study can inform models of demand-side flexibility by providing empirically grounded assumptions about the boundaries of realistic household reductions during emergencies. This adds behavioural realism to technical models of voluntary reduction and sheds light on how households mentally categorise electricity uses into “essential” versus “expendable” in high-stakes situations.

The study can moreover support the design of more effective communication strategies. On one hand, knowing perceptions on essential electricity needs of different societal groups allows messaging to resonate with such groups. Segments of the population with lower capacity of reducing electricity use may be identified, such as those with lower self-efficacy or higher household needs. Such groups could be targeted with tailored support, including financial assistance, alternative services, or specific guidance. On the other hand, identifying common misconceptions, such as overestimating the impact of small appliances or underestimating the load of larger ones, enables targeted corrections. If, for instance, many people assume that skipping a few coffee brews will meaningfully help in a power crisis, then clear and actionable guidance may be needed to redirect efforts toward high-impact behaviours.

As Sweden strengthens its resilience to electricity-related emergencies, understanding the public’s perceptions of what energy is essential, and what is expendable, is vital. This study offers an empirical step in quantifying that grey zone between luxury and necessity in household electricity use. It further clarifies how demographic background, psychological variables and crisis framing shape people’s imagined responses, and what that means for managing public cooperation during future energy crises.

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Beyond technology and energy supply. Conceptualising a toolbox for including sufficiency measures in scenario projections

Theme 6, sub-topic 6a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, Energy efficiency, Scenarios, Modelling, Behaviour, Decarbonisation

Extended abstract

Objective and scope

This work gives an overview on findings from a five-years' sufficiency research project regarding the tools in the box for modelling sufficiency in the German energy system context. We conceptualize sufficiency quantification by distinguishing between demand-side and supply modelling, external quantifications and policy impacts.



On a higher level, studies on "demand-side options" indicate substantial GHG mitigation potential, ranging up to 78% globally [1], [2], [3]. Regionally, the EU's CLEVER scenario projects a 50% reduction in final energy demand (FED)[4], while the UK anticipates a 52% FED reduction by 2050, with avoid/shift strategies contributing 50-90% [5]. Similar findings exist for Germany [6], [7]. A meta-analysis of approximately 100,000 academic publications on "demand reduction" highlights the crucial link between behavioral change and social norms, noting that demand-side solutions generally improve public health and require political intervention for implementation [8].

Incorporation of the sufficiency concept into scenario modeling is an emerging area. Reviews by van den Berg et al. [9] and Saujot et al. [10] examine the integration of lifestyle changes and sufficiency into integrated assessment models, emphasizing the necessity of connecting lifestyle changes to policy frameworks. European studies, such as one analyzing "new societal trends" [11] and another by Costa et al. [12] that found a 20% GHG reduction in the EU due to lifestyle changes (without explaining emergence), contribute to this field. The European FULFILL project has recently integrated sufficiency assumptions for five European countries into scenario projections [13], observing that while emission reductions were accompanied by negative impacts on GDP and employment [14], the impact on a "Sustainable Prosperity Index" was positive [15]. National examples include France's sufficiency scenarios from Association négaWatt [16] and several major German scenarios that cover sufficiency, though often not explicitly using the term [17], [18], [19], [20], [21]. However, many government-commissioned [22], [23] and other prominent German scenarios [24], [25] do not reference sufficiency.

Modeling sufficiency in energy systems largely focused on supply-side aspects remains challenging due to sufficiency's demand-side nature, necessitating sectoral demand models. While Germany has building sufficiency scenarios [26] and transport research [27], [28], sufficiency typically enters these projections as exogenous input parameters rather than being endogenously modeled. Most sectoral models, such as large transport models like TREMOD [29] or TEMPO [30] and building stock models like ProgRESS [30], Invert/EE-Lab [31], or GEMOD [32], do not incorporate sufficiency measures endogenously. System-wide scenario studies for Germany, despite varying model architectures and assumptions, lack a systematic overview and comparison assessing the impacts of demand reduction on overall system configuration [33], [34], [35].

Methodology

Over the five years of researching how sufficiency can be represented in scenarios for energy transition, as a tool of policy information and counselling on options [36], we identified as helpful a high-level view of how energy systems are typically modelled. This view can be extended and complemented to include further impacts, information and sectors. A basic version is shown in Figure 1.

Energy system modeling generally encompasses demand-side and supply-side models. Supply-side models, frequently termed "energy system models," primarily address technological energy supply options, often integrating grid/network models and conversion technologies such as fossil or electric vehicles and various heating systems. These models are typically optimization-based. Their main inputs are energy or energy service demands, which are either assumed based on existing literature or generated by demand-side models and supplied as energy vectors by carrier and sector.



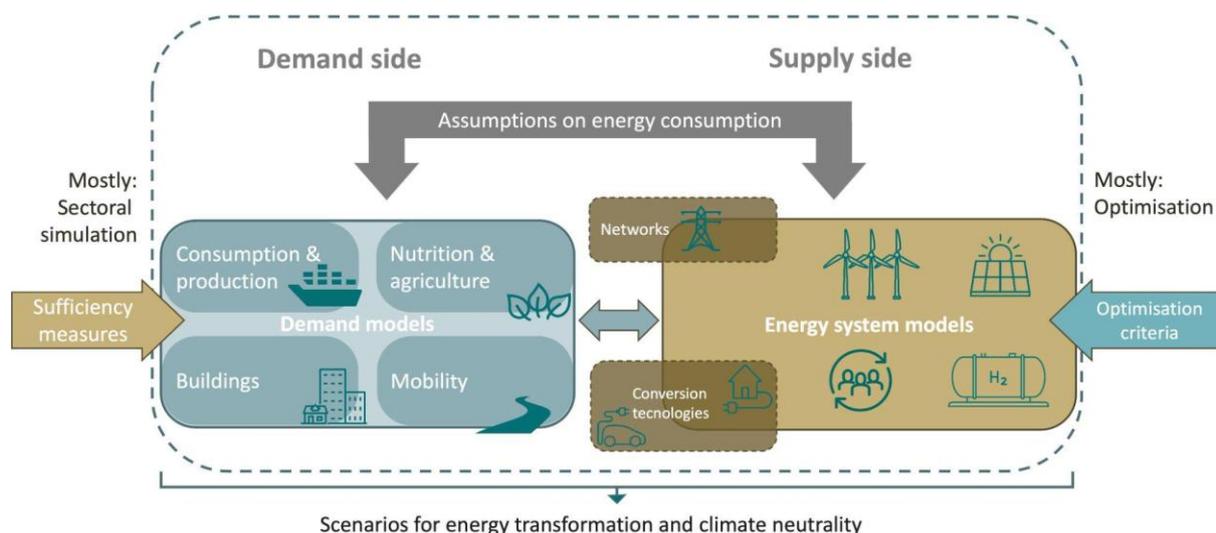


Figure 1: overview of typical energy system model elements and entry points for sufficiency.

Conversely, demand models are typically specialized by sector, reflecting the diverse logics and service demands that drive energy consumption across different areas. These models employ a variety of methodological approaches and are predominantly simulation models, rather than optimization models. The concept of sufficiency, which largely concerns demand-side actions, policies, and infrastructures influencing demand, presents a challenge for supply-side models. Sufficiency options generally enter scenario building through variations in energy demand. A burgeoning area of research involves incorporating sufficiency into supply-side models by including additional optimization criteria.

Sufficiency options at the demand side are numerous and again very context and sector-specific. To what extent they can be included in sectoral models depends on the specific model logic and architecture [37]. The scenario and modelling literature shows three general approaches in order to include sufficiency:

- Sectoral output adjustments: Energy system models without explicit demand-side components often adapt macro-level data with sufficiency assumptions, such as reduced transport demand or lower per-capita living space.
- Sectoral input assumptions: Explicit sufficiency modeling in sectoral scenarios often involves applying assumptions to simulate sufficiency-based projections, like changes in temperature settings, living space size, housing type, or transport mode shares.
- Endogenous policy modeling: Rarely do models endogenously simulate sufficiency impacts from external policy parameters (e.g., infrastructure changes, pricing). Many sufficiency aspects remain beyond current model capabilities.

In the EnSu research project, we have used and collaborated with others using all of the above approaches to quantify sufficiency impacts in various sectors (for an overview see <https://energysufficiency.de/en/resources-for-modelling/>).

For a new sufficiency scenario study on Germany, we set up a tool chain for developing and evaluating socio-technical context scenarios [38] based on the cross-impact-balance (CIB) method [39], [40]. Two of the resulting six climate neutrality scenarios for Germany are orientated to green growth and four are sufficiency-orientated with varying characteristics. We use scenario definitions to quantify energy demands with the simulation model Pathway Explorer (PWE) [41], [42] and feed results to the energy system optimisation tool PyPSA [43].

Conclusions from exemplary modelling studies

We find that most scenario studies do either not include sufficiency actions, or only on a very general level, based on strong assumptions – and very seldom as results from changes to policy frameworks and infrastructures. Supply-side models are little suitable to represent sufficiency, demand-side models are required. In order to capture sufficiency actions, respective sector models need to cover the logics of sufficiency impact chains, which is often not the case and excludes respective quantification. Models can however be developed in this direction and then show significant impacts of sufficiency action in scenarios.

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Reinventing our Ways of Life. From Awareness to Collective Action – Experimentation of New Indicators for Diverse and Just Sufficiency - Efficiency-Decarbonization Trajectories for the Well-Being of All

Theme 2, sub-topic 2a) 2b) 2c) 2d) Theme 5, sub-topic 5d)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: sufficiency, efficiency, alternative economic indicators, well-being, SPIRAL, Gaïa VL equation

Extended abstract

For many citizens, elected representatives, civil servants and social partners of local social economy organizations [1], making progress in the transition through a commensurate lifestyle change is like venturing into the fog. Starting with a transition topic raises many other issues, because the crisis is multifaceted. Searching for best practices requires choosing the right indicators beforehand. What's more, most data is either inaccessible or not adapted enough their specific questions, which limits their knowledge of potential options and their understanding of the impact of these choices. There is a lack of simple visuals and integrative indicators to facilitate diagnosis and planning.

Furthermore, debates about greenwashing, fears surrounding degrowth in relation to GDP (Growth Domestic Product) and scapegoating muddy the waters. This lack of visibility generates more anxiety and withdrawal than commitment.

More and more energy specialists are stressing the importance of the sufficiency trajectory topic, which involves lifestyle changes to reduce energy demand and carbon emissions. Sufficiency trajectories for France have been conceptualized since 2001 in the work of the



négaWatt association, and their importance is now being debated at a European scale with the Clever scenario [2], as well as in the IPCC's sixth report (2022). Since the Stieglitz-Sen-Fitoussi report¹⁷, a growing number of economists have agreed on the need for alternative indicators to GDP, to take account of ecological and social issues and the well-being of populations [3]. More recently, studies on the co-benefits of sufficiency and good living are developing, notably in France under the impetus of the ADEME Transition Agency [4].

Bearing this in mind, the authors a group of stakeholders, international networks and researchers, has set itself the following objective: to develop a tool that can visualize and share the current situation, and encourage desirable actions by highlighting the convergence between sufficiency - efficiency trajectories and good living together. The aim is to stimulate the interest of citizens and local authorities in collaborating to implement the energy, ecological and social transition at a local level. This presentation outlines this approach and how it is experimented in several pilot territories in Portugal, France and Cape Verde, as well as providing initial feedback, prospects and outstanding questions.

1 The measurement of the three footprints

In 2022-2024, we adapted a macroeconomic tool used for climate conferences to address human needs, incorporating the Doughnut theory¹⁸ and transforming it into educational and entertaining activities.

1a- New measurement equation (fig.1): Using the Gaïa VL equation¹⁹ instead of the Kaya equation²⁰ means that needs such as food and housing can be measured in physical units rather than monetary values. This makes it easier to understand real needs and environmental impacts. This highlights and prioritizes the three trajectories: sufficiency first, energy efficiency second, and decarbonization third.

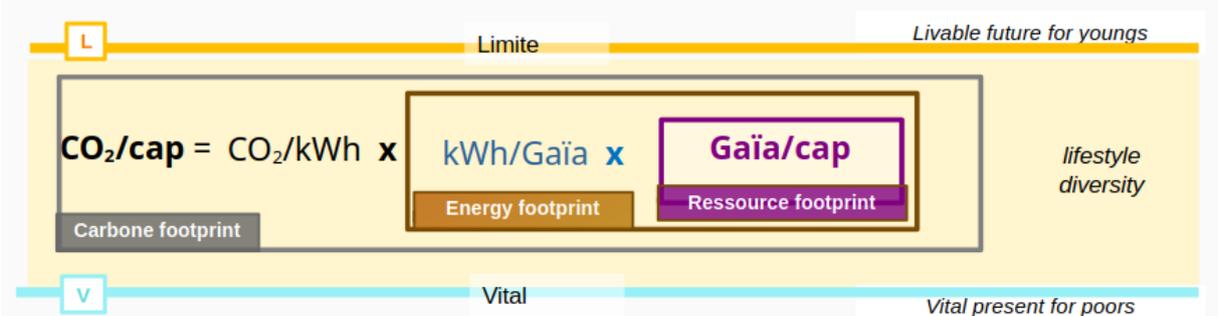


Fig 25: Gaïa VL equation, Gaïa stand for m² in housing, km in mobility ...etc. Sufficiency = decreasing Gaïa par cap, efficiency = decreasing kWh/Gaïa, decarbonization= decreasing CO₂/kWh

¹⁷ https://fr.wikipedia.org/wiki/Commission_Stiglitz
¹⁸ [https://en.wikipedia.org/wiki/Doughnut_\(economic_model\)](https://en.wikipedia.org/wiki/Doughnut_(economic_model))
¹⁹ <https://www.renoveco.org/equation-de-gaia>
²⁰ https://en.wikipedia.org/wiki/Kaya_identity

1b- Visual data representation (fig.2): The use of three spatial dimensions to represent the equation enables a clear and intuitive visualization of the data. For each need, goods consumed are represented by segments on an axis (purple), the energy required to produce them by surfaces (brown), and CO2 emitted by volumes (grey).

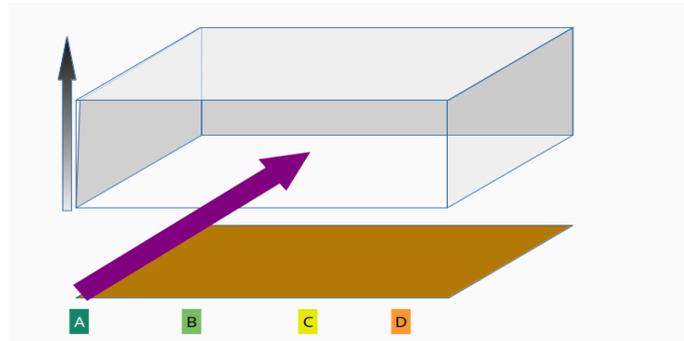


Fig 26: The three dimensions of the Gaia equation. In ordinate, the Gaia. In abscissa, the performance with energy labels. In height the carbon intensity

1c- Lifestyle in relief map (fig3): Creating a standardized 'lifestyle metric' (table1) enables the lifestyles of individuals or groups to be represented in a comparable way. This facilitates the compilation, comparison and monitoring of the effects of planned actions. 1 Gaia = 1 cm, 1,000 kWh = 1 cm², 0.25 t CO₂ = 1 cm³.

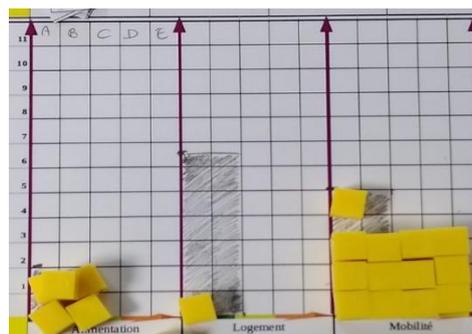


Fig 3: Lifestylemetric of 3 needs in relief map

Table 1: standardization of the needs footprints of an average family in France in cm, cm² et cm³

Needs	Quantity	Segment cm	kWh	square cm ²	T CO2	Cubes cm ³
Food	1,1 x Vital + 20 %	3,6	10 000	10	6,25	25
Housing	90 m ²	6	15 000 + 3000	18	6	24
Travelling	32 500 km	6,5	17 000	17	7,5	30
Equipment	1,7 x vital	4,8	16 000	16	4	16
Collective services	<i>not defined</i>				3,5	14
Total family	No possible cumulating		61 000	61	27,25	109
Per person (/2,7)			22 500	22	10	40

Meat 4 times a week dairy 6 x per week and 20% waste/ consumption 2400 kWh electricity and 10,000 kWh gas per year + 3000 kWh gray energy/ one car 11,000 km per year (5000 km alone and 6000 km with the family), Train with the family 800 km per year, Plane every 5 years long haul and once a year short haul



2 The local knowledge-building process

In 2025, we tested the extension of the SPIRAL²¹ approach to 'co-responsibility for well-being', developed by the Council of Europe, to ecological and social issues with the pilot sites in Odemira, São Lourenço (Cap-Vert), and Grenoble.

2a- CO2 emissions cap: Setting a CO2 emissions cap of 5 tons per person per year by 2025, with a gradual reduction to 2 tons per person per year by 2050, provides a clear and measurable target for emissions reduction efforts.



Fig 4: Session Grenoble École de Management janvier 2025

2b- Confrontation and Collaboration Sessions: The organization of confrontation sessions between neighbors (or collectives) to find solutions of trajectories together to reduce CO2 emissions encourages individual commitment and cooperation. These sessions help to co-define for each need a Vital (the minimum that would be fair to guarantee to each person in the territory), and a Limit (a ceiling considered harmful for the future).

2c- Game of well-being together (fig4): To facilitate its implementation, the approach is presented as a collective game. In 2025, it was experimented in pilot areas within neighborhood groups, schools, and associations; the first social development “facilitators” were trained. Their resulting collective action combine the variety of resources (time, money, carbon savings, skills, movable or immovable assets, etc.) arising from their diversity of social, professional, family and lifestyle situations, as well as age.

2d- Co-measuring the effects on well-being with SPIRAL [5]. By relying on the achievements of the SPIRAL method, participants identify their own individual and collective well-being criteria. They then discover how the approach and resulting actions meet these criteria, notably by reducing or even eliminating feelings and situations of ill-being, such as isolation, loss of meaning and anxiety about the future, guilt, etc...

3 Outlook

In 2026, it will be extended to other pilot territories on other continents in order to fine-tune and to assess its genericity. And it will be tested at other territorial scale

3a- Co-production of territorial data: Co-participation, by incorporating the knowledge and data of transition agencies, (external viewpoints) and citizen knowledge (internal viewpoints), produces fine-grained territorial data enabling a better understanding of local situations and the actions required to reduce CO2 emissions and improve well-being [6].

²¹<https://wikispiral.org/tiki-index.php?page=La+méthode+SPIRAL>



3b- Dialogue between territories: organizing same collaborative confrontation sessions between representatives of neighborhood in the same borough, and then between representatives of these boroughs in the same city (or rural area), enables to exchange best practices, consider political, legal and economic measures, and correct any undesirable side-effects resulting from the actions undertaken.

3c- Co-production of city climate action plans or others (energy, biodiversity, social cohesion, well-being, etc.) through citizen participation and skills-building, with municipal leadership, rather than top-down planning.

3d- Experimenting visual teaching tools at upper territorial levels. To answer the global challenge, and facilitate the transition from indicators and economic rules based on competition to those based on cooperation and peace [7], we will experiment Gaïa VL equation maps in one and two dimensions (fig. 5 6) in order to, put local to global and global to local trajectories into dialogue.

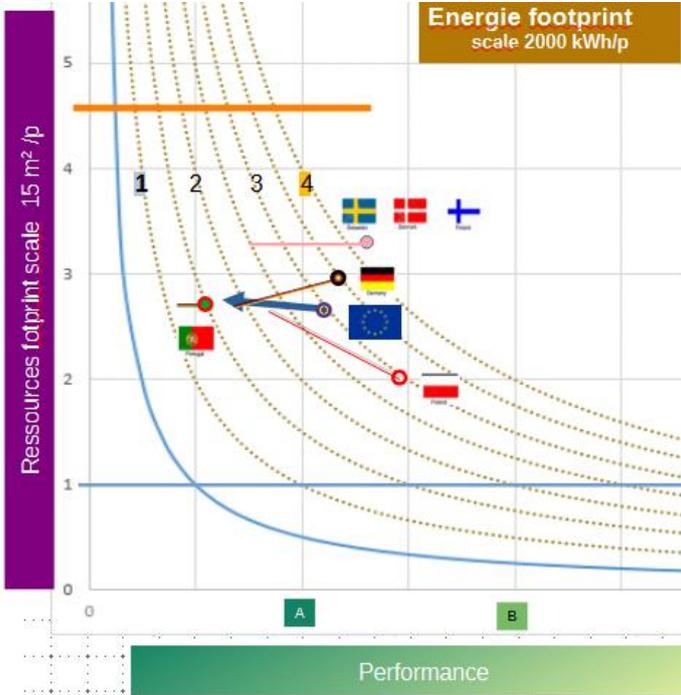


Fig. 5: Trajectories for housing in Europe from 2025 to 2050 according to the Clever scenario – case of Portugal, Germany, Scandinavian countries and Poland

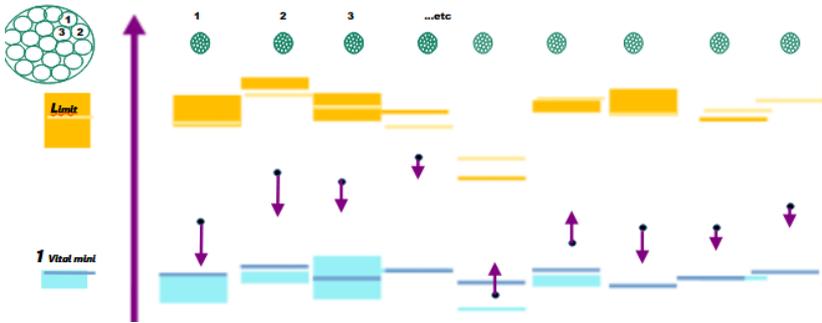


Fig 6 Footprint trajectories between Vital and Limit - comparison between neighboring territories

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What matters for heat pump adoption? Results from diagnostic surveys

Sub-topics: 1a; 1d; 3b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: heating systems; technology adoption; public perceptions; heating systems;

Extended abstract

Shifting from fossil-fuel heating systems is a core component of climate policy in multiple developed countries. Yet most countries have struggled to achieve mainstream adoption of low-carbon heating systems such as heat pumps (HPs). Diffusion of Innovations (DoI) Theory [1] offers a framework for understanding differences between consumers who adopt early and those more reluctant, with the potential for informing interventions that encourage adoption.

DoI posits that new technologies diffuse through a social system over time following an S-shaped curve, beginning with slow initial uptake, progressing through rapid growth, and ultimately reaching market saturation. Numerous studies have documented such diffusion patterns across diverse innovations [2 – Meade & Islam, 2006]. Central to DoI theory are factors such as individuals’ perceptions of a technology’s relative advantage, compatibility with existing practices, trialability, observability, and perceived complexity. Communication channels, ranging from interpersonal discussions to mass media, are proposed to play a pivotal role in influencing perceptions and adoption decisions. These information sources and perceptions may interact with individual-level personality traits, such as risk aversion, concern about social status and environmental concern, and socio-demographic characteristics, such as wealth.

Despite its prominence, several aspects of DoI remain under-tested in the context HPs. Existing studies often categorise individuals as potential early adopters based on broad demographic or psychographic traits, but these may vary in predictive value depending on the technology. For example, agent-based models simulating diffusion processes often assume that individuals can be classified into adopter categories based on personality traits that do not depend on the technology in question [3 – Meles & Ryan, 2022]. Critically, the decision-making context differs between technologies. For example, some technologies, such as EVs, may be adopted following a long-held plan for a car upgrade, HP adoption may occur reactively when an existing heating system fails, potentially compressing decision timelines and altering adoption dynamics.

To address these gaps, the present study provides an empirical test of key components of DoI theory in the adoption of HPs. Specifically, we examine whether adopter category can be predicted by: (i) technology perceptions, (ii) communication exposure, and (iii) individual characteristics. Our findings aim to inform both theoretical understanding of diffusion processes



and practical efforts to accelerate low-carbon technology adoption, including improving the assumptions underpinning agent-based models of technology diffusion.

Method

1,000 adults were recruited via a market research agency to complete an online survey in April 2025. Quota sampling was used to achieve national representativeness by age, gender, region, and socio-economic status. Participants reported on home ownership, heating systems, and upgrade intentions. Those without HPs were asked when they expected to upgrade and whether they would consider installing one. Adoption intentions were categorised in line with DoI theory: *early adopter*, *early majority*, *late majority*, or *laggard*.

Participants rated their perceptions of HPs across five DoI perception dimension:

- Relative Advantage (e.g., cost, comfort, reliability, environmental impact),
- Compatibility (installation hassle, disruption to routine),
- Simplicity (understanding of function, use, and running costs),
- Trialability (personal experience or exposure through others),
- Visibility (how often others in their area are seen using heat pumps).

Communication exposure was measured by asking participants whether they had heard about HPs via friends/family, media, social media, or professionals, and how positive or negative these messages were. Individual-level predictors included personal innovativeness, opinion leadership, environmental concern, status concern, risk aversion, and demographics.

Results

The distribution of adopter categories deviates somewhat from DoI predictions: 14.1% reported owning or intending to install a HP (i.e., innovators/early adopters), 45.3% are open to installing (early majority), 10.6% are cautious (late majority) and 29.7% are reluctant (laggards). A Chi-square Goodness of Fit test indicates that the observed distribution significantly deviates from the classic S-curve ($\chi^2 = 229,380$, $p < .001$), driven by fewer late majority adopters and a high proportion of laggards.

Perceived relative advantage of HPs versus existing systems shows a slight skew towards HPs as better, though the distribution spikes at the midpoint of the scale, with many of those responding as such reporting that they do not know how the heating systems compare. Similarly, lifestyle compatibility of HPs is marginally positive, though many appear uncertain. Though 26.8% reported some experience with HPs (i.e. trialability), in their own homes or in other properties, responses to perceived simplicity and visibility of HPs are strongly negative.

Those who reported hearing about HPs from family and friends, mass media, social media and industry professionals were more likely to report such communications were positive than negative (at a ratio of more than 3:1). However, half of all participants reported not hearing about HPs from any source.

Implications and Conclusion

These findings suggest that the diffusion of HPs in Ireland may not follow the classic S-curve anticipated by DoI. While a sizeable proportion of the population identifies as open to adopting HPs (early majority), a substantial minority remain reluctant, indicating potential barriers to widespread uptake.

Perceptions of heat pumps are mixed. Although many respondents see potential advantages and some degree of compatibility with their lifestyles, a significant share remains uncertain or lack



sufficient knowledge to form opinions. Notably, perceptions of heat pumps as complex and largely invisible in the community represent important obstacles to adoption.

Communication about heat pumps is overwhelmingly positive among those exposed to it. However, the fact that half of participants reported hearing nothing about heat pumps highlights a major gap in public awareness and engagement.

These results suggest that adoption, or at least openness to adoption, can be accelerated by reducing uncertainty around HPs, for example by delivering clear, comparative information on heat pumps versus conventional systems. Demonstrations, case studies, or opportunities for hands-on experience may help to improve perceived simplicity of HPs, while increasing visibility of heat pumps in local communities may help normalise adoption. Finally, expanding communication efforts, especially through trusted channels like family, friends, and industry professionals, to reach those currently unexposed to the topic may further help to improve perceptions and thereby openness to adoption.

Overall, targeted efforts to improve knowledge, simplify perceptions, and make heat pumps more visible and relatable may help shift larger portions of the population out of the laggard and cautious categories, supporting decarbonisation goals.

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Understanding energy poverty: the lived experiences and policy preferences of affected households in the Netherlands

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy poverty, just transition, policy, behaviour, energy consumption, lived experience

Extended abstract

In 2023, an estimated 400 thousand households lived in energy poverty in the Netherlands [1]. In order to combat energy poverty effectively, the qualitative study of energy poverty has gained increasing importance over the last twenty years [2]. After all, not all aspects of energy poverty can be captured through quantitative methods alone, such as the ways households cope with energy poverty in their daily lives [3]. Since 2023, TNO has been monitoring the lived experiences of households facing energy poverty using qualitative methods. So far, this monitor has provided insights into the impact of energy poverty on households’ daily lives. However, qualitative research on how households perceive and experience policy measures remains limited [4]. Therefore, this research focuses on the lived experiences of residents in energy poverty and their perceptions of measures aimed at addressing it.

Methods

We conducted 29 semi-structured interviews with residents living in energy poverty between January and April 2025. The participants included individuals who had participated in the qualitative monitor since 2023 or 2024, as well as individuals participating for the first time. We approached new participants through community organisations and societal partners. During the interviews, residents were asked about their living conditions and their preferences on the following policy measures, which were presented on illustrated cards with brief descriptions: an energy allowance, an energy price cap, subsidies and loans for energy retrofits, mandatory home renovations, white goods schemes, energy coaching, and rules against immediate energy disconnection by energy companies. All interviews were recorded, transcribed and coded based on the thematic structure of the interview protocol.

Results

We find that most residents live in homes of poor energetic quality, and cannot afford to



heat their home adequately in order to maintain a healthy indoor climate. Consequently, there is a general pattern of underconsumption, which leads to various physical and mental health problems among household members. However, heating needs vary between residents and depend on factors such as health conditions or the presence of (young) children in the household. Many residents are forced to choose between heating their homes and meeting other basic needs, such as food – commonly referred to as the ‘heating or eating’ dilemma [5]. Many residents do not appear believe that their situation will significantly improve in the future, as their housing conditions and energy bills have been a factor of concern for several years now (and in many cases, lifelong).

When asked to rate different policy measures, in general, residents appeared familiar with temporary short-term measures introduced during the energy crisis in the Netherlands, such as the energy allowance, the price cap, energy aid organisations or white goods schemes. However, we see that residents are not aware of rules and procedures on the disconnection from energy, subsidies and loans, or national performance agreements on home renovations with landlords.

Of all the policy options presented during the interviews, residents expressed the strongest preference for mandatory home renovations – specifically in the case of rental homes and flats (both private and social housing associations). While they also responded positively to energy coaching and white goods schemes, these measures were seen as mere ‘quick fixes’ that fail to properly address root causes of cold, draught and mold – issues that home renovations can resolve more structurally. Residents believe that home renovations will lead to lasting improvements in both their financial situation and overall living conditions.

Residents also emphasised the importance of rules and procedures against the disconnection from energy by energy providers in case of non-payment. Residents often describe energy as a ‘basic right’ – access to which should not depend on one’s financial situation. Opinions were more divided regarding the (targeted) energy allowance and (general) energy price cap – both short-term measures introduced during the peak of the energy crisis in the Netherlands. Compared to structural interventions like home renovations, these measures were seen as combatting the symptoms rather than the root cause – and an inefficient use of public money. Residents argued that improving the quality of their homes would reduce their reliance on other, more short-term financial support measures such as allowances and price caps.

Regarding subsidies and loans for home renovations, residents’ preferences – such as zero-interest sustainability loans and extended repayment periods – were largely in line with current policy implementation in the Netherlands. Some residents express that subsidies should exclusively be reserved for households who do not have the financial means to renovate their homes otherwise. This contrasts with the current policy framework, in which the main sustainability retrofit subsidy (*ISDE*) is widely available to all homeowners, regardless of income or other proxies. Residents generally held more negative views of loans compared to subsidies, often equating loans to debts and expressing unwillingness to take out a loan – even under favourable conditions.

Discussion and recommendations

Based on our findings, we recommended that governments invest in the social infrastructure – physical spaces and conditions that facilitate interactions among people and enable them to develop social capital. Examples include public spaces, energy coaching organisations and



community centres. These are important because of their local embeddedness and trust-based relationships with residents, helping to alleviate social isolation. Through such organisations, (local) governments and other stakeholders in the energy transition (such as landlords and local energy communities) can actively and transparently communicate about energy (poverty) policies and underlying considerations and trade-offs. This can foster trust and understanding between residents, governments and other partners.

We furthermore recommend improving the accessibility of home renovations through collaborative arrangements between governments, energy coaching organisations, contractors and construction companies, alongside improved enforcement of home renovation standards. Finally, governments should expand and extend financial support schemes for households in energy poverty (at least) up to the point where home retrofits have taken place and their energy bills are reduced. Currently, the only remaining scheme (the Energy Emergency Fund, or *Noodfonds Energie*) excludes households with low energy costs. The many households living in energy poverty that under-consume energy are consequently not eligible for support.

This third iteration of the qualitative monitor in the Netherlands had offered valuable insights into the living conditions and preferences of households affected by energy poverty. However, certain groups remain underrepresented – such as private renters, households living in rural areas, and residents with limited trust in public institutions, health issues, or language barriers. Furthermore, the study focuses on residents’ preferences, without fully exploring their assumptions or the actual effects of the policies. Future research could therefore examine the accuracy of these assumptions, the outcomes of measures, and the trust dynamics and values underlying policy acceptance. We particularly recommend targeted qualitative research on underrepresented groups and on residents’ perceptions of financial support mechanisms.

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Flexibility in the Domestic Energy Sector: Insights from Hybrid Working Patterns

Theme 1, sub-topic 1a)

“Academic contribution”

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Keywords: Energy demand, Flexibility, Working from home (WFH), Household practices, Survey

Extended abstract

1. INTRODUCTION

The transition to net-zero presents both challenges and opportunities for global energy systems. One emerging focus is the impact of increased remote working—especially post-COVID-19—on domestic energy use. With more people working from home, there's potential to shift demand away from peak times, easing pressure on the grid and supporting demand-side management and renewable integration.

However, evidence remains limited on how remote workers use energy at home and their capacity for behavioural flexibility. The role of Working from Home in grid balancing and its difference from office-based energy use is still underexplored.

As part of the Energy Demand Observatory and Laboratory (EDOL) project, this paper shares pilot findings that test methods and offer early insights into home energy behaviours. These will inform the analysis of a larger dataset from 3,806 households.

By identifying flexibility patterns and intervention points, the research supports demand-side strategies that could help decarbonise residential and commercial sectors by lowering peak demand and reliance on fossil fuels.

2. Methodology

This study employed a mixed-methods approach, combining qualitative and quantitative data collection tools to explore energy-related behaviours among WFH and non-WFH households. The methodology included a pilot study followed by a broader household survey considering time-use patterns, appliance usage, occupancy, and behavioural flexibility in the context of remote working.



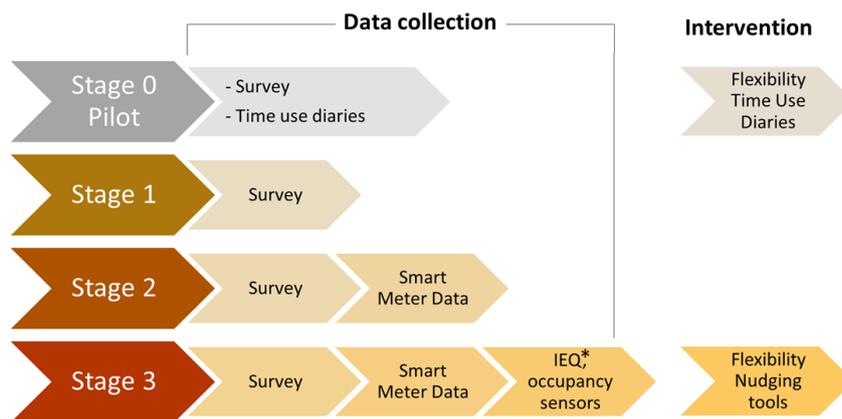


Figure 27: Overview of data collection phases and methods across EDOL study stages. (Note: IEQ* = Indoor Environmental Quality).

Insights from the pilot informed the next project stages. Conducted with 23 households (14 fully completing all phases), the study explored how households adapt and manage energy use beyond price signals. Qualitative methods, such as appliance-use diaries, revealed everyday energy practices and household dynamics. The trial took place over a three-week period in December 2024 and was structured into three main stages:



Figure 28: The pilot's different stages of data collection and a flexibility intervention conducted over a three-week period.

3. Findings

Findings from the pilot highlight that household occupancy patterns are likely to support energy flexibility, but that these patterns can include caregiving or retirement, as well as WFH. Energy flexibility is deeply social and contextual, shaped by routines, roles, spatial arrangements, and technologies. Social relations—like family needs, caregiving responsibilities (whether alongside WFH or not), and shared values—play a central role in shaping energy decisions. Daily practices such as cooking, laundry, cleaning, and bathing are often rigidly structured and shaped by gender roles. However, some flexibility in timing and sequencing does emerge, especially when routines are disrupted by competing demands—such as shifting family dynamics captured through a chore-assignment app, changes in electricity tariffs, or supplier-led flexibility opt-in events. A few households used automated functions (e.g. scheduled or programmed appliance operation), actively managing and reconfiguring timers and smart devices to better suit the needs of their everyday lives [1].

3.1.EDOL Survey

Insights from the pilot informed the design of selected questions included in the EDOL 2025 Survey that would help Inform occupancy profiling and that explore appliance and EV ownership: Examine ownership by household size to understand its effect on energy demand.

This analysis examines correlations between occupancy, appliance ownership, and usage practices across a sample of 3,806 households. These findings will inform the next phase, which integrates smart meter data to validate and enrich the survey results.

4. RESULTS

Early EDOL survey findings highlight working-from-home trends at both the individual and household level. The comparison between current working-from-home frequency data and lockdown-era findings offers complementary insights into the evolution of remote work. Figure 3 shows that a significant share of respondents now work from home or engage in caregiving at home three or more times per week. While the graph provides a snapshot of current household-level work-from-home frequencies [2], adds depth by highlighting how these patterns shifted within households during a period of societal disruption. It provides a temporal and household-level perspective, capturing shifts in work-from-home practices before and during the COVID-19 lockdown. The analysis showed 61.4% of households saw no change, 30.9% an increase, and 7.7% a decrease in time spent at home—highlighting both the rise of remote work and its varied, context-dependent evolution.

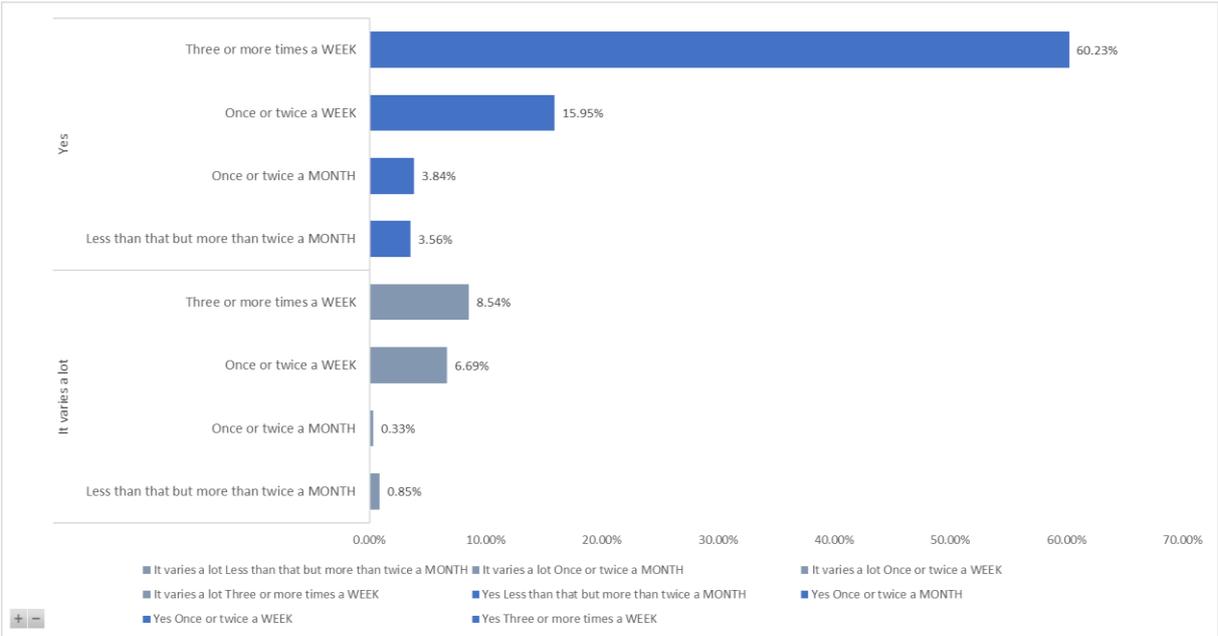


Figure 29: Patterns and frequencies of weekday home occupancy due to remote work, caregiving and other activities.

The EDOL survey (n = 3,806) shows widespread ownership of core appliances: refrigerators (97%), TVs (95%), vacuum cleaners (93%), laptops (89%), washing machines (88%), and irons (87%). Modern kitchen devices are also common, with 73% owning microwaves or air fryers, and 65% owning dishwashers. Cooking appliances are split between gas hobs (49%) and electric alternatives (45%). Smart tech adoption is growing —45% use smart assistants and 20% smart plugs. Mid-level ownership includes electric showers and freezers (40%), heaters (33%), and fans (28%). Less common items include gas ovens (16%), washer-driers (11%), and electric drying racks (9%). These trends reflect a strong reliance on traditional appliances, with gradual uptake of smart and efficient technologies.

EDOL Survey 2025 - Household Appliance Ownership (Sample Size: n = 3,806)

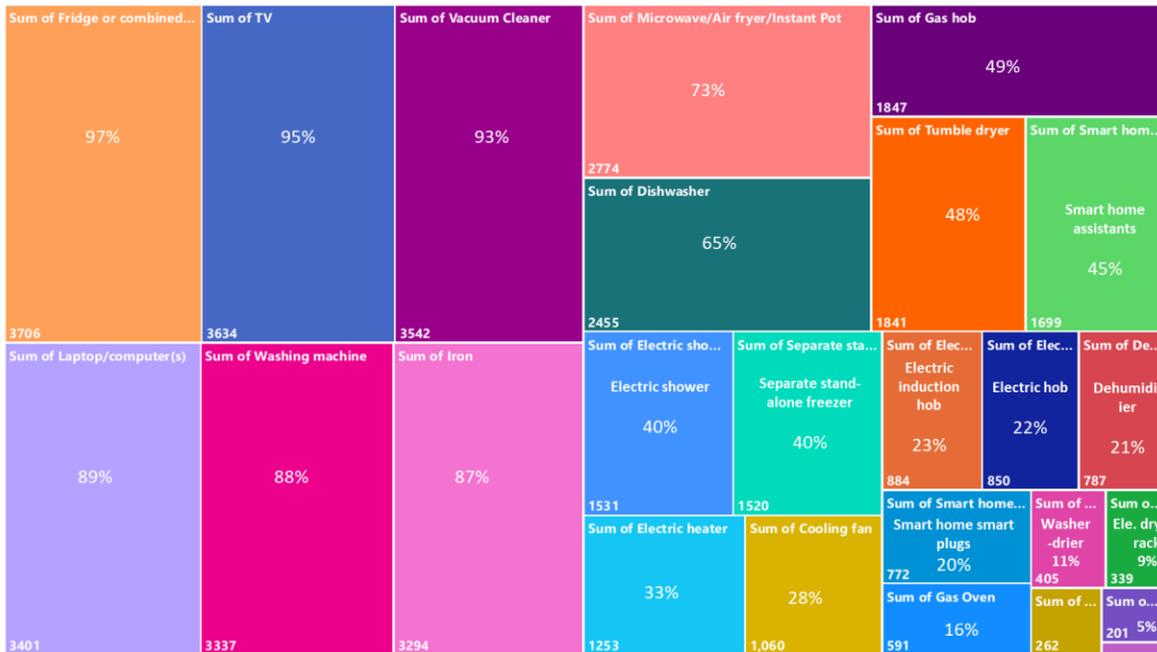


Figure 30: Prevalence of household appliances among UK respondents (EDOL Survey 2025 n = 3,806).

EDOL 2025 Survey: Changes in appliance usage timing when Working or caring from home on Weekday (Sample Size: 3,806)

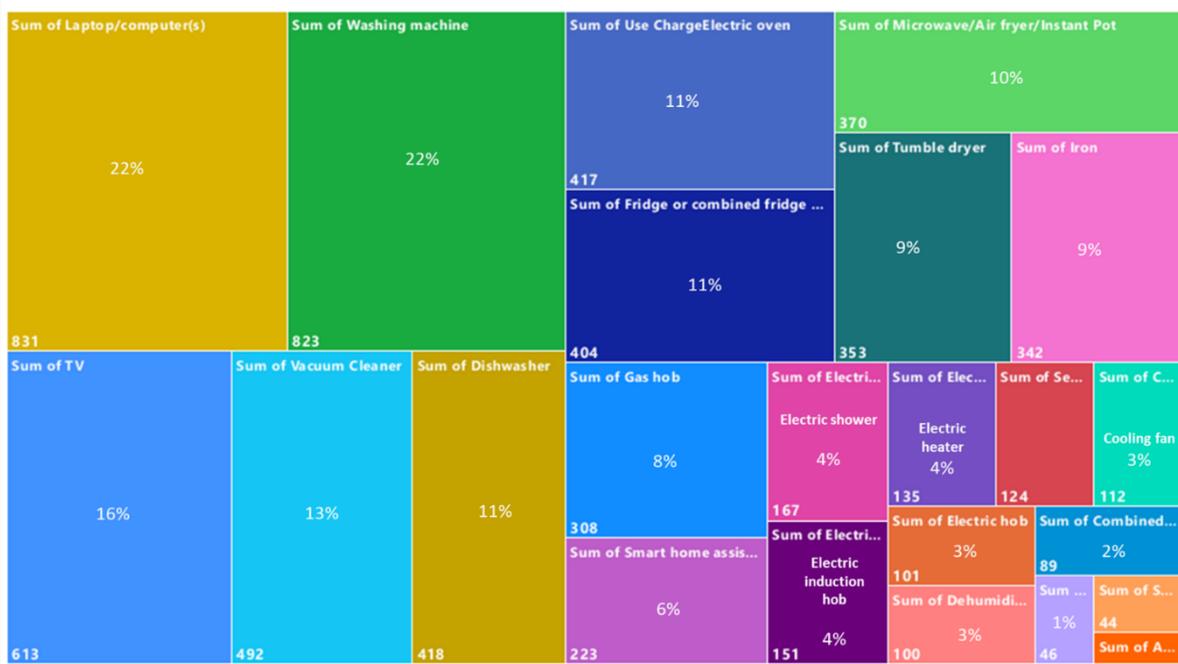


Figure 31: Changes in Weekday appliance usage when working or caring from home (n = 3,806).

A comparison of appliance ownership and weekday use during remote work or caregiving shows clear gaps between possession and flexible use. Despite high ownership—TVs (95%) and vacuum cleaners (93%)—weekday use is low (16% and 13%, respectively). Laptops and washing machines, each owned by over 88%, show the strongest alignment with use (22%), reflecting their role in WFH routines. Common appliances like microwaves, ovens, and dishwashers (48%–73% ownership) are used by only 9%–11% of households. Smart devices also show limited use—6% for assistants and 4% for plugs—despite moderate uptake. These

findings highlight that ownership alone doesn't reflect flexible or frequent use, reinforcing the need to assess actual engagement in energy behaviour.

5. DISCUSSION AND NEXT STEPS

Scaling the pilot methodology to a national level poses technical and logistical challenges. While the pilot offered valuable insights into occupancy, appliance use, and behavioural flexibility, applying these methods at scale requires streamlined tools, harmonised data, and attention to participant diversity. Simplified diaries or passive sensing may be needed to capture time-use patterns without overburdening participants.

Survey data reveal clear trends in ownership, occupancy, and flexibility, but these self-reported behaviours must be validated. Integrating smart meter data will enable real-time analysis to confirm reported flexibility—such as shifting appliance use during WFH—and detect load-shifting potential.

Next steps include building dynamic models using survey data, smart meters, and IEQ sensors to identify segments best suited for demand-side response. In parallel, selected households will test behavioural nudging tools—like feedback, automation, and incentives—to evaluate their impact.

This work ultimately supports equitable, user-centred flexibility strategies, contributing to a more inclusive and resilient path to net-zero.

Acknowledgements

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Between Optimization and Self-Limitation: Social Practices and the Politics of Urban Energy Communities

Theme 2, sub-topic 2d) / Theme 5, sub-topic 5b)

“Academic contribution”

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Keywords: Urban Energy Communities, Self-limitation, Social-practices, Hybrid Forums, Social Innovation

Extended abstract

The transformative power of energy communities has been widely explored across the social sciences. For the purpose of this paper, we identify three main strands of scholarship. The first and most prominent is the Multilevel Perspective (MLP), which conceptualizes socio-technical transitions through the interaction between niches, regimes, and landscapes [1]. While this framework provides valuable insights, it tends to overlook the conflicts, negotiations, and power struggles inherent in such transitions. The second strand emerges from political sociology, which stress the hybrid character of energy communities, at the intersection of individual and collective action. These works interpret energy communities through the lenses of sustainable community movement organizations [2], lifestyle politics [3], and new sustainable materialism [4], [5]. However, this literature often focuses on the more radical and anti-capitalist initiatives and thus fails to capture the heterogeneity and broader scope of the movement. A third line of inquiry conceptualizes energy communities through the frameworks of energy democracy [6], energy citizenship [7], and energy justice [8]. These approaches have significantly advanced our understanding of the relationships between materiality, technology, and social organization. Yet, they also present two major limitations. First, they tend to be normative rather than empirically grounded [9]. Second, as recent studies have pointed out, there is significant conceptual ambiguity and overlap between democracy, citizenship [10], and energy justice [11] with insufficient theorization of their intersections [12], [13], [14].

Together, these bodies of literature do not fully account for the heterogeneity that characterizes energy communities. This leads us to pose the following research question: How, and to what extent, do energy communities transform social relations to energy in European cities?

To address this question, we draw on the concept of self-limitation, not as a normative prescription but as an analytical lens for assessing and comparing the transformative power of energy communities. Mobilized in post-1973 oil crisis debates - particularly in Ivan Illich’s Energy and Equity [15] - the concept of self-limitation underscores the need for voluntarily setting collective limits on energy use through a political process. More recently, Luc Semal and Bruno Villalba have expanded this notion through the concept of subversive



sobriety [16], which emphasizes that sufficiency must be defined through collective negotiation. This process should ensure a fair distribution of both energy and the effort required to reduce consumption, and must be grounded in the recognition of energetic finitude.

We propose disaggregating the concept of self-limitation into three interrelated dimensions. The first is **democracy**, understood as the capacity of energy communities to function as “hybrid forums” [17], deliberative spaces that open energy transitions to public contestation and negotiation over the legitimate uses of energy. The second is **citizenship**. Drawing on Social Practice Theory [18] we move beyond individual behavioural change to examine how communities intervene in the material arrangements, competencies, and symbolic meanings that constitute everyday energy use. The third is **justice**: building on the work of Frank Moulaert, who conceptualizes social innovation as the pursuit of socially inclusive goals alongside the amplification of marginalized voices in governance [19], we account for distributive, recognitional, and procedural dimensions, often overlooked in mainstream energy justice literature.

This paper is based on a comparative qualitative study of 15 energy community projects located in Paris, Barcelona, and Milan. Drawing on semi-structured interviews, participant observations, and document analysis, we identify four ideal types of energy communities, each reflecting different configurations of the democracy – citizenship - justice triad.

The first ideal type is *eco-modernization*. These projects are grounded in technological and administrative innovations aimed at optimizing the use of locally produced energy. However, they do not question underlying energy needs or dominant consumption models. Governance tends to be technocratic, with decision-making concentrated in the hands of a small group of experts. Residents are invited to participate only in pre-designed initiatives, and concerns related to social justice are marginal or secondary.

The second type is *social ecology*. Projects in this category explicitly link environmental goals with social justice imperatives. Participants are selected based on technical (e.g., energy consumption profiles), legal (e.g., municipally owned but delegated properties), and social (e.g., organizations providing social services) criteria. These entities often engage in everyday forms of environmentalism, such as food donation, clothing recycling, and waste reduction, as a means of addressing material needs. The selected organizations benefit from reduced energy costs, which in turn support their social initiatives. However, they are not participatory: end users are not involved in governance and benefit only indirectly through the cost savings accrued by host organizations.

The third type, *participatory ecology*, is characterized by a hybrid form of participation, both institutionalized and spontaneous. These projects emphasize plenary assemblies as spaces for knowledge sharing, mutual learning, and occasional political engagement with energy issues. In terms of social practices, they prioritize energy efficiency and promote alternative practices without explicitly challenging dominant norms or questioning collective priorities. Although justice considerations do emerge, they typically appear late in the process and are primarily limited to issues of distribution. Questions of recognition and procedural justice remain largely unaddressed.

Finally, the fourth type is *self-limitation*. These projects view energy not merely as a technical resource, but as a means for broader social and political transformation. Residents are actively involved from the outset, and deliberative spaces are used to collectively define



energy needs, challenge consumption norms, and redistribute both energy resources and the responsibilities associated with their use. These communities combine redistributive justice with goals of social and political empowerment, engaging all three dimensions of social practice. They create enabling material conditions (e.g., solar energy production, shared electric vehicles, building retrofits), foster local competencies, and help reframe the meanings and values associated with energy consumption.

By conceptualizing self-limitation through the interconnected dimensions of democracy, citizenship, and justice, this paper develops a novel analytical framework for assessing the transformative power of energy communities. Theoretically, it aims to advance the literature on energy democracy, energy citizenship, and energy justice by emphasizing the interactions among these concepts. Empirically, the paper demonstrates that while technical devices can catalyze changes in social practices, the depth and character of these transformations vary widely: from optimization to self-limitation. Crucially, the extent of transformation depends on the social and political appropriation of technology, as technical devices may serve as instruments that support broader political projects aimed at social change.

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Reducing Barriers to Heat Pump Uptake: A Cost and Choice Comparison Tool

Theme 3, sub-topic 3b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Heat pumps, Cost comparison, Decision making, End users, Decarbonisation

Extended abstract

Recent technological advancements have made heat pumps a competitive alternative to fossil fuel heating in existing buildings. Their ability to provide both heating and cooling from a single unit makes them especially attractive in the context of a changing climate. Heat pumps emit less greenhouse gas emissions and offer a higher efficiency than traditional oil or gas boilers [1]. In 2023, only 26.2% of heating and cooling was generated by renewable energy sources [2]. The installation of heat pumps in the EU has slowed down between 2022 (3 million units) and 2024 (2.2 million units) which shows that there is still a long way to go to reach the RePowerEU target of installing 60 million additional heat pumps in the EU by 2030 [3,4].

Heat pumps are the main means for the electrification of the heat sector in the built environment and increasingly support grid integration by leveraging periods of renewable energy surplus and low electricity prices [5,6]. Therefore, heat pumps act as a crucial technology to achieve efficiency gains and leverage cost-effectiveness of renewables for the clean energy transition. Despite these advantages of heat pumps and growing importance of electrifying heating systems, many building owners are reluctant to install heat pumps. Barriers include high upfront costs, limited awareness about the full spectrum of benefits, regulatory barriers, mismatched incentives (e.g., landlord–tenant issues) and limited availability of qualified installers [7].

This paper deals with the financing aspect of the heat pump rollout and presents a tool for end users and homeowners to compare costs of different heat pump technologies to facilitate their decision-making process in changing their heating system. Users of the tool can compare the investment and operating costs of different heat pump technologies to their existing heating system and will be able to display how alternative business models can reduce upfront investment costs and provide predictable monthly fees. The tool displays the investment and operating costs of the heat pump, as well as the annual cost savings and annual CO₂ emission avoidance compared to the existing heating system.

The tool is specifically designed to incorporate applied behavioural insights. In particular, it focuses on simplifying decision-making by reducing the complexity of cost comparison, highlighting key benefits in a clear visual format, and tailoring recommendations to the



individual user's input.

The cost comparison tool is being developed in the EU-funded LIFE-project *install.res*. The tool builds upon an existing tool [8] and provides cost comparison for different heating technologies in Austria, the Netherlands, North Macedonia, Poland, and Slovenia. Users of the tool receive investment and operating costs for different heat pump technologies in just a few clicks. Following data is required by the users to enter into a simple online environment: location, heated living space, number of residents, heat distribution system, existing heating and hot water system, the current heating consumption (in kWh), radiator type and availability of photovoltaic systems. In a further development stage, the possibility to enter the insulation stage of roof, windows and walls will be added to the tool to include insulation costs into the outcome.

Based on default values for investment, installation, maintenance, and financing costs, users receive a detailed cost distribution for air-to-air, air-to-water, brine-to-water, water-to-water and photovoltaic thermal heat pumps. The default values used for calculations are adjusted to the local context of each country. The data on the different cost components are based on opensource databases and data from implemented heat pump projects in single-family and multi-apartment buildings. As costs are displayed over a timeframe of 15 years, certain parameters such as inflation and development of energy prices underly the cost calculation. These assumptions are displayed in the tool to ensure transparency. Additionally, an expert mode exists which allows users to manually enter specific costs or adjust parameters based on specific offers of manufacturers, installers, or financing institutions they receive.

A further extension of the tool is the display of alternative business models for heat pump installation. Knowledge of innovative financing models for heat pump adoption remains limited among building owners, who mostly rely on the traditional purchase model using subsidies and loans [9]. However, the high upfront costs of heat pump installation and limited adaptability to diverse customer needs hinder investments into heat pumps. In response, alternative business models have emerged, tailored to different customer preferences, and often reducing upfront costs. Such alternative business models range from renting and contracting offers over group purchasing initiatives to full-service packages for all-electric buildings.

The tool aims to display these alternative business models to show that high upfront costs can be reduced. Business models such as Heat as a Service, Rent a Heat Pump, Energy Performance Contracting or On-bill Financing offer customers a monthly fee which covers installation, maintenance and partly performance optimisation. The upfront investment cost is being reduced within these models yet overall lifecycle costs are often higher than a one-time purchase. Higher lifecycle costs stem from the inclusion of different services (such as maintenance, breakdown protection, performance monitoring and optimisation) into these offers. These offers are more attractive to end users and homeowners who prefer a full-service package and are willing to pay for their reduced time effort and outsourcing maintenance and possibly performance risks [10].

By displaying these alternative business models next to the traditional purchase model for heat pumps, the tool offers end users and building owners the possibility to weigh different heat pump technologies and financing options against each other. This way, the tool not only simplifies the decision-making process but actively addresses behavioural barriers by reducing uncertainty and cognitive load, helping users identify the option that best fits their needs and preferences. Enhancing awareness, simplifying the decision-making process, and



improving knowledge about heat pumps are essential in ensuring that end users and buildings owners take an active role in enhancing the heat pump rollout in the EU.

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Closing the Green Gap with social comparison nudge ? A lab-in-the-field experiment on energy conservation

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Extended abstract

This paper provides an experimental analysis of the interaction between economic preferences, pro-environmental attitudes (PEA) and pro-environmental behavior (PEB) through the lens of energy conservation. PEA have been revealed to be a weak predictor of PEB ([1], [2]) but the majority of existing studies lack a complete dataset. Indeed, most of studies aiming at explaining pro-environmental behavior (PEB) use self-reported data (typically, [3], [4]), exposing their result to a social desirability bias. Self-reported data brings necessary information on attitude toward a behavior or an intention (see [5] on the perception of climate risk and the individual intentions to mitigate it) but actual PEB is observed in the field or in laboratory experiments ([6]), where the participants are given the choice between acting pro-environmentally or not. This experimental set up collects both field behavior and survey data.

Behavioral predictors of PEB can be intrinsic economic preferences of the individuals ([3]) such as altruism via the ”prioritizing the self” mechanism ([7]), or risk aversion. Indeed, PEB can be described as a response to an environmental risk ([8], [9]), and proenvironmental attitudes and intentions are driven by the perception of this specific risk ([5]). Furthermore, PEB has been studied as an element of the external validity of risk preferences ([10], [11]), [4]). Those economic preferences can be assessed either with self-reported data, i.e. questionnaires as in [12] or [13]. This method allows a data collection on a large panel, but is submitted to the social desirability bias. Another way to measure those preferences are experimental methods, often more expensive, but allowing a greater control on the potential noises affecting the results. Another advantage of experimental methods is that they often include a real monetary gains, and then put the participant in more realistic conditions ([14]). We opted for that method to measure both risk preferences and altruism.

A comprehensive overview of the various existing methods to measure risk preferences can be found in [15]. The Gneezy-Potters method and multiple price list methods offer two notable



advantages. The simplicity of the Gneezy-Potters method enhances its ability to predict actual behavior, while multiple price list methods enable researchers to calculate risk aversion indexes that better reveal individuals' true preferences (see computation method in [16]). For altruism, the standard experimental method is the dictator game, which consists in proposing to each participant an outcome solution where a part of the outcome can be given to another participant. In experiment focused on the dictator game, the researcher can test several dimensions of altruism such as difference aversion, increase welfare or reciprocity ([17]). In the adapted framework of [18], the participant is given an initial endowment and chooses a way to split it between him and an anonymous partner, with a changing relative price of giving. According to Charness and Fehr, this measure is the most accurate to assess altruism. The dictator game has also been simplified to be addressed to small children ([19]). The latter study studies the difference in behavior when the altruism addresses a similar subject or a subject with different living conditions. The purpose of this study is to understand the mechanism laying behind the green gap, in order to find solutions to reduce it. Behavioral solutions are often mentioned as being specifically tailored for behavioural inconsistencies. More precisely, nudges - defined as a slight change in the set aiming at changing individual behavior - has been studied as a solution to close the green gap. The efficiency of nudges in promoting pro-environmental behavior has been assessed in many sectors such as energy conservation ([20], [21], [22], [23], [24]), on the adoption of green energy sources ([25]) or on the waste of paper ([26]). However, fewer studies have been dedicated to the role of nudges in the reduction of the intention-behavior gap. The studies connecting nudges are the green gap focused on specific PEB: [27] on energy use or [28] on waste management. This paper then explores (1) the role of economic preferences in the green gap, (2) the impact of behavioral policies in the reduction of the green gap and (3) the differences in impact of behavioral policies on consumption according to economic preferences.

To do so, we implemented a three-steps design over the current academic year. The first phase consisted in an online experiment computerized with oTree ([29]). This online experiment has two principal parts: a questionnaire to elicit PEA and a series of games to elicit economic preferences. More precisely, the questionnaire collected information on proenvironmental concerns, beliefs, and daily habits. With a principal component analysis, three indicators of PEA have been computed: a general, a belief and an action one. The first one was based on all the answers to the questionnaires, and the two other on respectively beliefs/concerns and habits related questions. The risk aversion elicitation methods were an investment task of the model of [30], and a single choice task following [16]. The altruism was elicited via a dictator game similar to the one of [18]. The second step of the protocol was a Home Energy Report experiment, following the model of [31] or [20]: the students had access to an application displaying real-time consumption. The treatment group had a full access to the application and was therefore able to compare their consumption to the average consumption of the building. The control group only had a partial access to the application: the application displayed a blank screen for them. This application was completed with a paper mail communication addressed only to the treatment group, displaying the same information as the app. This experimental step last from October 2024 to March 2025, covering the whole winter season, when energy (and especially heat) consumption is at the highest. Finally, the last step of the experiment consisted in another round of the questionnaire of the first period in order to assess any kind of modification in PEA during the period. This questionnaire also included satisfaction questions about the home energy reports to assess whether the app and the paper mail had been consulted enough during the treatment period. Our results confirm previously made studies on the effectiveness of nudges in the reduction of energy consumption, but bring more precision on the types of consumers who react better to the nudge. First, PEA was a relatively good predictor of PEB before the beginning of the nudge phase: the pro-environmental students tend to consume significantly less energy than the others. Second, it appears that the reduction of



consumption due to the nudge is not significantly higher among the highest consumers, for whom the marginal cost of reducing energy consumption is the lowest. Third, the Home Energy Report treatment effect was significantly higher among the proenvironmental participants, who were already consuming less before the treatment period. These results are in line with a previous study of [32] who found that democrats neighborhoods were more responsive to HER than republican ones. These results may question the welfare effect of nudges, as they reveal that they potentially increase efforts among the population with the highest marginal cost of effort. This goes in line with the recent questioning on the welfare effect of nudges made by [33].

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From innovation to overshoot: How data centre expansion risks derailing climate goals

Theme 1, sub-topic 1d)

Theme 5, sub-topics 5a), 5c), 5d

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, data centres, artificial intelligence, environmental impacts, energy consumption

Extended abstract

The growth of artificial intelligence (AI) and digital services is driving a sharp increase in data centre infrastructure. In the EU, the European Commission has announced a EUR 200 billion AI infrastructure plan and member states have come forward with similar initiatives.

Political discourse on the topic of digitalisation tends to marginalise critical questions about necessity, purpose, and proportionality. The implicit assumption is that more data, more processing power, and more connectivity are always beneficial. This techno-solutionist mindset leads to unchecked infrastructure expansion, with growing and wide-ranging impacts.

This growth comes with significant environmental costs: high electricity consumption, water and land use, raw material demand, and increasing pressure on local communities and infrastructures. However, the new data centres and AI ‘gigafactories’ initiatives, come without a coherent vision for their environmental governance.

Policy efforts in the EU currently focus largely on enabling digital competitiveness, often through efficiency improvements. While important, efficiency fails to address the structural issue of ever-rising demand. This paper makes the case for integrating sufficiency into the governance of AI and data centres, through policy choices seeking to limit unnecessary resource use and infrastructure growth.

The International Energy Agency (IEA) attributes a major share of global electricity demand growth in 2024 (4.3%) [1] to data centres, driven in large part by AI workloads. Water use and raw material needs have increased in parallel. Countries like Ireland, the Netherlands, and Belgium have reported significant issues, regarding strain placed on local grids.

Much of the rising demand stems from low-value or non-essential applications—such as content generation, advertising, or novelty AI tools—which provide limited public benefit but consume vast resources.



Efficiency gains are quickly erased by rebound effects and an inflated sense of digital ‘need’. A failure to question what kinds of digital services are truly essential will most likely lead to overshoot and jeopardise climate goals.

Methodology

This policy paper is based on a critical review of publicly available qualitative and quantitative data on consumption as reported by the International Energy Agency, research studies and EU institutional documents as well as corporate environmental disclosures from major digital infrastructure operators.

It also draws from recent technical and NGO reports on the environmental and social impacts of data centres and AI. Our analysis synthesises quantitative estimates such as energy use, emissions, and water consumption from credible sources to highlight key environmental pressures associated with infrastructure growth.

EU policy frameworks such as the Energy Efficiency Directive, Renewable Energy Directive, and the draft Cloud and AI Development Act, among others, are assessed in terms of their scope, regulatory strength, and ability to address the many challenges of data centre expansion.

The paper critically examines how current policy trajectories can be improved and how sufficiency can serve as a practical tool along with efficiency and how to create accountability and integrity for a future-proof twin transition — both digital and environmental.

Overview

Our policy paper is organised as follows: In Part 1, we present the different kinds of data centres and AI-driven changes on the infrastructure. In Part 2, we elaborate on what environmental ambition looks like for this sector, and why we need it. In Part 3, we summarise the existing EU policy landscape and the opportunities to course-correct concluding in Part 4 with recommendations for action, including a dedicated section on sufficiency-related measures.

The report notes that data centres consumed an estimated 240-340 TWh globally in 2022— 1-1.3% of global electricity — rising to nearly 460 TWh when accounting for AI-driven demand [2]. In the EU, data centres consumed 45–65 TWh (1.8-2.6% of electricity use), with Ireland’s share reaching over 18% [3]. By 2030, European data centre electricity consumption is projected to more than double to 150 TWh, or 5% of total EU demand [4].

AI workloads are especially energy-intensive: Microsoft’s supercomputer for OpenAI includes over 285,000 CPU cores and 10,000 GPUs. Training large AI models requires dense GPU clusters and high-speed interconnects, dramatically increasing energy use and heat output—leading to widespread adoption of water-intensive liquid cooling systems. A Google data centre consumes ~450,000 gallons of water daily [5], and estimates suggest 43.2 billion litres are used annually by EU centres employing liquid cooling [6].

Hardware turnover is also a concern: GPUs typically last 3–5 years, contributing to mounting e-waste. Data centres are heavy users of raw materials—copper, aluminium, rare earths, lithium, cobalt—with AI growth expected to drive up copper demand alone by ~1 million tonnes by 2030 [7].

Companies often rely on renewable energy certificates (RECs) or offsets like Microsoft’s 3.5 million carbon credit purchase from Brazilian reforestation to claim climate neutrality,



despite growing emissions: Microsoft's emissions rose 30% since 2020, Google's by 48% since 2019, and Meta's more than doubled.

The policy review reveals that the European Union currently lacks a coherent and binding regulatory framework to address the environmental impacts of data centres.

While the revised Energy Efficiency Directive introduces mandatory reporting for large facilities, it does not impose binding limits on energy or emissions, and excludes many smaller, less efficient centres. The Renewable Energy Directive sets economy-wide renewable targets but does not specifically regulate the sector. The Ecodesign Regulation for servers and storage devices supports efficiency and reparability but applies only indirectly to data centres and lacks requirements for best-available technologies.

Forthcoming legislation, such as the Cloud and AI Development Act, proposes to significantly expand infrastructure without embedding enforceable environmental safeguards. Broader instruments like the CSRD and the CSDD offered potential for improved transparency and accountability, but recent proposals would delay implementation and limit their scope.

Voluntary initiatives, including the EU Code of Conduct, Green Public Procurement criteria, and the Climate Neutral Data Centre Pact, provide technical guidance but lack legal force, relying instead on self-reporting.

As a result, EU policy remains structurally inadequate to address the sector's accelerating impacts and specifically overconsumption.

Recommendations

To align digital development with environmental and social objectives, sufficiency must become a guiding principle in EU policy. This means not just making data centres more efficient, but critically assessing how much infrastructure is truly necessary, and for what purposes. Our paper recommends the following measures:

- Prioritise sufficiency in infrastructure planning. New data centre construction should be allowed only when there is clear evidence of societal need and system benefit. Expansion must come after the full optimisation of existing facilities.
- Differentiate essential and non-essential digital services. Policymakers should establish a taxonomy that classifies digital and AI applications by public value. More specifically they should:
 - Prioritise socially beneficial uses (e.g. science, education, public health).
 - Deprioritise high-impact, low-utility services (e.g. personalised advertising, generative AI for entertainment).
 - Use this taxonomy to guide public procurement, investment decisions, and energy allocation during peak demand.
- Set binding, absolute reduction targets on energy use, emissions, water consumption, moving beyond monitoring.
- Eliminate greenwashing mechanisms. Sustainability claims must be based on real impact, not certificates unless they reflect verifiable renewable supply. Carbon offsets should not be acceptable.



- Public financial support should be conditional on demonstrable environmental and social alignment.
- Enable democratic oversight. Communities and consumers must play an active role in shaping digital priorities through:
 - Launching public campaigns to raise awareness of the environmental costs of digital services and labelling of AI models.
 - Involving communities in infrastructure planning, especially in water- or energy-stressed regions.

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From energy sufficiency to material sufficiency: interdependencies, inertias, and organizational challenges in planning energy transition with raw materials policies

Theme 1, sub-topic 1d); Theme 6, sub-topic 6b)

- “Academic contribution”
 “Policy/practice contribution”

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Extended abstract

Since COP21 and the Paris Agreement, many states have begun planning their transition toward carbon neutrality, adopting roadmaps, strategies, and plans defining targets for reducing greenhouse gas emissions. The implementation of these energy transition policies has notably resulted in increased reliance on renewable energy and the electrification of various uses, such as mobility. This is particularly the case in France with the national low carbon strategy. This key document frames the national energy-climate policies, and foresees a substantial rise in electrification and the share of renewable energy in the energy mix without implying significant changes in lifestyles [1]. Transforming the energy system to carry out low carbon transition in this particular way requires a major increase in the consumption of certain mineral resources and metals such as lithium, cobalt, nickel, rare earth elements, or copper, which are now recognized as strategic components in the value chains of batteries, wind turbines, photovoltaic panels, and digital energy management systems [2],[3],[4],[5].

The material dependency of the energy transition has gained visibility in recent years due to geopolitical tensions in supply chains and market instabilities occurring alongside recent crises like Covid-19 (2020) or the war in Ukraine (2022). Both the European Commission and national governments, including France, have multiplied initiatives (mining exploration, criticality evaluations, R&D for substitutes in industrial processes, diplomacy for mineral resources, dedicated legislations...) to secure access to these critical and strategic materials, which are considered essential for industrial sovereignty, economic resilience, and the achievement of climate goals by public administrations [6],[7]. However, despite the growing urgency and proliferation of measures aimed at securing these supplies, there remains a persistent difficulty in articulating them with climate and energy policies. On the one hand, state-led energy planning exercises at the level of the DGE (General Direction of Energy and Climate) hardly account for their material implications in terms of mineral and metal supplies, while they induce industrial choices with strong ethical, social and environmental dimensions linked to resource extraction [8]. On the other hand, mining policies and related industrial policies, both in France and Europe, are being developed in relative autonomy from the actors involved in energy planning. In France, they are led by different administrations across the ministry of economy.



These two categories of public action have their own communities of experts and policy networks, with different forms of legitimate methods and knowledge to anticipate the future and plan public action, even if they rely more and more on each other. Over the past decade, numerous researches in political science and sociology of public action have shown how mining policy in France and Europe have been reshaped around the goal of securing supply chains, leveraging the framework of the energy transition to its advantage with new uses of mineral resources and the subsurface [9],[10],[11]. This strong link between the deployment of renewable energies at industrial levels and raw materials consumption is unsurprising. Energy and materials share a long history of additionality and symbiosis putting into question the credibility of the very notion of energy transition [12],[13].

This difficult articulation between energy and raw materials public policies raises central questions for low carbon transition and for sufficiency. Is it possible to think energy sufficiency apart from material sufficiency? What are the obstacles and implications for anticipating and planning transition with regard to energy-material sufficiency for experts, scenarios and foresight exercises?

This contribution is part of an ongoing PhD research focusing on the expertise of risks in anticipatory and planning public policies for low carbon transition. It is based on a qualitative and inductive methodology from the sociology of organizations [14], focusing on the concrete activities of actors, their interactions, and the nature of their relationships. Empirical material for our contribution consists of:

- Over 200 institutional and public policy documents related to energy transition strategies and the securing of critical raw material supplies;
- Archives about the administration of energy and non-energy resources in France;
- A corpus of experts' written production and discourse;
- A set of 20 semi-structured interviews conducted between September 2024 and May 2025 with institutional stakeholders, industry representatives, and experts in critical raw materials and low-carbon transition policy. These interviews were recorded, transcribed, and systematically coded.

This study examines the construction of critical and strategic materials supply as a public problem at the intersection of multiple policy sectors in France. Empirically, we trace the successive and sometimes parallel framings of the problem of mineral resources by different coalitions of actors with different views on resource consumption, anticipatory methods, and policy instruments. This reveals how the interplay between multiple expert communities is deeply shaped by organizational contexts that constrain coordination, production of anticipatory knowledge and agenda-setting. This study also draws insights from the most recent developments in the sociology of organisations [15], aiming to identify organisational, institutional, and cognitive structures within the categories of public action to understand how they enable or hinder institutional change.

Our preliminary findings show a) the institutional inertia in the construction of the public problem posed by access to minerals and metals, controlled by mining and industrial actors; b) the difficulty for experts to integrate foresight exercises related to resource supplies with those related to energy transition; c) the sometimes contradictory logics prevailing in mining policies and in energy transition policies; and d) the organizational logics explaining the resistance to articulating these public policies, thus closing the door to broader reflections on energy-material sufficiency in energy transition planning.



Expanding the discussion, this contribution argues that if there is a crisis in raw material supply, it is partly due to the inability to jointly organize public policies fuelling minerals and metals consumption with those answering this demand. The limits of low-carbon transition planning when it comes to mineral resources are shaped by interdependencies between experts communities, public administrations and industrial actors. These interdependencies constitute zones of uncertainty that each group of actors seeks to control, as they may challenge existing policy decisions, goals, and organisational structures. The difficulties in bridging low-carbon transition planning and mineral resource supply security ultimately raises the question of what can imply organizationally the production of anticipations and plans integrating energy-material sufficiency in public policies for low-carbon transition.

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Citizen support services for the low-carbon energy transition: A social practice approach

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Social practices, Consumer behaviour, Energy consumption, Energy transition, Decarbonisation

Extended Abstract

1) Introduction

ADENE, the Portuguese Energy Agency, has a long history of promoting energy efficient behaviours, traditionally through awareness raising campaigns that encourage individual behaviour change and by focusing on the economic and environmental benefits of energy efficiency. Seeking to strengthen the scientific foundation of its approach, ADENE joined forces with academic expert Dr Idalina Baptista, from the University of Oxford, to consider the multidimensional scope of the energy and climate transitions and the specificities of citizen mobilization through the lens of Social Practice Theory. This collaboration led to the exploratory project “Citizen Support Services for the Low-Carbon Energy Transition: A Social Practice Approach,” which had three main objectives: (1) to support ADENE staff develop a deeper understanding of Social Practice Theory – focusing on the materials, competences and meanings that shape everyday energy use – and its usefulness in shaping energy demand and consumption patterns; (2) to apply practice-based knowledge to reshape ADENE’s citizen support services for households; and (3) to co-produce a set of principles and a typology based on practice theory to guide ADENE’s design of future citizen services to complement its behavioural portfolio and encourage citizens’ engagement in the energy transition.

2) Methodology

The project took place between 1 April and 31 July 2025 at ADENE. It had the support of an Oxford Policy Engagement Network Fellowship to support Dr Baptista’s policy placement in Lisbon for the duration of the project. The project had 4 stages. During the first stage (April 2025), the academic partner (Baptista) worked closely with the ADENE leads (Vales and Vicente) to familiarise herself with Portugal’s energy transition policy context while also begin a programme of capacity building of ADENE staff on social practice theory and its application. In the second stage (May 2025), the academic partner



interviewed twenty-eight ADENE staff members across all seven Directorates and the Board of Directors. The interviews focused on: understanding the work undertaken by ADENE staff across its different departments; identifying and characterising key citizen support services; and (3) identifying interviewees perceptions of the main strengths and opportunities for improvement in those services, why and what could be done to improve them. These two phases allowed the academic lead to develop a deep understanding of how ADENE staff framed the problems they were engaged with on an everyday basis, the nature of obstacles and of possible solutions, and their theory of change. The third stage (June 2025) was dedicated to introducing social practice principles to a broader number of ADENE staff and key stakeholders. To this end, the project hosted two workshops, one with 14 stakeholders and another with 15 ADENE staff, where participants tested and operationalised a typology for addressing energy consuming social practices. The final stage (July 2025) entailed the development of two ADENE citizen support services using a social practice approach and one workshop to delineate their respective implementation plans. The two initiatives – one to improve access to energy poverty services and the other to improve soft-mobility services provided at the existing one-stop shops – were identified and developed by ADENE staff with the support of the academic lead. After the conclusion of the project, the authors will continue to collaborate to develop this paper as a project output, not just to be presented at the Behave2025 conference, but also for publication in an academic peer-reviewed journal.

3) Findings and Results

At the time of this writing, the project’s final stage is still underway, so we can only provide a preliminary account of the project’s findings and results. At any rate, we believe there are three main themes worth noting.

First, project participants instinctively understood the usefulness of the social practice approach and welcomed its multidimensional typology. Social practice theory suggests that individuals consume energy while performing routine and often essential social practices of their daily life – from heating/cooling, cooking and washing, commuting, travelling for shopping or leisure, or caring for children or the elderly. These time-sensitive practices are performed through infrastructures or spatially-bounded systems – e.g., roads, public transport, office buildings, shopping centres, daycare – which provide goods and services outside of individual control. These energy-consuming practices are also embedded in culturally accepted notions of comfort and convenience that no single individual can change alone. Moreover, such practices reveal expectations or aspirations of wellbeing and social status that depend on socio-economic characteristics such as gender or income class. For most citizens, changing such energy-consuming practices does not feel like an individual choice, at least not without substantive negative impacts on how they ‘normally’ go about their lives. Therefore, if policymakers are to make inroads towards the energy transition, they need to focus efforts on reconfiguring energy-consuming social practices in their multiple dimensions (temporal, spatial, cultural, and socio-economic), not just on stimulating individual behavioural change.

Second, project participants began placing greater attention in how citizens frame their everyday concerns while performing their energy-consuming social practices. This represented a shift from advising households on how to take advantage of incentives available or suggesting how they ‘ought’ to behave to engage in the low-carbon energy transition. Project participants acknowledged this shift requires they develop additional skills regarding active listening, fostering opportunities for direct involvement with relevant



communities, and learning on to systematize and synthesise knowledge developed from such interactions into practical interventions.

Finally, project participants realised that adopting a social practice approach in energy policy practice is not without its challenges. For one, practice theory constitutes a substantive change to established ways of thinking and doing energy policy. While it offers a more holistic understanding of the dynamics of energy consumption, it is more complex and challenging to translate and operationalize into practice. It also requires a substantive engagement of social scientists alongside engineers, communication experts, and other behavioural professionals (e.g., psychologists), whose professional mindsets do not always align neatly. Yet, exploring the potential of a social practice approach and ways of overcoming its challenges seems worthwhile in a context whereby accelerating the energy transition and decarbonisation is the order of the day.

4) Conclusion

ADENE is committed to sharing this new approach and the results of this project with other agencies and organizations working in the field of energy transition, hopefully contributing to accelerate energy transition and decarbonisation at the European and Global level.



A socio-technical model coupling to identify transition pathways and policies towards self-sufficiency prosumers

Theme 6, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy sufficiency; Self-sufficiency; Flexible energy use; Energy transition; Prosumer households; Agent-based modelling

Extended abstract

1. INTRODUCTION

The energy transition demands not only the widespread deployment of renewable technologies but also fundamental shifts in household consumption patterns and behaviours. Prosumer households, that produce and consume energy, are uniquely positioned to contribute to more sustainable and efficient energy systems. This study investigates how households can transition toward energy self-sufficiency by co-adopting and flexibly using combinations of low-carbon technologies, including photovoltaic (PV) systems, electric vehicles (EVs), heat pumps, and home storage batteries.

The central objective of this research is to identify pathways to household energy self-sufficiency that go beyond individual technology adoption to include co-adoption and flexible usage. Self-sufficiency here refers to the extent to which households meet their energy needs



through locally generated solar power. We explore how combinations of technologies and their flexible use can minimize dependence on grid electricity and enhance local self-consumption of PV energy. The study also assesses the influence of different policy mixes on adoption patterns and flexibility behaviour.

To this end, we couple two complementary models: (1) an agent-based model (ABM) that simulates adoption and co-adoption behaviour over time, and (2) a household energy flow model that evaluates energy self-sufficiency based on actual energy usage patterns and technical constraints. The ABM is empirically grounded in a discrete choice experiment (DCE) dataset collected from 1,469 respondents in Switzerland. This enables us to simulate realistic household decisions based on heterogeneous preferences, contextual barriers, and social influence.

While existing energy transition models often examine the diffusion of individual technologies (e.g., solar panels, EVs), few studies consider the co-adoption of multiple technologies and even fewer investigate their combined usage patterns and the potential for demand-side flexibility. Yet, energy sufficiency and self-sufficiency require not only technological uptake but also behavioural change, particularly in how and when energy is used. This research addresses that gap by combining quantitative simulation with behavioural insights derived from experimental data.

2. METHODS

Our modelling framework consists of two main components:

Agent-Based Model (ABM) of Co-Adoption

The ABM simulates adoption and co-adoption of PV panels, EVs, heat pumps, and storage batteries by households over the period 2022–2050. Agents in the model are based on real participants from the DCE study, each with individual preferences and trade-offs of factors such as purchase price, savings, environmental impact, autonomy, and peer influence. In the model, agents make decisions at each time step, representing one year, on whether to adopt one of these technologies, and these decisions are influenced by internal motivations and external factors such as subsidies, cost decreases, technological performance improvements, and social norms.

Prosumer Household Energy Flow Model

The second model simulates how different combinations of technologies operate on a daily basis to meet household energy demands. The model calculates energy flows in 15-minute intervals, optimizing the use of PV generation, battery storage, EV charging, and heat pump operation to maximize self-sufficiency. Flexible usage is modelled based on self-reported likelihoods from the DCE respondents to use smart EV charging and smart heat pump heating for maximizing PV self-consumption.

By coupling these models, we assess how adoption patterns, usage preferences, and policies interact to shape long-term outcomes in terms of energy self-sufficiency and PV self-consumption.

3. RESULTS

Our simulations produce several key findings:

Simulated co-adoption patterns, presented in Figure 1, highlight that, under supportive policy mixes, co-adoption of technologies (especially PV with EVs and/or heat pumps) increases



significantly over time. However, early adopters are more likely than later adopters to adopt multiple technologies together.

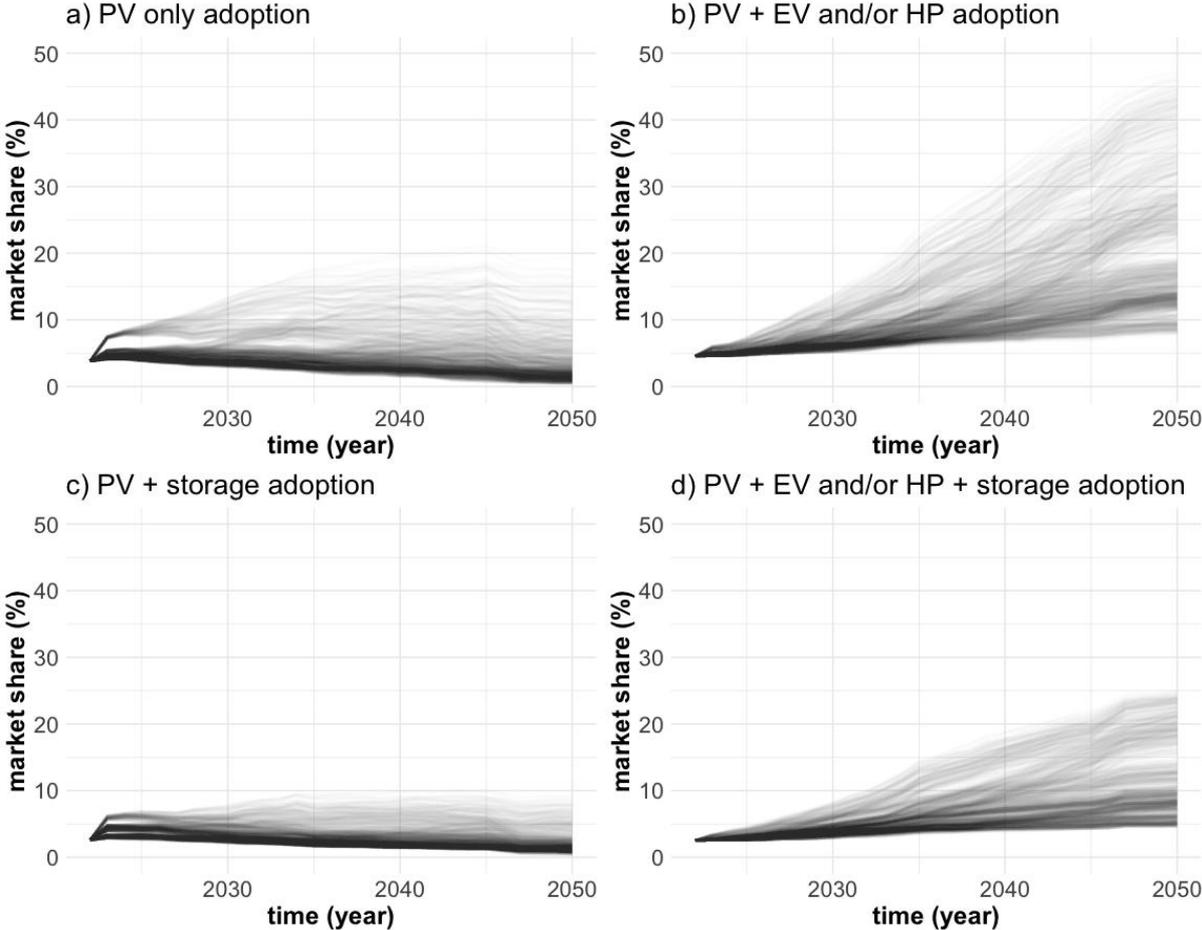


Figure 1. Simulated diffusion curves (2022-2050) among the 1469 agents of a) standalone PV solar panels as stand-alone, b) PV solar panels with an EV and/or a heat pump (no storage). c) PV solar panels with storage (no EV or heat pump), and d) PV solar panels with an EV and/or a heat pump, and storage. Each line represents one of 1024 simulated scenarios. Reproduced from [1]

Across the sample, a majority of respondents expressed a willingness to use smart systems to increase PV self-consumption, see Figure 2. Flexibility was more appealing for heat pumps than for EVs, likely due to the perceived lower disruption to daily routines. Notably, respondents who were interested in flexible EV charging also tended to show interest in flexible heat pump operation, indicating cross-technology consistency in flexibility preferences.

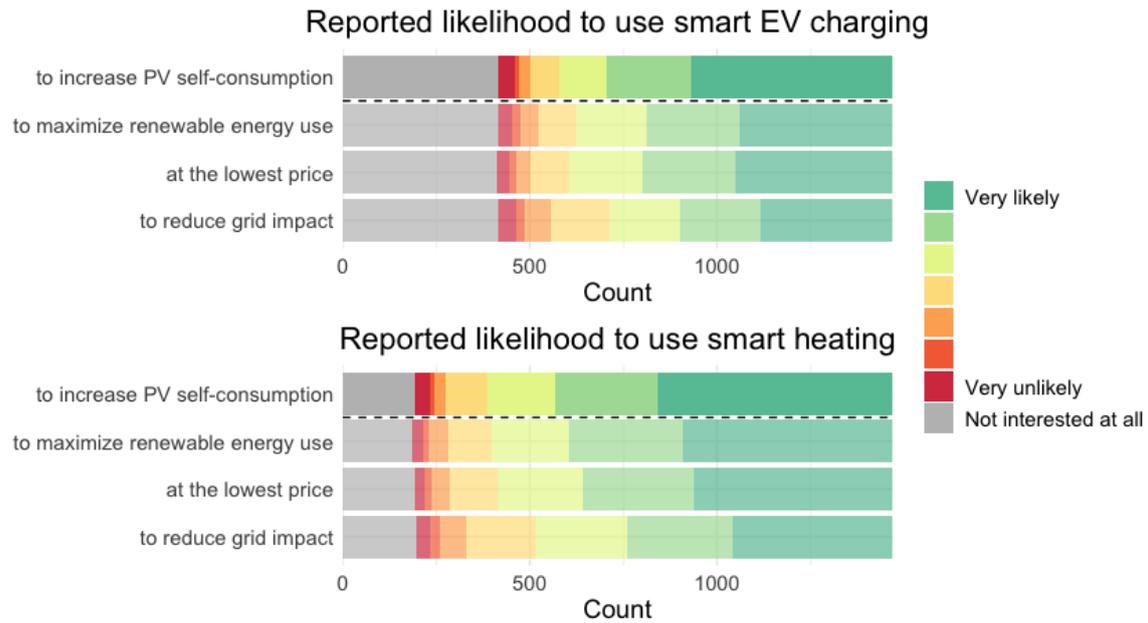


Figure 2. Distribution of answers of survey respondents (N = 1469) on the likelihood that they would use smart EV charging and smart heating for specific purposes. Respondents could indicate that they had no interest at all in the smart system or indicate their likelihood to use it on a 7-point scale between very unlikely to very likely. Reproduced from [1]

Combing the simulated co-adoption patterns (Figure 1) with the self-reported likeliness to use smart energy systems (Figure 2), we find that while absolute adoption of flexible energy technologies increases over time, the relative share of flexible use declines, indicating that flexibility is more popular among early adopters, see Figure 3. In turn, this leads to lower self-sufficiency levels among prosumer households later in the adoption curve, see Figure 4. Our simulation results thus show that while technological adoption is expected to continue rising, energy self-sufficiency among prosumer households may plateau or even decline unless flexibility increases in parallel. This emphasizes the importance of sustaining behavioural engagement over time, especially among later adopters.

4. CONCLUSION

Our findings reveal that early adopters, often motivated by environmental values, are more likely to engage in flexibility-enhancing practices. Therefore, policies aiming to increase adoption should be complemented by interventions that promote flexible use, such as dynamic pricing, behavioural nudges, and targeted incentives for smart system usage.

Crucially, policy timing and targeting matter. Incentives for flexibility should be sustained throughout the adoption curve and not limited to early adopters. Support should be tailored to reach later adopters and tenants, whose flexibility engagement may be lower without ongoing support.

By integrating empirical data within coupled simulation models, this study offers a novel contribution to the literature on energy sufficiency transitions. It provides an evidence-based simulation framework for understanding how co-adoption and energy flexibility can be aligned to advance energy self-sufficiency in a decentralized energy system.

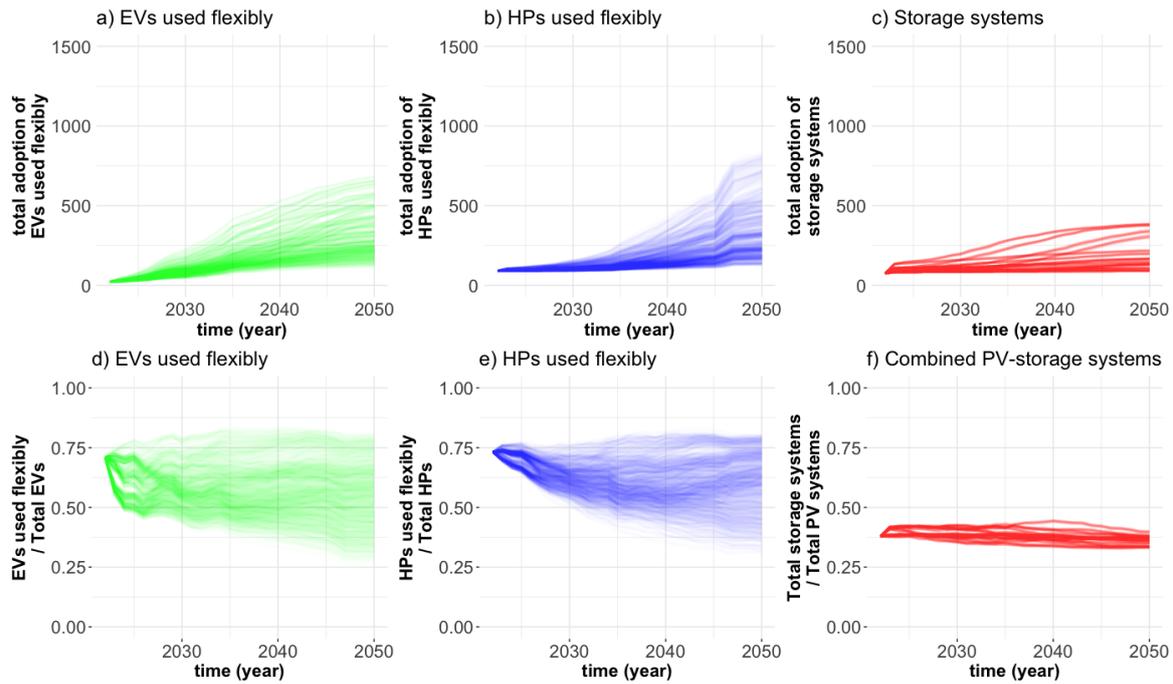


Figure 3. Simulated diffusion curves (2022-2050) among 1469 agents of the total number of a) EVs, b) heat pumps (HP) and c) storage systems that are used flexibly, and their relative number compared to the total adoption of d) EVs, e) heat pumps, and f) PV solar systems, respectively. An EV or heat pump is used flexibly if the following two conditions are met: (1) the agent also adopts PV solar panels, (2) the corresponding respondent indicated 4 or higher on the 7-point scale that measure the interest in using a smart system to increase PV self-consumption for EV charging (in the case of EV adoption) or heating (in the case of heat pump adoption). Each line represents one of 1024 simulated scenarios. Reproduced from [1]

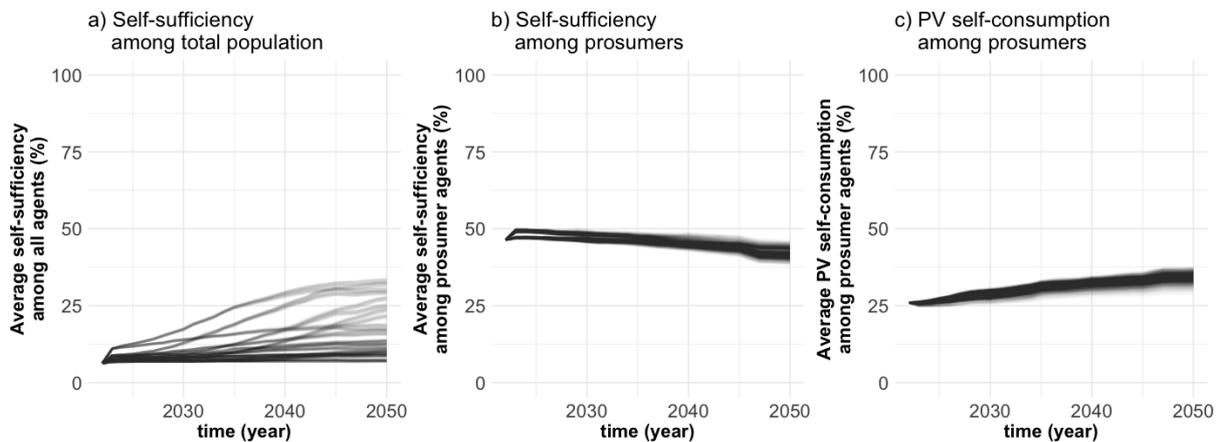


Figure 4. Simulated development for the period 2022-2050 a) average self-sufficiency among the total population of 1469 agents, b) average self-sufficiency among prosumers (i.e., PV adopters), c) average PV self-consumption among PV adopters. Each line represents one the 1024 simulated scenarios. Reproduced from [1]

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Characteristics of Effective Energy Coaching as Policy Measures to Alleviate Energy Poverty-Related Aspects

Theme 1, sub-topic 1d

Theme 2, sub-topic 2b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy coaching, local embeddedness, recruitment, residential comfort, health, sustainable behaviour

Extended abstract

Introduction

Since the start of the energy crisis in 2021, the Dutch government has provided a total of €550 million in specific allocation funds (SPUK funds) to municipalities to help energy-poor and vulnerable residents with energy savings and improving their overall living conditions, such as housing comfort, health, and financial concerns about paying energy bills. Many municipalities have chosen to use the received grants to deploy energy coaches. This form of aid helps households to save energy through installing minor energy-saving measures in homes (e.g. radiator foil, draft strips, door brushes) and advice on sustainable energy practices.

Research objective

Previous research has shown that these measures are affective **Erreur ! Source du renvoi introuvable.,Erreur ! Source du renvoi introuvable.** However, there are many differences in energy coach organizations and practices, and, until thus far it remains unclear what characteristics of energy coaching make this form of aid effective. Hence, this study aims to identify which characteristics (local embeddedness, visiting aspects, workforce, and recruitment) typify effective energy coaching and to what extent these characteristics improve residents' living conditions: residential comfort, physical and mental health, financial concerns about paying energy bills, loneliness, and sustainable behaviour. Based on this, recommendation are provided for national and provincial governments, municipalities, energy coach organizations, and also housing associations about how to facilitate or incorporate these characteristics within energy coach organizations.

Research method



The research was conducted in collaboration with thirteen energy coach organizations that, prior to and after the provided energy coaching, distributed a paper and/or digital questionnaire to residents. The questionnaire was made available in six different languages (Dutch, English, Turkish, Arabic, Polish and Somali). A total of 1877 residents filled in the questionnaire. We compared the living conditions of residents who have received energy coaching (N = 1213) with the living conditions of residents who have not yet received energy coaching (N = 664). When this significantly differs and improves aspects such as residential comfort, health, and sustainable behavior, and reduces loneliness and financial concerns, we speak of effectiveness.

Conclusion

1. Local embedding is most important for the effectiveness of energy coaching.

Energy coach organizations that have been active in a municipality for more than five years generally improve residential comfort and physical and mental health, and reduce financial concerns and loneliness among residents. Moreover, energy coach organizations that started as a local initiative also improve residential comfort and physical health and reduce financial concerns. These organizations likely have gained better insights into which residents are most in need of help, allowing for more improvement in their overall living conditions.

2. Multiple and longer visits by energy coaches contribute to improved residential comfort and physical health and promote sustainable behavior.

Energy coaches who visit residents at least twice, improve physical health and sustainable behavior. Additionally, energy coaches who visit residents over four hours in total, improve residential comfort and physical health. Multiple and longer visits give energy coaches organizations the opportunity to tailor help to residents' needs. Furthermore, regular feedback is crucial for behavior change in energy consumption, which is only possible through multiple visits [3].

3. Energy coach organizations that employ volunteers and labor-restricted workers improve residential comfort and physical health and reduce financial concerns.

Energy coach organizations working with volunteers generally improve housing comfort and physical health of residents and reduce their financial concerns. Organizations employing people that are labor-restricted also show a positive effect on trust in the housing association among tenants. These positive findings can possibly be explained by the intrinsic motivation of these energy coaches and the extra guidance and support they receive from the organization. Furthermore, organizations that employ volunteers typically make longer and more frequent visits to residents, increasing the effectiveness of energy coaching.

4. Collaboration with a housing association and targeted recruitment helps reach vulnerable residents.

Energy coach organizations collaborating with a housing association generally improve residential comfort and physical and mental health, and reduce financial concerns and loneliness. Housing associations seem to assist energy coach organizations in recruiting residents with lower incomes and poorer quality housing. Additionally, energy coach



organizations focusing specifically on recruiting low-income residents generally improve residential comfort.

Recommendations

Allow energy coach organizations to establish themselves in local level for multiple years and offer intensive help to residents. This way, they gain knowledge of the target group and can carefully tailor their help to support vulnerable residents. Energy coach organizations that are more than five years active in a municipality show the most effect on improving residents' living conditions, and for lasting sustainable behavior change, visiting at least twice is necessary.

Create local employment opportunities by engaging volunteers and supporting labor-restricted workers. This way, more labor force gets to work, and residents receive more intensive help. Energy coach organizations using volunteers make longer and more frequent visits to residents than those working solely with paid staff. Supporting and guiding labor-restricted workers requires extra attention from the energy coach organization, potentially spilling over to a more effective approach for the residents.

Promote collaboration between housing associations and energy coach organizations. Housing associations have a good view of the quality of the housing and can help energy coach organizations recruit residents most in need of help by sharing this information. The aid can also be a valuable bridge until the housing association implements more extensive insulation measures.

Provide municipalities with structural funding for continuing energy coaching. Given the positive effects that energy coaching can achieve on residents' broader living conditions, it is valuable to continue subsidies for energy coach organizations beyond 2025. This makes the transition for energy-poor and vulnerable households, who must wait until their homes are properly insulated, more bearable.

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The double-edged nature of ambivalence. A field study among Dutch car owners revealing how ambivalence motivates and undermines car travel behaviour change

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Keywords: ambivalence, mobility, car use, personalised travel feedback, mobility apps, field experiment

Extended abstract

Transport is a major contributor to climate change, accounting for 27% of global greenhouse gas (GHG) emissions ^[1,2], with emissions from this sector rising rapidly in recent decades^[3,4]. In the Netherlands, road traffic represents 17% of national emissions, 57% of which stem from private cars ⁵. Both the number and size of cars have increased steadily since 1990 ^[6]. Despite the urgent need for a modal shift toward low-carbon transport options ^[7], car use remains dominant in Western countries ^[8,9]. Research shows that people experience conflict about resigning from environmentally unfriendly behaviours or adopting environmentally friendly ones ^[10, 11], but this is not necessarily negative. Research indicates that internal conflicts, i.e., ambivalence, can serve as a promising route to behaviour change.

Car travel differs from other environmental behaviours in ways that may influence the role of ambivalence. First, high sunk costs—such as car ownership and infrastructure—reduce the perceived cost of driving and discourage alternatives ^[12]. Second, travel decisions are more constrained by practical factors (e.g., access, logistics) than by environmental values ^[13]. Third, daily travel is often automatic and habitual, limiting the role of conscious intentions ^[14,15]. This study examines whether the motivation to resolve ambivalence can meaningfully influence car use in such a context, where behavioural change is especially difficult.

Objective

The present study, therefore, investigates whether activating ambivalence about car travel can drive reductions in habitual car use. By investigating ambivalence in the context of car travel, we address a critical gap in the literature. This study extends ambivalence research to a particularly challenging domain where behavioural change is characterised by strong habits and sunk costs. This study examines three core questions. First, we assess whether ambivalence directly reduces car travel intentions and behaviour. Second, we investigate its dynamic role by experimentally activating ambivalence and testing for mediation effects. Third, we examine individual differences in response to ambivalence, expecting stronger effects among those with



strong environmental values or a high need for consistency. This approach advances theoretical understanding and offers practical insights for promoting low-carbon travel.

Method

To test our hypotheses, we conducted a six-week field experiment with 298 urban car owners in Amsterdam, randomly assigned to a control or experimental condition in a mixed between-within design. During the first two weeks (control phase), all participants used a basic version of a mobility app that showed trip start/end points and transport modes, allowing them to verify and adjust travel data. After this phase (T1), participants were randomly assigned to either continue with the basic app (control group) or receive personalised CO₂ feedback on all travel movements (experimental group), aimed at activating ambivalence about fossil-fuel use. Subjective ambivalence and travel behaviour were assessed through surveys before (T0) and after (T1) the intervention. Throughout the study, participants were asked to regularly check their trip data for accuracy. This design enabled us to track changes in ambivalence, intentions, and actual behaviour in response to the intervention.



Figure 1. Visual of personalised feedback per trip in the application

Results

Although the CO₂ feedback intervention did not successfully increase ambivalence, and ambivalence did not mediate the feedback's effects on intentions or behaviour, the study yielded valuable insights. Consistent with previous research, subjective ambivalence about car travel was linked to reduced car use intentions and behaviour—but only in the control group. In the experimental group, this relationship disappeared, and car use and CO₂ emissions even increased. These findings suggest a boundary condition: when behaviour is habitual and tied to sunk costs, activating ambivalence may disrupt rather than motivate change. Further evidence comes from participants with strong green consumption values. Although these values predicted lower-carbon intentions overall, ambivalence had a weaker negative effect in this group, suggesting emotional coping in response to dissonant feedback. Rather than adjusting their behaviour, individuals may disengage or rationalise when feedback conflicts with self-relevant values and follows behavioural decisions.

Conclusions

This study highlights the motivational role of subjective ambivalence in travel behaviour change. Among car users, higher ambivalence about car travel was associated with reduced intentions and actual car use—but only in the absence of intervention. In contrast, participants who received personalised CO₂ feedback, aimed at activating ambivalence, did not show these

reductions. Instead, car use and emissions increased, suggesting that under certain conditions, triggering ambivalence salience may backfire.

These results underscore the complexity of changing habitual behaviours like car travel, that are characterized by habits and sunk costs. Although psychological conflict can motivate change, our findings suggest that if this conflict is provoked through emotionally charged or self-relevant feedback—especially after a behavioural decision—it may trigger emotional coping strategies such as disengagement or rationalisation, rather than behaviour change.

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Reducing Sludge for Residential Retrofitting

Theme 1: Instruments, interventions and evaluation of behaviour change and evolution in social practices in the field of energy and the environment

Sub-topic 1b) Behavioural Solutions in Companies

□ “Academic contribution”

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Keywords: Retrofitting, Energy Efficiency, Administrative Burden, Sludge Audit, Customer Journey

Extended abstract

The residential sector accounts for approximately 25% of Ireland's total energy consumption and represents a critical pathway for achieving national climate objectives [1]. Despite substantial government investment in retrofitting programmes— including grants of up to €50,000 per household—uptake remains low, with only 2% of Ireland's housing stock achieving deep energy retrofits annually [2]. This research addresses a fundamental yet under-explored barrier to residential energy transition: the administrative burdens that homeowners encounter when navigating retrofitting programmes [3].

Administrative burdens, conceptualised as the unnecessary friction that citizens face when interacting with procedures and services, manifest in retrofitting contexts as complex information requirements, extensive documentation procedures, and demanding decision-making processes [4][5]. These 'sludge' factors represent a significant behavioural barrier to energy transition that deserves increased attention in both academic literature and policy design. Understanding and addressing these administrative obstacles is essential for achieving the scale and pace of residential retrofitting required to meet Ireland's climate commitments whilst ensuring equitable access across diverse socioeconomic groups.



The One-Stop-Shop (OSS) model has emerged as a policy response designed to streamline the retrofitting process by consolidating services under a single provider responsible for coordinating the entire customer journey. In theory, this integrated approach should reduce administrative burdens by eliminating the need for homeowners to navigate multiple service providers, standardising procedures, and providing expert guidance throughout the retrofitting process. However, the extent to which OSS models successfully reduce administrative sludge in practice remains empirically underexplored, particularly regarding the specific types of burdens that persist and their differential impacts across homeowner segments.

Research Objectives and Methodology

This study employs a comprehensive sludge audit methodology [5][6] to examine the customer journey through an Irish OSS retrofitting programme. The primary objective is to systematically identify and categorise administrative burdens experienced by homeowners throughout the retrofitting process.

The research design combines multiple qualitative methods to provide a holistic understanding of administrative burden manifestations. Customer journey mapping was conducted through collaborative meetings with OSS personnel and the direct observation of customer service interactions during two different critical decision points. An audit of *most* documentation requirements—forms, technical specifications, and financial considerations— and communication between the organisation and the customers quantified the procedural length and complexity imposed on homeowners.

The core empirical component comprises 20 in-depth interviews with homeowners who had engaged with the OSS retrofitting process within the preceding 12 months. Participants are recruited following a brief customer satisfaction survey conducted by the OSS provider. The semi-structured interview protocol, adapted from the Administrative Burdens as Barriers to Implementation of Ireland’s Climate Action Plan (ABICAP) [7] methodology, incorporates a visual customer journey map to facilitate recall and discussion. Interviews explore three dimensions of administrative burden: search costs (e.g., through complex information and hidden fees), cognitive costs (e.g., complex information and uncertainty) and psychological costs (e.g., frustration, anxiety & loss of motivation)[6][8].

The thematic analysis of interviews and documents uses a hybrid approach combining deductive coding based on administrative burden theory with inductive coding to capture emergent themes specific to the retrofitting context. This analytical framework employs a systematic sludge audit inspired by the New South Wales government toolkit [9] and adapted by ABICAP [7].

Key Findings

The preliminary results point to a complex retrofitting landscape where some administrative burdens persist even in the OSS model. Homeowners typically engage with two to four different individuals throughout their retrofitting journey, depending on the nature of the retrofit (standard or consultancy). Additionally, they encounter a number of distinct forms requiring completion or signature, and spend a few hours on documentation activities alone. These findings highlight the continued fragmentation of the long customer experience despite OSS coordination efforts. While this points to many involved steps, it does not imply that each of these steps is sludge.

Search costs are expected to emerge as particularly significant, with participants likely to report feelings of being overwhelmed by technical complexity regarding insulation specifications,



heating system parameters, and ventilation requirements. Grant eligibility understanding is also likely a sustained challenge, given the complex relationship between Building Energy Rating (BER) requirements, energy consumption reductions (100 kWh/year uplift), and funding availability (uncertain until after the home energy assessment).

Cognitive costs are likely to remain substantial despite OSS integration, with homeowners conveying that financial documentation requirements emerge as particularly onerous and excessively bureaucratic. The persistence of information duplication across different documents and stakeholders contributes to perceived inefficiency and frustration.

Psychological costs include decision fatigue, trust-related vulnerability, and disruption anxiety. These are often exacerbated by the 6–8 month project duration and complex household occupancy patterns or caring responsibilities.

Importantly, the research identifies inequities, with older and digitally excluded homeowners facing disproportionate burdens. These equity implications suggest that existing OSS models may not entirely remove the unequal barriers to retrofitting access for vulnerable populations, potentially exacerbating some energy inequality rather than promoting just transition outcomes.

Innovation and Implications

This research makes several important contributions to understanding behavioural barriers in energy transition contexts. First, it extends administrative burden theory by examining how burdens manifest in intermediated service models where commercial organisations function as an interface between citizens and access to government grants. The findings reveal that whilst intermediation redistributes certain administrative burdens, it simultaneously introduces new friction points related to agency relationships, information verification, and trust dynamics.

Second, the study highlights the temporal concentration of administrative burdens around transitional phases in extended service journeys rather than uniform distribution throughout the process. This insight has significant implications for designing targeted interventions that address critical friction points during journey transitions, potentially yielding disproportionate improvements in customer experience and programme effectiveness.

Third, the research provides empirical evidence of the substantial work already undertaken by OSS providers to simplify the retrofitting process, whilst simultaneously identifying specific opportunities to improve/reduce the administrative burdens, and identify those burdens that are outside of the OSS's control (e.g., due to grant eligibility requirements). The findings suggest that OSS models represent a significant advancement over traditional fragmented service delivery, but additional refinements are needed to fully realise their potential for burden reduction.

The policy implications extend beyond residential retrofitting to broader energy transition initiatives. This sludge audit methodology offers a transferable framework for evaluating and streamlining administrative processes across various energy programmes, including commercial retrofitting, renewable energy adoption, and electric vehicle infrastructure development.

For practitioners, the findings emphasise the importance of considered customer journey design within such integrated government-organisation service models, including proactive communication protocols and decision support tools calibrated to different levels of technical literacy. The research also highlights the critical role of trust-building mechanisms through enhanced transparency, independent verification opportunities, and peer support networks.



Conclusion and Broader Relevance

This research demonstrates that administrative burden reduction represents a critical yet underutilised leverage point for accelerating energy transition behaviours. The persistence of significant sludge factors despite OSS integration indicates that achieving truly accessible energy transition requires systematic attention to administrative design alongside technical and financial considerations. Addressing these barriers is essential not only for programme effectiveness but also for ensuring that energy transition benefits are distributed fairly across society.

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Energy saving potential via sufficiency measures in residential buildings in Europe

Theme 5, sub-topic 5a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, Sensitivity, Energy efficiency, Decarbonisation, Residential Buildings, Europe

Extended abstract

Introduction

There is growing evidence of the potential impact of sufficiency measures on the energy savings and the environmental footprint of buildings [1], [2]. It is estimated that sufficiency measures alone (excluding building size measures) could lead to a 23% reduction of greenhouse gas (GHG) emissions in the residential sector in Europe [2], but there are large differences in such estimates [3], [4], [5]. These hamper correct evaluation of the potential impact of sufficiency measures impeding adequate development or finetuning of policies aiming at energy and emission savings in residential buildings.

Objectives and scope

Our research aims to quantify the potential impact of sufficiency measures in residential buildings in Europe, including a sensitivity analysis of the input parameters. The research is part of the streamSAVE+ project²².

Sufficiency measures could avoid energy demand while still maintaining levels of quality

²² <https://streamsavenplus.eu/> This project has received funding from the European Union’s LIFE programme. Project No. 101167618 — LIFE23-CET-streamSAVEplus.



and services that buildings should offer within acceptability ranges or according to decency standards of human occupancy.

Only sufficiency measures at the individual housing unit are considered. Measures that involve energy transfer between housing units or with non-residential units are not considered. Rebound and spillover effects [6], limiting the effectiveness of the sufficiency measures, are not taken into account.

Methodology

The potential impact of sufficiency measures is determined for residential buildings in the EU-27 member states per end-use service; space heating (SH), space cooling (SC), domestic hot water (DHW), lighting (LI) and other (OTH). The energy data for the residential sector from the JRC-IDEES database [7] and the climatic data from BizEE [8] are used. The methodology quantifies the minimum service levels a residential building should offer to its occupants based on acceptability ranges - where available - or other (such as decency) standards of human occupancy. Standard and sufficiency adapted values are assigned to the indoor temperature (in heating season $T_{i,SH}$, and in cooling season $T_{i,SC}$), the ventilation air flow rate v_{vent} , the DHW service level (water flow rate V_{dhw} , shower frequency n_{sho} and duration t_{sho}), the lighting service level E_v and the size (SI) of the residential building unit (useful floor area A_{use}). Table 9 summarises these assumptions, including minimum and maximum values for sufficiency adapted parameters for input of the sensitivity analysis.

	SH	SC	SH & SC	DHW			LI	SI
	$T_{i,SH}$	$T_{i,SC}$	v_{vent}	V_{dhw}	t_{sho}	n_{sho}	E_v	A_{use}
	[°C]	[°C]	[U(s.m ²)]	[l/min]	[min]	[n/w.p]	[lx]	[m ² /hh]
Minimum value for sufficiency adapted parameter	15,7	27,0	0,18	5,0	4,0	2,5	100	30
Representative value for sufficiency adapted parameter	15,7	28,0	0,22	8,0	4,5	3,5	150	42,5
Maximum value for sufficiency adapted parameter	20,0	28,0	0,35	9,0	5,0	4,5	166	55
Representative value for standard parameter	19,4	26,0	0,41	10,0	7,5	5,6	db*	db*

*db: value for EU27 and per members state are adopted from JRC-IDEES database [7]

Table 9 Assumptions on input parameters per end-use category.

In addition, one weekly bath replacement by a shower [9] and a bath water volume reduction by 10% are considered. The reduction of the building size is applied only to new and renovated buildings. However, the impact of size reductions applied to all buildings is also analysed to determine the full potential achievable (over time) across the entire residential building stock. The assumptions made for the input parameters are based on the references listed in the Table 10.

Parameter name	Symbol	Unit	References
Indoor temperature during heating season	$T_{i,SH}$	[°C]	[10] [11] [12] [13] [14] [15] [16] [17] [18] [19]
Indoor temperature during cooling season	$T_{i,SC}$	[°C]	[10] [11] [12] [13] [14] [15] [16] [18] [19] [20]
Specific ventilation air flow rate	v_{vent}	[U(s.m ²)]	[10] [11] [12] [13] [14] [15] [21] [22] [23] [24] [25]
Shower water flow rate	V_{dhw}	[l/min]	[26] [27] [28] [29] [30] [31]
Shower duration	t_{sho}	[min]	[26] [27] [29] [30] [31] [32] [33] [34]
Number of showers (per week and person)	n_{sho}	[n/w.p]	[26] [27] [29] [32] [35] [36] [37] [38] [39] [40] [41] [42]
Illuminance level	E_v	[lx]	[43] [11] [18] [19] [7] [44]
Useful floor area (per household)	A_{use}	[m ² /hh]	[3] [45] [46] [18] [19] [7]

Table 10: References used for establishing input parameter assumptions.

Results and discussion



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Standard (full bar lengths), sufficiency adapted (subscript ‘suf’ - broad part of bars) and saved (subscript ‘sav’ - small part of bars) annual final energy use per capita in residential buildings (Q) are depicted in Figure 32 together with the relative saving factor (F_sav_RES).

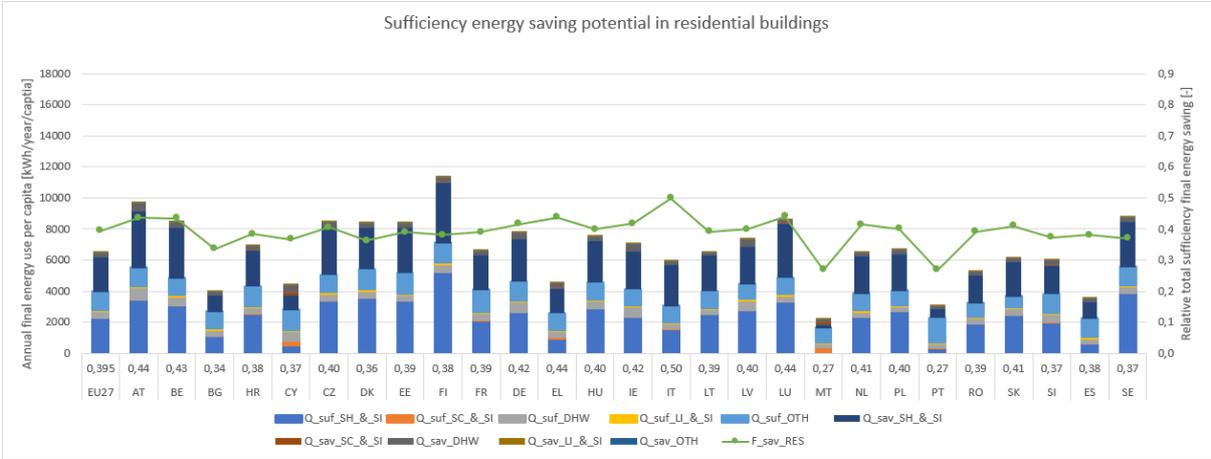


Figure 32: Full potential of energy saving via sufficiency measures in residential buildings in EU27 member states.

The results show a potential reduction of 39,5% of the final energy use and 48,3% reduction in CO₂ emissions in the residential buildings in the EU-27 member states, with large variation across member states and services. The highest energy savings are achievable in Italy (49,9%), the lowest in Malta (26,8%). The highest energy savings are achieved for space heating (49%) and the lowest for lighting (26%). No sufficiency measures are applied to the end-use category other (energy saving factor of 0%). Only 1 or 2 absolute percentage contributions stem from the size reduction measures (when applied to only new and renovated buildings).

However, the analysis with size reductions applied to all buildings reveals a potential saving of 59,5% of final energy use and 72,4% reduction of GHG emissions for the EU-27. On average, the useful floor area could be reduced by as much as 55%. However, a full reduction in size is not practically feasible, particularly in existing buildings in the short term. This hints at further research into means to unlock this substantial saving potential. Such research could explore options for reorganising and resizing the building stock to better align with sufficiency-reduced space requirements.

Without size measures, the potential reduction of the final energy use is reduced to 38,9% and 47,6% of GHG emission savings. This result is significantly higher compared to the findings of another study, which reported 23% of GHG savings via sufficiency measures in residential buildings in Europe - also calculated without size measures [2].

Sensitivity analysis reveals substantial variation in the results due to uncertainty of the inputs. The relative final energy savings for EU-27 vary between a minimum of 5,1% and a maximum of 42,7% (calculated with size measures applied only to new and renovated buildings). All results should be interpreted with caution and considered in light of the uncertainty in the underlying assumptions. They also highlight the need for further research to finetune the boundaries of acceptable levels of quality and services.

The results reflect the full potential of savings achievable via sufficiency measures. In practice, actual savings will be lower due to partial uptake of the measures and partial cumulation of their effects. On the other hand, the analysis does not account for all end-use services or behavioural and systemic factors that could lead to even higher energy demand

savings. Furthermore, higher savings can be expected by lowering levels further down to minimum levels of health and wellbeing. Although in some situations this already may be occurring to some extent, it is not reasonable to assume broad public support for policies that promote minimum levels of service and comfort, even if these policies remain within acceptability ranges. To enhance the adoption of sufficiency measures, additional public sensitization efforts are needed. Emphasis on the broader multiple benefits can help build support for a reasonable and socially acceptable implementation of sufficiency measures.

Conclusion

Our research presents a methodology for quantifying the potential impact of sufficiency measures in residential buildings across Europe. The methodology is based on a review of sufficiency-reduced levels of quality and services in residential buildings. Such sufficiency measures can result in potential final energy savings of 39,5% and associated GHG emission reductions of 48,3%, with significant variation across the EU-27 member states and among different services. In case of fully adapting the residential building stock to the sufficiency reduced sizes for the current household compositions, the potential savings could reach 59,5%. However, this level of transformation is not practically feasible any time soon. All results should be interpreted with caution, as sensitivity analysis reveals substantial variation in the output due to uncertainty in the assumptions about sufficiency levels.

The research shows the vast potential of energy savings via sufficiency measures in residential buildings across Europe. It also underscores the need for further research into unlocking this potential and exploring strategies to increase the public support for policies aimed at reduced levels of service and comfort, even within acceptability ranges.

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Mapping the Reuse Potential of Vacant and Under-occupied Buildings for Housing: insights from the project TRIOMPH

Theme 5, sub-topic 5a

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Adaptive Reuse, Built Environment, Housing, Mapping

Extended abstract

To reach net zero targets and mitigate the environmental impact of new construction, the building sector is shifting from an extensive planning model based on land consumption to a more sufficient model. This model is based on optimising and reusing the existing building stock, vacant and/or under-occupied [1]. Vacancy and under-occupation of buildings is likely to increase, according to the last statistical projections [2], taking into account demographical tendencies, such as population’s ageing, and new ways of work and living. However, quantification of this vacant and under-occupied stock remains a challenge for policy-makers, due to the lack of data and knowledge about what can be effectively reused [3]. In addition, the transformation and renovation of existing buildings is considered more costly than demolition and reconstruction, thus hindering the widespread adoption of these practices.

The project TRIOMPH (i.e Transformation and Reuse of Buildings for the Optimisation of the Living spaces) aims to address those challenges, focusing on the transformation of the existing building stock to provide affordable housing. This research is funded by the French Agency for Ecological Transition (ADEME) and coordinated by the French Scientific and Technical Centre for Construction (CSTB), with three main partners (Ekopolis, Territoire Circulaire, and Greater Paris Metropolis).

The research addresses three main solutions for the adaptive reuse of buildings: reversibility (e.g. converting office buildings into office units), intensification of use (i.e. longer-term use and greater functional diversity) and new housing models (e.g. collective housing). The project aims to determine the potential for scaling up these solutions at national and local levels and to develop adaptive reuse scenarios that address housing needs. To achieve this, it is necessary to identify criteria that determine the feasibility of these pathways from a multi-level perspective (from local to national) and to assess the impact of the solutions on reducing emissions, construction waste and land artificialisation. In order to visualise the potential of these



solutions, the project proposes analysing spatial data to map areas suitable for some scenarios. The aim will be to define criteria for the relevance of these scenarios depending on factors such as the existing building stock, nearby facilities and urban planning criteria. The various scenarios will have economic and environmental impacts, which the project will seek to quantify in order to select the most relevant ones. Beyond technical and economic considerations, the operational setup of these projects must be analysed. It is important to understand the interplay of stakeholders that will facilitate paradigm shifts and identify levers for public policies, beyond theoretical potential. Stakeholders that will make certain paradigm shifts possible, and to identify the levers for public policies.

In the first stage of this research, 11 case studies have been examined through semi-structured interviews with project owners. Based on the lessons learned from these case studies (in terms of replicability, number of dwellings produced, economic and social benefits), several types of scenarios will be selected for the adaptive reuse potential analysis.

Eleven case studies were selected following a review of the literature and an analysis of existing projects. They were chosen for their potential for replication, territorial representativeness (including urban, rural and peri-urban areas) and social and environmental impact. Semi-structured interviews were conducted with project team leaders to identify criteria that facilitate the implementation of solutions and to define effective scenarios for the transformation of building stock.

Thus, two key scenarios have been defined: one involving a change in the use of tertiary buildings and one involving tools to reduce under-occupation and vacancy in housing, such as renovation leases. For the first scenario, the main criteria are public ownership and properties owned by only one landlord. For the second scenario, the main criteria are the current state and obsolescence of the buildings and the financial capacity to renovate.

A method has been established for mapping the potential implementation of these scenarios on a national scale using the National Building Database (BDNB), which is owned by the CSTB. This database provides a comprehensive overview of the national building stock and incorporates several territorial data sources into the analysis (e.g. proximity to facilities, transport links and green spaces) to account for the heterogeneity of local dynamics.

This paper will discuss the main outcomes of these scenarios and how feasible they are in terms of the levers and challenges raised by stakeholders. Based on these scenarios, the project will further investigate their environmental, social and economic impacts compared to a reference scenario involving new construction. The main objective is to test the methodology of mapping the potential for reuse at a territorial level in order to obtain feedback from local authorities and urban planners and to provide recommendations for public policy.

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The role of electric vehicle ownership and earmarking for the acceptability of charging infrastructure projects in France and Germany

Theme 3, sub-topic 3a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Acceptability, Electric vehicle, Charging infrastructure, Mobility policy

Extended abstract

Motivation

Despite an increasing market share of electric vehicles (EVs) in Europe, regional differences remain and many countries are falling short of adoption targets, including Germany and France [1],[2],[3]. It has been shown that apart from economic barriers, structural and psychological barriers persist among both EV owners and non-owners, such as range anxiety and perceived lack of public charging infrastructure [4],[5],[6],[7]. With a large part of the German and French population living in urban and rented spaces where private charging points are inaccessible, improving public charging infrastructure is of interest to both EV owners and non-owners and can be linked to higher EV adoption [8]. To meet governmental targets concerning public charging stations, considerable investments and construction projects are necessary. While extensive research has been conducted on barriers and drivers of EV adoption (e.g., [4],[5],[6]), less is known about public perceptions of EV charging infrastructure, particularly regarding the acceptability of implementing new infrastructure [7],[9]. Furthering the knowledge on acceptability is vital to successful policymaking, as low public acceptability can lead to resistance against energy projects, which can impede their success [10],[11]. In the case of EV charging points, a study by [9] revealed that trust in the industry and problem awareness impact acceptability of public



charging infrastructure, but it did not address potential differences between EV owners and non-owners.

The current study analyses the influence of EV ownership status and policy earmarking on the local acceptability of implementing new charging points among a representative French-German sample. The objective is to assess public perceptions of charging infrastructure projects, which are so far underresearched, and to study possible factors influencing acceptability. The distinction between EV owners and non-owners is addressed here, as a policy design that leads to an unequal distribution of benefits among the addressed group might influence effectiveness beliefs concerning the policy, which in turn can affect acceptability [12],[13],[14],[15].

Current research and method

Using an experimental design, we study the scenario of implementing EV-exclusive charging points next to existing parking spots, which is beneficial for EV owners but disadvantageous for owners of non-EV cars. Specifically, the earmarking (i.e., the distribution of funds or allocation of revenues to funds) was described as either user-funded or municipally funded. Based on previous research [13], we hypothesised that the acceptability of the project scenario is higher for municipal funding than for user funding and higher among EV owners compared to non-EV-owners. Moreover, we expected that the effect of EV ownership on acceptability is mediated through perceived effectiveness, and that the links between EV ownership, effectiveness perception and acceptability of the charging points are stronger for municipal funding compared to user funding.

Data was collected in samples of 813 participants from Germany and 790 participants from France, representative for gender, age, education status and household income. To ensure feasibility of the analysis, EV owners were oversampled in both countries relative to the population (16% in the German and 21% in the French sample). Participants were randomly assigned to one of two earmarking conditions, which either stated that new EV charging points near their place of living were municipally funded or funded through increased charging prices for users. Differences in acceptability depending on earmarking scheme and EV ownership were analysed with a robust ANOVA from RStudio's WRS2 package [16], using 20% trimmed means and bootstrapping to account for unequal variances. The effect of EV ownership on acceptability was analysed in a multi-group structural equation model (SEM), with earmarking as the grouping factor. EV ownership was dummy coded, with participants stating their household owned at least one EV classified as EV owners and those who stated owning zero EVs classified as non-owners. Acceptability was assessed as a latent variable based on three items. Perceived effectiveness was constructed as a latent variable based on seven items and modelled as a mediator between EV ownership and acceptability. Due to findings on charging preferences and sociodemographic characteristics of EV owners [5],[6], homeownership, ownership of a private wall charger, future interest in EV ownership and future interest in wall charger purchasing were included as covariates. To account for inter-country differences, the country of residence was included as a covariate. The influence of the covariates was modelled on both mediator and dependent variable.

Results and discussion

The robust ANOVA showed significant main effects of earmarking ($Q = 5.22, p = .024$) and EV ownership ($Q = 62.39, p = .001$), with acceptability being rated higher for municipal funding and among EV owners, while the interaction was not significant ($Q = 1.41, p = .236$). In the

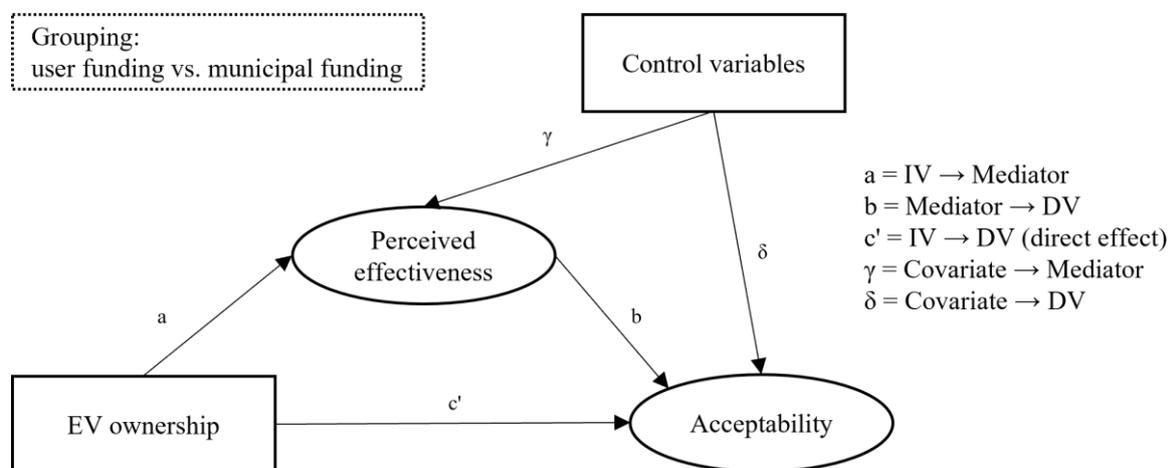


multigroup SEM, a baseline model with freely estimated paths was compared to constrained models. A conceptual model of the multigroup SEM is displayed in Figure 1. The baseline model showed good fit to the data, $\chi^2(164) = 477.506, p < .001, CFI = .98, RMSEA = .049, SRMR = .019$. Constraining the b-path to be equal across groups significantly worsened fit, while constraining the a- and c'-paths did not. Fully constraining the paths showed good fit, $\chi^2(167) = 483.116, p < .001, CFI = .98, RMSEA = .049, SRMR = .024$, and did not significantly worsen model fit, $\Delta\chi^2(3) = 5.61, p = .132, \Delta CFI < .001$. The fully constrained model was retained for interpretation, supporting equal mediation paths and direct effects across the two levels of earmarking.

The direct effect of EV ownership on acceptability was not significant ($\beta = .01, p = .93$). While perceived effectiveness significantly predicted acceptability ($\beta = .77, p < .001$), EV ownership did not significantly predict perceived effectiveness ($\beta = -.11, p = .182$), and the bootstrapped indirect effect from EV ownership on acceptability through perceived effectiveness was not significant, $\beta = -.09, 95\% \text{ CI } [-.21, .04]$. The intention of buying an EV in the future had a significant positive effect on acceptability, $\beta = .14, p < .001$, and perceived effectiveness, $\beta = .32, p < .001$. Perceived effectiveness was significantly predicted by the intention to purchase a wall charger, $\beta = .062, p = .012$, indicating higher perceived effectiveness for those wanting to buy a wall charger in the future, and country, $\beta = .28, p < .001$, indicating higher perceived effectiveness among French participants.

Although earmarking and EV ownership were significant in the ANOVA, the SEM did not support the hypothesised relationships between EV ownership, earmarking, perceived effectiveness and acceptability. However, the significant relationship between perceived effectiveness and acceptability is in line with prior research on energy projects [12],[13],[14],[15]. Additionally, the effects of the covariates, notably intention to purchase an EV in the future, point to the fact that intended ownership rather than current ownership might be a stronger predictor of effectiveness perception and acceptability of charging infrastructure projects. This, alongside inter-country differences, should be explored in further research. The results underline that policymakers should consider the self-interest that residents of a neighbourhood might have in charging infrastructure. The findings support that improving effectiveness perceptions can be a valuable step in ensuring the acceptability of implementing charging infrastructure. Future research could study other possible influences on acceptability of these projects, as the speed of the energy transition and attainability of EV mobility targets hinges on accessible charging for everyone.

Figure 1



Conceptual Model of the Analysed Multi-Group SEM

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From Perception to Participation: How Intergroup Dynamics Drive Local Energy Collaboration

Theme 3, sub-topic 3b

“Academic contribution”

“Policy/practice contribution”

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Keywords: Flexibility, Electric Vehicles, Group Perceptions, Collaboration

Extended Abstract:

As renewable energy technologies such as solar and wind continue to be integrated into modern energy systems, the need for greater flexibility is becoming increasingly urgent [1]. These technologies, while essential for decarbonisation, are inherently variable and weather dependent. This variability can result in mismatches between electricity generation and consumption, creating challenges for maintaining a stable and reliable grid. In this context, flexibility refers to the ability of the energy system to balance supply and demand in real time [2]. While technological solutions such as smart grids, home battery storage, and electric vehicles (EVs) play a critical role in achieving this, flexibility is not solely a technical issue. It also requires active behavioural engagement [3].

Although much of the current emphasis remains on supply-side innovation, there is considerable untapped potential in demand-side flexibility. This involves encouraging individuals to adjust their electricity consumption patterns, such as shifting when and how they use energy [3]. Examples include participating in local energy trading schemes, generating electricity at home, and adopting flexibility-enabling technologies. Realising this potential requires not only individual behavioural change but also new forms of collaboration among local actors who are taking increasingly active roles in the energy system.

The growing presence of prosumers, who generate, store, and trade electricity at the household level, signals a shift from passive energy consumption to more active and decentralised participation. As a result, energy relationships are no longer confined to isolated users but involve interactions between those who produce and those who consume electricity within communities [4]. However, collaboration among local actors cannot be assumed. Participation in such practices depends on a range of psychological and social factors, including, we argue, individuals' perceptions of the motivations and values of others in their community. To better understand what supports demand-side flexibility, it is essential to explore the role of perception in shaping individuals' willingness to engage in collaborative practices.

Existing research suggests that individuals' willingness to act collectively on environmental issues is influenced by how they perceive the values and motivations of others. For instance,



when people believe others are motivated by biospheric values, or a concern for the environment, they are more likely to engage in environmentally responsible behaviour themselves. Bouman et al. (2020) found that perceiving others as environmentally motivated encourages personal action in line with those perceived group norms [5]. While this does not directly address collaboration, it demonstrates the central role of perceived value alignment. In collaborative settings, perceiving others as committed to shared environmental goals can increase psychological alignment with the group and strengthen the motivation to participate. Therefore, understanding how people perceive the motivations of others is crucial for encouraging collaborative flexibility behaviours.

To examine this, we investigated how people respond to electric vehicle (EV) drivers as potential partners in local energy collaboration. EV drivers provide a relevant case for studying perception, as public views of their motivations are often mixed [6][7]. While EVs are widely recognised as environmentally beneficial technologies, EV ownership can also be associated with wealth, status, or convenience. These differing cues may lead people to perceive EV drivers as either biospherically or egoistically motivated. We propose that this variation in perception influences individuals' willingness to collaborate with EV drivers in local energy initiatives.

We conducted an online survey with a representative sample of the Dutch population ($n = 1,239$). Participants were asked about their willingness to accept the installation of EV charging infrastructure in their local area and their willingness to engage in electricity trading with EV drivers. These questions were followed by items assessing how participants perceived the motivations of EV drivers, as well as their own likelihood and ability to adopt EVs in the future.

The results suggest that participants generally perceive EV drivers as more egoistically than biospherically motivated. However, it is the perception of biospheric motivation that is positively associated with both the acceptability of local charging infrastructure and the willingness to trade electricity with EV drivers. In contrast, perceptions of egoistic motivation do not show a significant association with either outcome.

On top of this, this relationship is moderated by participants' own likelihood of adopting an EV. Those who are least likely to become EV drivers themselves exhibit the strongest positive association between biospheric perceptions and willingness to collaborate. This suggests that when individuals do not see themselves as likely adopters, they become more sensitive to how they perceive the motivations of others. In such cases, perceiving others as environmentally driven appears to serve as a key motivator for engagement. Income level also moderates this relationship, suggesting that socioeconomic context shapes how individuals perceive others and engage in energy-related behaviours, consistent with findings from previous research.

These findings highlight perception as a central psychological process in shaping participation in local energy collaboration. While technological capability and policy incentives are important, how people interpret the values and intentions of others may ultimately determine whether they choose to engage. EV drivers, as visible representatives of flexibility technologies, may unintentionally influence others' behaviour depending on how their motivations are perceived. This creates an important challenge for energy policy and communication efforts: the success of decentralised energy systems may depend not only on what people do, but on what others believe about why they are doing it.

The findings suggest several implications for policy and practice. Communication strategies should prioritise messages that highlight shared environmental values and collective benefits, rather than focusing on individual gains such as cost savings or status, which may reinforce egoistic perceptions and reduce support for collaboration. At the same time, structural barriers

to participation must be addressed, particularly for lower-income households who may face financial or infrastructural constraints and feel disconnected from early adopters.

In conclusion, flexibility in the energy system is not just a matter of infrastructure or technological innovation. It is shaped by how people perceive one another's motivations and values, particularly as collaboration will increasingly involve actors who may or may not have access to flexibility technologies. Understanding and addressing these perceptions is therefore essential for designing inclusive and effective strategies that support a socially robust energy transition.

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Uncovering Residential Gas consumption ARCHETYPES: Machine Learning-Based Household Segmentation Using WOON 2018

Theme 2, sub-topic 2c)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Hierarchical clustering, Residential gas use archetypes, Behavior and awareness, Energy efficiency, tailored strategies

Extended abstract

1. INTRODUCTION

To enhance the effectiveness of energy policies, it is essential to recognize the diverse factors influencing household energy consumption, including building characteristics, household profiles, and environmental attitudes. By uncovering distinct household energy use archetypes that integrate these dimensions, this study aims to support more targeted and effective strategies for reducing residential gas consumption.

2. METHODOLOGY

Clustering was selected to uncover natural groupings without prior assumptions [2] using the Woononderzoek Nederland (hereafter, WoON) database 2018. A two-step machine learning based clustering approach was adopted to enhance segmentation quality [3]. Step 1 applied hierarchical clustering with Gower distance to group households by mixed-type socio-demographics—income, size, and age—producing structural types used as a new categorical variable. In Step 2, the new categorical variable was combined with house type, energy label, reported gas-saving behavior, and three awareness indicators [4][5][6], capturing attitudes toward energy efficiency and heating practices using the same clustering algorithm. Three residential gas consumption archetypes were gained, each reflecting distinct household profiles, action, and awareness levels. To interpret clusters, we used **total variation distance**, χ^2 tests, and **Cramér’s V** to assess feature importance, ensuring a transparent and reproducible analysis [8].

3. RESULTS



The first-step clustering yielded six household types that align with known social patterns and income profiles, seen in the last column of Table 1. These results support the interpretability and real-world relevance of the clustering output.

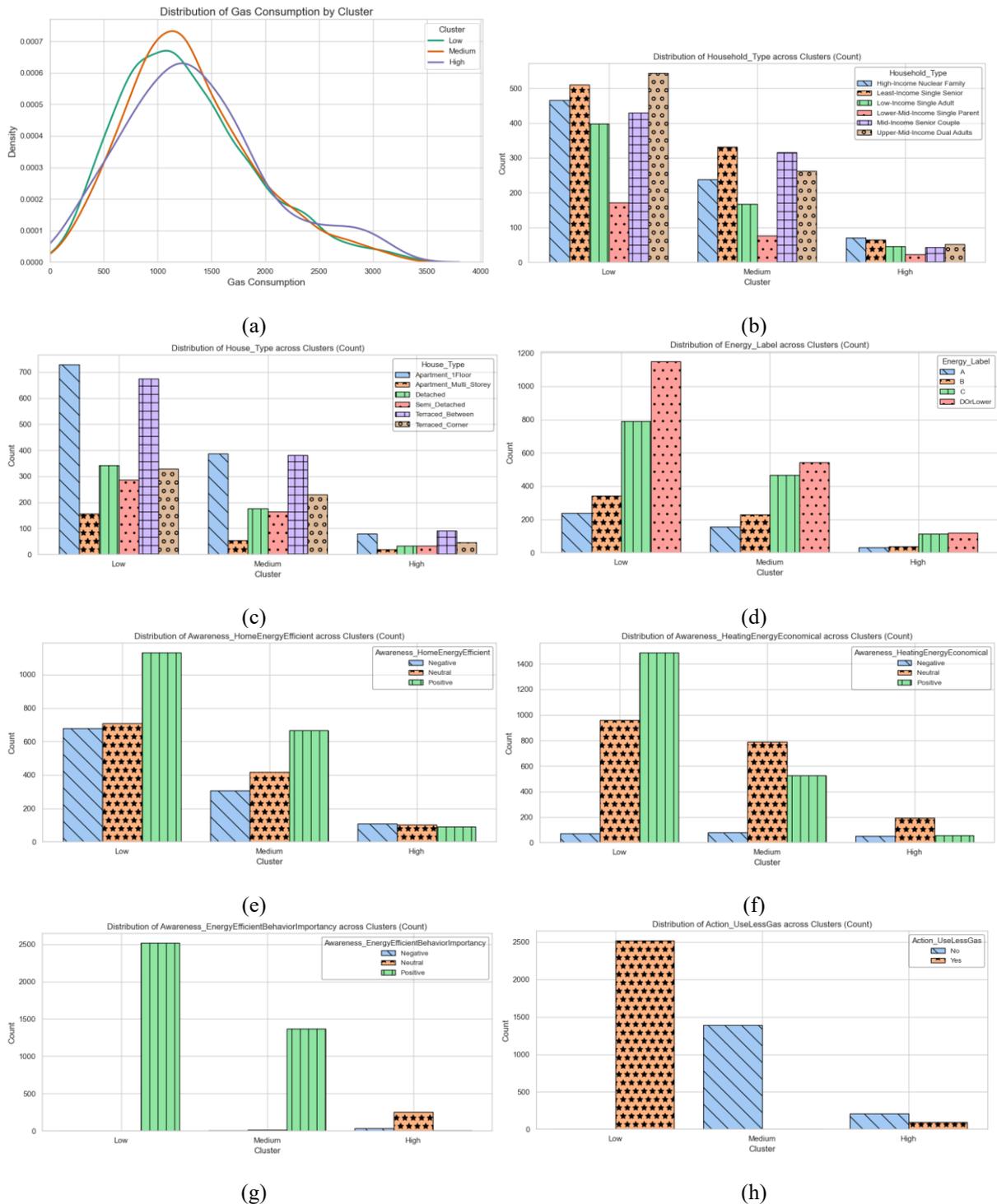
Table 1: Six Household Types Clustered by Hierarchical Clustering Algorithm

	Respondent	Partner	Youngest Kid	Household Size	Income_Disposable	Label
Cluster 1	Young (under 35 years old) and Mid-aged (35-64 years old) respondents included. Mid-aged ones dominate	Young and Mid-aged	Mainly 5 or older, some under 5	Mainly 3-5	Highest disposable income with an average of around 60000 euros	High-Income Nuclear Family (18%)
Cluster 2	Young, Mid-aged and Senior (over 64 years old) respondents included. Mid-aged ones dominate	Young, Mid-aged, and Senior included, the first two kinds dominate	No kids	2	Average around 50000 euros	Upper-Mid-Income Adult couple (20%)
Cluster 3	Only Mid-aged respondents	No partner	No kids	1	Average around 27000 euros	Low-Income Single Adult (15%)
Cluster 4	Young, Mid-aged and Senior respondents included. Mid-aged ones dominate	No partner	Mainly 5 or older	Mainly 2-3	Average around 37000 euros	Lower-Mid-Income Single Parent (6%)
Cluster 5	Only Seniors	Senior partners	No kids	2	Average around 42000 euros	Mid-Income Senior Couple (19%)
Cluster 6	Young and Senior respondents included. Senior ones dominate	No partner	No kids	1	Least, average around 25000 euros	Least-Income Single Senior (22%)

Next, we applied the second Gower-based hierarchical clustering step using the *Household_Type* gained above, combined with seven additional features: *Gas_Consumption*, *House_Type*, *Energy_Label*, *Awareness_EnergyEfficientBehaviorImportancy*, *Awareness_HomeEnergyEfficient*, *Awareness_HeatingEnergyEconomical*, and *Action_UseLessGas*. With the number of clusters set to three, the silhouette score (0.211) and cophenetic correlation (0.621) indicated a reasonable fit for mixed-type data. The resulting three clusters—provisionally labeled Low, Medium, and High—had mean annual gas consumption of approximately 1250 m³, 1300 m³, and 1350 m³, respectively. As shown in Figure 1(a), the Low cluster (green) appears furthest left, while the High cluster (purple) is furthest right with a heavier upper tail, indicating a subgroup of very high users. The Medium cluster (orange) shows the tightest distribution; the High, the widest spread. These differences underscore the need for

tailored strategies. Panels (b) to (h) in Figure 1 display the distributions of categorical features, illustrating how household structure, housing, behavior, and awareness affect gas consumption.

Figure 1: Distributions of Eight Features by Clusters



We ranked these features by total variation distance and confirmed significance using χ^2 tests and Cramér's V, as seen in Table 2. Cramér's V was used to identify practically relevant differences. All features were significantly associated with cluster membership ($p < 0.001$). Action_UseLessGas had the highest variation score (0.454) and effect size ($V = 0.966$), marking it as the most discriminative variable. In contrast, House_Type and Energy_Label had low

scores ($V \leq 0.07$), due to skewed distributions with a few dominant categories. Their limited variation across clusters justifies their minimal role in the following archetype analysis.

Table 2: Feature Importance and Association with Clusters

Feature	Variation Score	χ^2 stat	p value	Cramér's V
Action_UseLessGas	0.454	3933.9	<0.001	0.966
Awareness_EnergyEfficientBehaviorImportancy	0.128	3745.6	<0.001	0.667
Awareness_HeatingEnergyEconomical	0.119	355.5	<0.001	0.205
Household_Type	0.044	47.0	<0.001	0.075
Energy_Label	0.033	22.4	<0.001	0.052
Awareness_HomeEnergyEfficient	0.030	42.5	<0.001	0.071
House_Type	0.023	21.2	<0.001	0.050

3.1. Engaged Low Consumers Archetype (2518 households, accounting for 60% of the sample), standing for unity of awareness and action, low gas use despite high demand potential

As shown in Figure 1(b), this archetype is primarily composed of upper-middle-income adult couples without children (22%), low-income single seniors (20%), high-income nuclear families (19%), and mid-income senior couples (17%). Despite 46% of homes having low energy labels, gas consumption remains low, likely due to limited budgets (low-income single seniors), smaller household sizes (adult couples), and either energy-conscious behavior or efficient dwellings (senior couples and nuclear families). Supporting this, over 97% of these households report economical heating habits, 73% perceive their homes as energy efficient, most emphasize the importance of energy-saving behavior, and all report actively reducing gas use. These patterns help explain their clustering in the low-consumption group.

3.2. Passive Moderates Archetype (1392 households, 33%) represents aging, and two-income households with awareness-action gap showing low motivation to change

This archetype primarily comprises low-income single seniors (24%), mid-income senior couples (23%), upper-middle-income adult couples without children (19%), and high-income nuclear families (17%) (Figure 1b). Despite differences in household composition and income, most of these groups generally share small household sizes and similar housing characteristics to those in the low-consumption cluster (Figure 1c), contributing to their moderate gas use. While 98% acknowledge the importance of energy-efficient behavior and nearly half believe their home is efficient (30% are neutral), none report deliberate gas-saving actions. This disconnect suggests an awareness–action gap, likely driven by comfort preferences among seniors and complacency among financially secure households.

3.3. Strained High Consumers Archetype (302 households, 7%) shows awareness-behavior mismatch within a mix of household types spanning both ends of the income spectrum

This archetype primarily includes high-income nuclear families (24%), low-income single seniors (21%), upper-middle-income adult couples without children (17%), and low-income single adults (16%) (Figure 1b). These household types span both ends of the income spectrum—while nuclear families and adult couples tend to have higher incomes, single seniors and single adults have the lowest. High gas consumption in this cluster likely stems from

different drivers: comfort-oriented demand in larger, wealthier households, and constrained inefficiency in lower-income ones. For the latter, limited financial resources may hinder upgrades, while older systems and longer occupancy hours raise demand. Only 30% of this group consider their home energy-efficient (34% are neutral), and confidence in heating economy is similarly low. Just 3% view energy-efficient behavior as important—the lowest of all clusters—yet 32% report active gas-saving efforts (Figure 1h), suggesting that for many, action is driven by necessity rather than conviction.

4. CONCLUSION

This study identified three distinct household energy archetypes using a two-step clustering approach grounded in demographic, behavioral, and housing features. These archetypes differ not only in gas consumption but also in awareness, behavior, and socioeconomic context. Tailored strategies are essential to support the residential energy transition, particularly in reducing natural gas use.

For Engaged Low Consumers, who already act on their energy-saving beliefs, policies should sustain engagement and encourage deeper efficiency gains. Targeted measures include retrofitting poorly labeled homes [9], incentivizing advanced technologies [10] (e.g., hybrid heat pumps, smart zoning systems), and leveraging these households as peer influencers to help maintain savings and influence other segments [11].

For Passive Moderates, who are aware but inactive, interventions should bridge this awareness–action gap. Smart thermostats and automated heating systems can help seniors balance comfort and efficiency [12], while pre-set heating schedules and remote-control apps reduce efforts for busy households. Incremental feedback, such as comparative billing or monthly summaries, can enhance motivation [13], and messaging should validate current attitudes while encouraging simple actions, like adjusting night-time temperatures or participating in local energy challenges.

For **Strained High Consumers**, facing both behavioral and financial barriers, dual-targeted strategies are needed. Lower-income households may benefit from affordable upgrades (e.g., radiator foil, thermostatic radiator valves) [14], appliance subsidies [15], and energy coaching [16]. For higher-income groups, personalized energy feedback [17] and family-oriented engagement (e.g., gamified energy-saving challenges [18]) can drive behavioral change.

These findings highlight the value of segmenting households by structure, behavior, and context. The proposed archetypes and targeted strategies offer a practical foundation for equitable, behaviorally informed energy policies, especially in efforts to reduce household gas dependence.

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Macroeconomic impacts of a sufficiency scenario for the EU: the CLEVER scenario

Theme 1, sub-topic 1c)

- “Academic contribution”
- “Policy/practice contribution”

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Keywords: Sufficiency, Energy efficiency, Behaviour, Decarbonisation, CLEVER, multisectoral CGE modeling, Macroeconomic modeling.

Extended abstract

Summary

This study presents a macroeconomic assessment of the CLEVER scenario (Collaborative Low Energy Vision for the European Region), which proposes a demand-driven pathway to carbon neutrality for the European Union. Using the hybrid CGE model ThreeME-EU27, the analysis quantifies the aggregate and sectoral economic effects of a deep decarbonisation strategy centered on sufficiency, energy efficiency, and renewable energy deployment. The simulations suggest that decarbonisation can be achieved without compromising macroeconomic stability in the EU. A reduction in energy demand appears not to be incompatible with positive economic dynamics, including increased employment, reduced import dependency, and the reallocation of spending towards labour-intensive sectors such as construction and services. By 2050, GDP and investment are slightly higher than in the baseline scenario, largely due to shifts in household consumption patterns and structural transformation of the economy.

Context / Motivation

As the European Commission proposes a 2040 climate target [1], the EU begins new negotiations on its post-2030 energy and climate framework. Political debates focus on energy security, electrification, and infrastructure, but energy demand reduction remains largely overlooked. While energy efficiency is well recognized [2], broader strategies for energy savings, including sufficiency and absolute consumption reduction, face economic [3] and political [4] concerns, despite growing recognition that demand-side action is essential for a



just and secure transition.

To respond to this challenge, the CLEVER scenario [5], built on 26 national EU expertise, proposes an ambitious bottom-up pathway to net neutrality in the EU, combining sufficiency, efficiency, and a 100% renewable energy mix by 2050.

This study uses the ThreeME-EU27 model [6] to assess the macroeconomic impacts of the CLEVER scenario. It explores whether a demand-driven pathway can support climate goals while remaining economically viable and socially beneficial. The findings challenge the view that sufficiency leads to contraction, showing instead that demand-side measures can boost investment, consumption, and jobs, making them key to the EU's post-2030 agenda.

Methodology

The analysis relies on the **ThreeME-EU27 model**, which integrates top-down and bottom-up approaches to simulate energy and economic systems. An adapted scenario based on CLEVER is proposed and adopted to the model framework, in which the assumptions are aggregated to European Union level. The measures integrated in the simulation target all major sectors:

- **Residential sector:** limited growth of living space per capita, accelerated building renovations, and sufficiency changes reducing energy use (e.g., hot water, lightning).
 - Floor area: concrete trajectory of households' living area per capita, it is projected to rise about 5% from 2019 to 2050 in the EU.
 - Energy performance (Renovation): Deep-renovation rates stay below 1%/year until 2026, climb to 1.8% by 2040, and then level off through 2050, driving efficiency gains and a shift to renewable resources.
 - Other measures targeting hot water, electrical appliances and lightning: roll out of performant equipment and sufficiency measures.
- **Transport:** reduction in passenger transport demand, modal shift to rail and active mobility, fewer cars per capita, and increased electrification.
 - Reduction of passenger transport need: A slight reduction of 3% of passenger transport from 2019 to 2050 is assumed.
 - Modal shift of passenger transport: By 2040, 15–50% of passenger transport could shift to public transport, and 7% to active mobility.
 - Modal shift of freight: Rail transport will cover about 9% of all freight needs.
 - Reduction of cars usage: About 1.9 passengers per vehicles is proposed in 2050. Car sharing, carpooling and other incentives will help to reduce the car numbers.
 - Energy performance: Electricity will play more and more important role in energy consumption, along with increase of energy efficiency of car engines.
- **Industry:** material sufficiency, circular economy measures, and enhanced energy efficiency.
 - Sufficiency measures: To cut raw material production, demand for high-emission products will fall, for example by 38% for cement and -15% for steel (compared to 2015 level).
 - Circular economy: High-emission materials will rely more on recycling, for instance 75% for steel and 62–80% for paper.
 - Energy efficiency: Industrial energy efficiency will be enhanced through regulations and technological advances.



- **Energy supply:** large-scale deployment of renewables, hydrogen integration, and reduced energy imports.
 - Renewable electricity: Renewable electricity, mainly wind and solar, will take large place in electricity generation, in order to reduce fossil energy.
 - Bioenergy: In 2050, biofuels will cover 66% of liquid fuel demand, and biogas will replace 91% of grid gas supply.
 - Energy imports: thanks to energy savings and renewables, energy can be reduced by 86% in 2040 [7] and to almost 0% in 2050.
- **Agriculture:** emissions reduction through changes in consumer demand.
 - The emissions derived directly from agriculture activities are assumed to decrease due to diets changes related to sufficiency measures and agroecological practices [8].

We thus assess a CLEVER scenario that incorporates all these measures and compare it to a reference scenario.

Results

Caveat: The results are preliminary, as the baseline scenario is still being finalised and CLEVER measures currently cover only the residential and passenger transport sectors. A more complete simulation will be available by the time of the conference.

Macroeconomic Impact

By 2040, EU GDP is up to 1.58% higher than in the BAU scenario, showing that demand-side decarbonisation can align with positive macroeconomic trends. However, GDP alone hides key structural shifts. By 2050, household consumption rises by 2.6%, along with a 96% drop in energy bills, reducing energy’s share of household spending from 7.3% in 2019 to 0.2%. Investment falls by 1.9% to 3.0%, driven by lower demand for fossil fuels, vehicles, and real estate. Fossil fuel imports drop by 26% and vehicle imports by 11%, improving the trade balance. Unemployment falls by 4 points, with a net gain of 9.3 million jobs by 2050, 10.6 million created in renewables and services, offsetting 1.3 million lost in construction and fossil fuels.

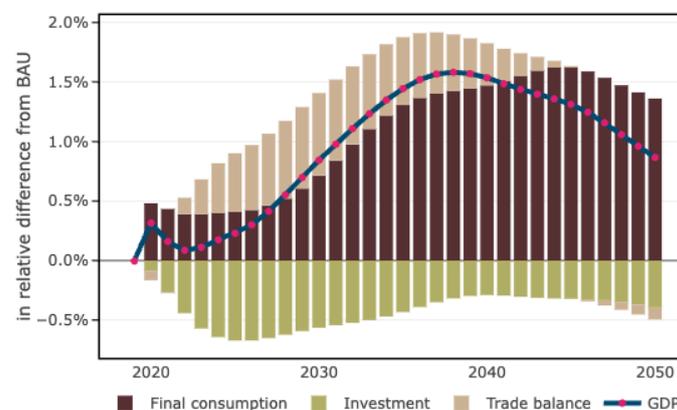


Figure 1 GDP's evolution and the contribution of its components, in relative difference from BAU



Sectoral Effects

The employment dynamics reflect deeper structural shifts in the economy. The REN sector sees a 30% increase in production compared to the BAU scenario over the medium to long term, driven by both electrification and redirected investment flows. The service sector expands by 9% by 2050, supported by changes in household consumption patterns and increased labour intensity. Conversely, fossil fuel sectors contract by 24% in terms of output by 2050. Capital flows increase towards labour-intensive and low-carbon sectors, while emissions-intensive sectors experience a decline.

Climate Impacts

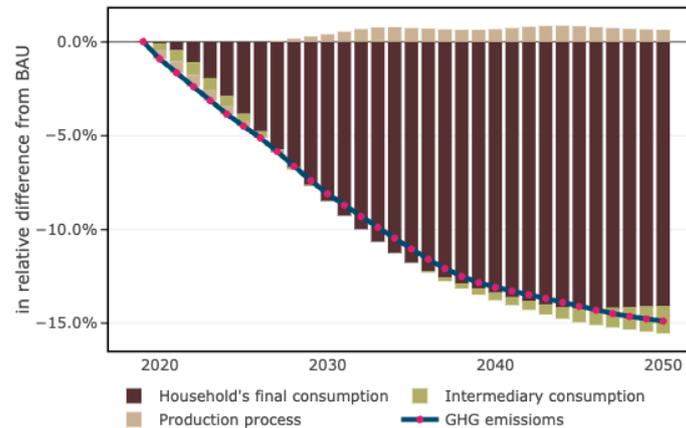


Figure 2 Projected GHG emissions pathway and the contribution of different drivers, in relative difference from BAU

The CLEVER scenario cuts household-related GHG emissions by 95% by 2050 compared to BAU, mainly through lower energy demand and improved carbon intensity—without compromising income or welfare. It illustrates that deep decarbonisation is achievable without adverse socio-economic trade-offs.

Conclusion

The macroeconomic assessment of the CLEVER scenario shows that demand-side decarbonisation, especially through sufficiency, is not economically detrimental in the EU. In today's context of energy and climate instability, shifting policy focus from supply to demand is both necessary and viable. Rather than a constraint, energy savings can drive economic resilience, social cohesion, and a new model of European prosperity based on innovation, circularity, and reduced resource dependence. CLEVER illustrates how sufficiency must become central to the EU's future strategy.

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The relationship between energy equity and sufficiency: Initial expert perspectives

Theme 2b) and 5b)

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Keywords: Energy equity, energy sufficiency, energy transitions, Global North, expert elicitation, energy demand

Extended abstract:

Energy is a vital tool for improving people's lives across the world. Despite this, inequities exist in the way and extent to which differing groups have access to energy services, the ability to engage in energy systems, and the ability to shape their own energy use, distribution and/or production [1–3]. As a result, there are often calls for energy equity considerations to be built in to decarbonisation and energy systems planning [4]. Despite these calls, there is no clear and agreed upon definition of what energy equity is [5]. Differing, and sometimes contradictory, definitions exist, also varying between places e.g. Global North vs Global South, and scope of study e.g. energy demand vs supply. That said, implementing actions that aim to reach energy equity goals with regard to demand, however defined, can result in reduced energy poverty [6], but also a range of more widely distributed other personal and societal financial, health, wellbeing, environmental and energy system co-benefits [7, 8].

Meanwhile, energy sufficiency, “a state in which people's basic needs for energy services are met equitably and ecological limits are respected” [9], explicitly aims for ‘energy equity’ as a core principle. Energy sufficiency is seen as an important part of the energy transition in addressing greenhouse gas emissions from energy demand, mostly through the balancing of energy use throughout a population cohort by modelling ‘optimal’ energy use and creating maximum thresholds for each person or household locationally [10, 11]. This goes further than efficiency approaches and challenges the dominant social paradigm centred around wealth and influenced by capitalistic norms [12]. It will likely mean that certain groups, particularly those that use more energy and tend to be wealthier, would have to reduce their overall energy use, while allowing those underusing to continue increasing their energy use to a common agreed-upon level [11].

While there are many commonalities in conceptualisations of energy equity and energy sufficiency, some contradictions exist that raise questions about the interoperability of the two concepts in real-world energy transitions. This includes discussions of ‘ability to afford’ energy versus ‘ability to access or generate’ energy [13], the purposes of the two terms and potential conflicts between energy equity and environmental goals [14], unexpected behavioural impacts such as rebound effects and their implications [15] and energy sufficiency's social acceptability as a policy approach [16, 17]. Others argue that sufficiency paradigms for the energy transition are necessary to support energy equity goals [18]. This debate is instructive, suggesting that more work is needed to understand the relationship between the goals of energy equity and sufficiency in the policy context [19], particularly in diverse geographical, social, economic and Global North/South scenarios.



As such, this exploratory study investigates the concept of energy equity, and its relationship with sufficiency in the Global North context. This study aims to not only better understand the shared meaning of energy equity, but the relationship between energy equity and sufficiency goals: especially focused on the extent to which these are shared, or in conflict with one another. We aim to accomplish this through a literature review and present results from online interviews with 8 energy experts predominantly based in research institutions in the UK to be conducted in July and August 2025. These energy experts come from a range of related fields, including energy systems, energy ethics, energy economics, sociology, political science and human geography. Most are senior in position or prominence in the field, and we ensure a gender balance in interviewees. We use a semi-structured interview method, with each interview expected to last between 30 and 45 minutes. Coding will be undertaken by a single, independent coder in NVivo and analysis will follow an inductive approach using grounded theory [20], reflecting the open and exploratory nature of the interviews due to their larger purpose. This study has received ethical approval from the University of Exeter Medical School Research Ethics Committee.

As part of a literature review of titles, keywords and abstracts conducted on Scopus, we find that the term “energy equity” (405 documents) has slightly more publications than “energy sufficiency” (317 documents). The number of documents with both terms (including abstractions e.g. “equity” or “sufficiency”) stands at 268. Documents containing both terms (“energy equity” and “energy sufficiency”) specifically in the abstract, keywords and/or titles is much lower, at 10 documents. In terms of trends, “energy sufficiency” is a historically more commonly-used term, beginning in 2008, while “energy equity” has received more attention in more recent years, where use of the term has increased almost eightfold since 2017 (12) compared to 2024 (94). While the most-contributing nation to both terms is the United States, China and the United Kingdoms are the second most-contributing to “energy equity” and “energy sufficiency” respectively.

When examining the focus of these articles, 60 documents contain both “energy sufficiency” and “demand”, while 69 do so for “energy equity” and “demand”. Combining the three terms (including abstractions), 31 documents are found; without abstractions, no publications include all three keywords (“energy equity”, “energy sufficiency” and “demand”) as of 2025. This highlights a gap in the literature on the combination of these explicit terms, and their relationship to one another.

While conclusions from the interviews are yet to be drawn, we expect discussion among respondents relating to arguments raised in the literature discussed earlier in this abstract. As well as providing findings of its own, this interview study forms the initial part of a larger project. It also informs the first round of a Delphi study of a wider pool of academic and non-academic energy experts’ understandings and views on energy equity. Namely, we will focus on how these experts define, measure, and see the value of energy equity as a goal and/or state in the Global North. Our goal is to co-create usable resources for better understanding, evaluating and implementing energy equity principles in the broader energy transition. This pool of experts will also answer questions related to energy sufficiency and its relationship to energy equity, and results will be compared to the findings of this study.



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Not All Flexibility Is Equal: Empirical evidence how context and technology shape acceptability of household flexibility provision

Theme 3, sub-topic b

☒ “Academic contribution”

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Keywords: Demand-side flexibility, household energy use, automation, energy communities, experimental survey

Extended abstract

As electricity systems decentralize to more local and renewable production, households are increasingly agents of demand-side flexibility to help optimize the system¹. Flexibility in consumption proposes **shifting** consumption to more opportune times, such as when a high proportion of local photovoltaic electricity is available, or **increasing** or **decreasing** consumption in response to a signal². These demand-side actions address new system needs to optimise price, reliability, consistency, and sustainability³. Additionally, flexibility will play a key role in upcoming Swiss regulation in 2026 that allows peer-to-peer electricity networks to be formed⁴.

Technical solutions underscore demand-side flexibility⁵, as households require smart meters, household level distributed energy resources (DER) such as electric vehicle batteries (EV), and home energy management systems (HEMS). However, critically their effectiveness hinges on users' willingness to accept and engage (manually or automated) with these technologies to adjust consumption patterns⁶. The social acceptability of such set-ups remains poorly understood regarding **what types of automation users will tolerate, under what scenario, and involving which household DER.**



The study focuses on household flexibility provision through automated (e.g., externally controlled), semi-automated (e.g., set-point by user) or manual control of household DERs: white appliances, electric hot water systems (HW), heating and cooling (H&C), and EV. We investigate the willingness to provide flexibility under three different scenarios when the system would benefit from a demand-side response and how the rationale of the scenario influences both the general willingness to adjust electricity use and the preferred level of automation. By comparing rationales, DER types, and automation levels, the study identifies key design features and communication strategies that shape public and stakeholder acceptance.

Methodology

A survey was conducted with Swiss households (n=1,378 responses). The respondents were randomly assigned to one of three flexibility scenarios:

- **Local electricity community (LEC) participation**, emphasizing participation in local peer-to-peer electricity trading using locally generated renewables;
- **Local grid congestion**, emphasizing technical grid management and public cost avoidance;
- **Extreme national energy security**, emphasizing national energy security during geopolitical or climate crises.

Each scenario included the necessary technical (i.e., DER and level of automation) and datasharing requirements and was carefully worded in natural language to reflect real-world policy initiatives. Participants indicated their willingness to adjust usage and preferences for automation type.

Results

Our findings highlight the nuanced and contextual nature of acceptability for flexibility provision. Figure 1 presents the DER, control type and rationale for those willing to provide flexibility.

Willingness to provide flexibility using EV, H&C or HW adjustments are broadly the same (figure 1a-left), with equal interest in adjustments being done manually or automatically. We see, however, a preference to adjust appliance use manually which could look like someone deciding, based on a signal, when they turn on the washing machine or dishwasher. This appears logical as adjustments to EV charging and thermal storage (in HW and H&C) offer flexibility with minimal lifestyle disruption, whereas appliance use is closely tied to daily routines. This suggests that potential of appliance flexibility may be limited or require more tailored systems.



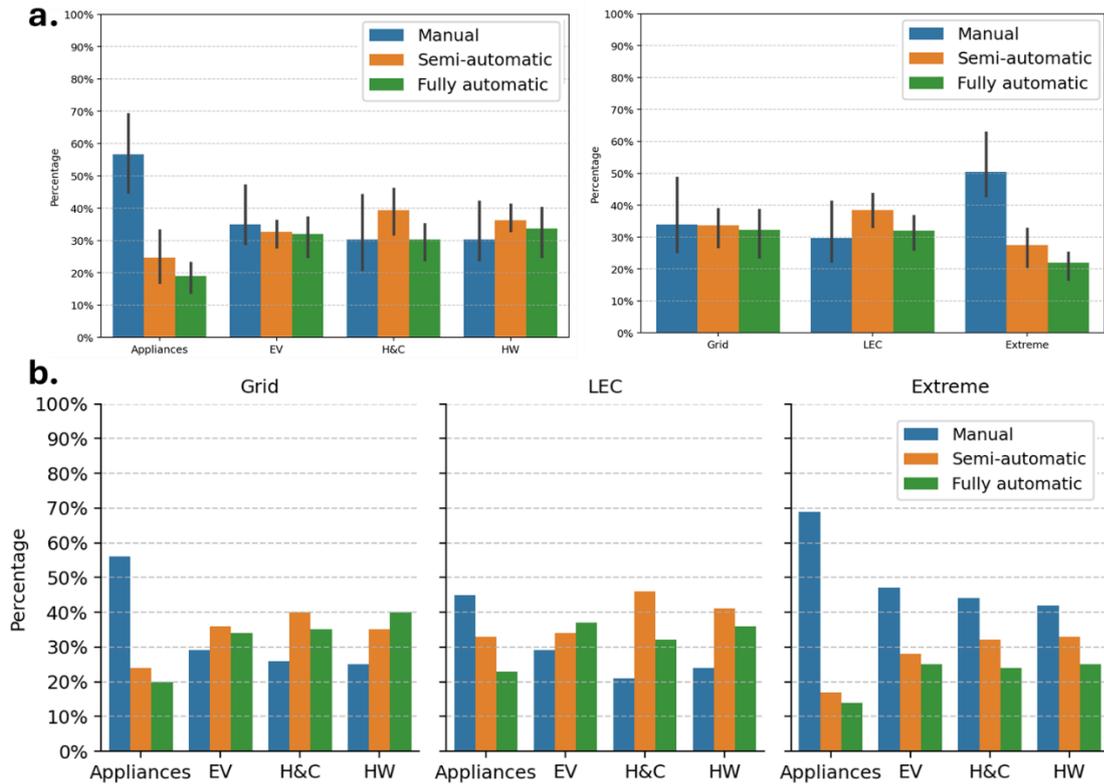


Figure 1 (a-left) Percentage acceptance of control type for flexibility provision across DER (Appliances, EV, H&C, HW) and (a-right) rationale scenarios (Grid, LEC, Extreme). (b) Percentage acceptance of DER and control type under different rationales.

The willingness to provide flexibility under different scenarios varies both by control type (Figure 1a-right) and DER (Figure 1b). A MNLogit was conducted to assess the influence of rationale and DER on the likelihood of a control type to provide flexibility (Table 1). Respondents exposed to the extreme event scenario preferred manual control than those in the Grid ($\beta = 0.6027$, $p = 0.003$) and LEC ($\beta = 0.9260$, $p < 0.001$) rationales. This could be due to the infrequency of an extreme event, a desire to retain agency in emergency contexts, or potentially scepticism towards remote or automated intervention during crises. In contrast, those in the LEC scenario were more open to semi-automatic systems, suggesting that automation could be legitimized when combined with perceived collective benefit, frequent participation and transparent management.

Table 1 Comparison of main effects of Rationale and desired automation level

Rationale Comparison	Manual vs. automated (β , p-value, 95% CI)	Semi-Manual vs. automated (β , p-value, 95% CI)	Fully Semi-automated vs. Fully automated (β , p-value, 95% CI)
LEC vs. Extreme	$\beta = -1.0973$, $p = \mathbf{0.000}$, CI [-1.453, -0.742]	$\beta = 0.9260$, $p = \mathbf{0.000}$, CI [0.534, 1.318]	$\beta = -0.1713$, $p = 0.459$, CI [-0.625, 0.282]
Grid vs. Extreme	$\beta = -0.5537$, $p = \mathbf{0.003}$, CI [-0.920, -0.188]	$\beta = 0.6027$, $p = \mathbf{0.003}$, CI [0.211, 0.995]	$\beta = 0.0489$, $p = 0.839$, CI [-0.423, 0.521]
LEC vs. Grid	$\beta = -0.5435$, $p = \mathbf{0.002}$, CI [-0.887, -0.200]	$\beta = -0.3233$, $p = 0.090$, CI [-0.050, 0.697]	$\beta = -0.2202$, $p = 0.300$, CI [-0.637, 0.197]

Notably, semi-automatic and fully automatic options can flip preference in the Grid and LEC scenarios, while manual control remained distinctly lower, particularly for H&C and HW management. This seems to imply that people differentiate primarily between systems they



control versus those that act autonomously, however more nuanced distinctions between levels of automation may be relevant in real-world implementation.

Discussion

As energy systems increasingly rely on household participation for balancing and optimization, understanding the social acceptability of automation becomes critical, as automation offers more real-time and accurate flexibility potential. The results demonstrate that public acceptability is highly sensitive to both **technical context** (type of DER, level of automation) and **social framing** (rationale, trust, community).

Participants were more willing to adjust (automatically) H&C and EV use compared to appliances, likely due to greater service latency tolerance. Rationale did, however, shape automation preferences: extreme event scenarios led to a preference for manual control, whereas the LEC scenario increased openness to semi-automated systems.

Conclusion

These findings contribute directly to the ongoing discourse around the potential of capturing flexibility for system management and how to align technological innovation with usercentered policy design. Key insights include:

1. **Trust and context matter:** Acceptability of automation is not only about technology, but how it is framed. National emergency contexts, while being a more accepted rationale for flexibility provision, are likely best managed with communication campaigns so people can make manual changes. Conversely, community-based framings with transparent data practices and financial benefits support willingness to provide flexibility using more automated systems.
2. **DER-specific strategies are necessary:** Household engagement and system design must consider DER characteristics and related social practices. Technologies with latent service capacity (e.g. thermal storage in buildings or boilers) are better candidates for automation, while those embedded in daily routines (e.g. salient use of appliances and EV charging) require a different approach.
3. **Automation design is not neutral:** Users distinguish sharply between manual and nonmanual control, but less so between semi- and fully automatic options—unless differences are clearly communicated. This opens opportunities for designers and policymakers to promote intermediate systems that balance automation with user agency.
4. **Policy messaging must match risk tolerance:** Public acceptability is closely tied to perceived control and risk. Automated systems should be introduced in a graduated way, with manual or opt-in stages that preserve agency and build comfort. Policies and systems that ignore these interdependencies of technical context and social framing risk rejection or underutilization, regardless of their technical potential.

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Crisis-proof, socially and environmentally compatible - Impulses for the development of a sufficiency strategy for Germany

Theme 5, sub-topic 5d)
X “Academic contribution”
X “Policy/practice contribution”

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Keywords: Sufficiency strategy, Policy instruments, Over- and underconsumption, Sufficiency indicators, Multiple benefits

Extended abstract

Objective and scope

The aim of this paper is to outline key problematic trends and indicators for the building and transport sector and discusses potential sufficiency-oriented futures. We provide insights into potential policy instruments and conclude with thoughts on the implementation of an integrated



sufficiency strategy and need for research. We here focus two sectors in the German context in terms of examples and data, but general trends, future visions and indicators are not Germany-specific. More extensive descriptions for all sectors can be found in [1].

Methodology

The identification of indicator-based main problems is derived from demand modelling of the German transport [2][3] and building sector [4] and from a meta-analysis of scenarios [5]. Potential future developments are a synthesis of the narratives and trends used in the European Clever scenario [6] and the three-stage scenario process of sufficiency-orientated scenarios for Germany [7].

Current trends, barriers and potential sufficiency-oriented development

In the building sector, rising living space and its inappropriate distribution are key trends that impede the pathway to a socially just and climate neutral building sector. Although efficiency improvements have reduced specific energy consumption per square meter by about 30% in Germany between 1990 and 2024, total energy demand has stayed almost constant, due to rising per capita living spaces [8][9]. Due to long-lasting structures of the built environment, inertia of residential mobility and the trend towards single flats, already a stagnation of existing living space is seen as ambitious [6][10]. New builds are connected to 37 hectares of new land use per day which is more than 70% of total area use in Germany [11] as well as energy intensive building materials and emissions. In addition, the new buildings often do not match the housing needs: 44% of the land consumption happens in shrinking regions [12]. Furthermore, while more small affordable flats are required, 72% of newly built flats are still single family houses in Germany although the number of families has been declining in Germany [1].

A future, demand-oriented utilisation of the existing housing stock can be supported by adaptations of the building regulations focussing on flexibility and modification of existing buildings and on the creation of small, affordable flats by support of remodelling and splitting dwellings. Also the right to exchange flats without rent increase, as existing in Austria would enable more residential mobility. An indicator for the degree of needs-based distribution of living space is the occupancy density as a measurement of the number of people per room showing over- and under-occupancy. Occupancy requirements themselves as in many Swiss housing cooperatives are also a very effective way of reducing under- and overoccupancy. Stabilisation of rents and property prices support adapting of housing situations to changes in life phases.

The transformation of the mobility sector is still massively hampered by car and road centrality. High investments in road infrastructure and declining investments in rail infrastructure contribute to rising numbers of passenger-km, tonne-km, cars in Germany (person-km: 34% 1991-2019 [13] / ton-km: 75% 1991-2022 [14] / cars: 32% 1991-2024 [15]). Cars are also significantly heavier; 30% of all new registrations in Germany are SUVs [16]. As with living space, the distribution problem is obvious here: In Germany, 53% of very low-income households do not own a car, whereas in the highest income group, 10% have three cars and only 8% have no car at all [17]. The current funding structure fuels this inequality further [18]. From a sufficiency-oriented perspective, the overarching goals for the transport sector is to ensure that all people can fulfill their needs with as little traffic generation and environmental impact as possible. Model results for the German transport sector show that a 33% reduction in passenger-km until 2035 through sufficiency policy is possible [3]. Reduction of trips and trip distances by improving local supply strategies can significantly reduce overall traffic volume and especially the dependency on private cars. Deincentivising car use by high progressive taxes, park slot reduction in inner cities and reallocation lines for active modes and transport



are one side, massive support of public transport and active modes the other side of supporting mode shift. In Ghent for example, parking and passage reductions have led to halving car use between 2012 and 2019 [19]. Reallocating infrastructure and support to rail, bus, bike and foot increases mobility options for all people as car ownership is closely connected to income [20][21].

The current German road traffic regulations have recently been amended to allow for other goals, such as climate and environmental protection, health, and urban development, in addition to the overarching goal of smooth (car) traffic. German municipalities can now more easily establish 30 km/h speed limit zones and bicycle lanes. This is a first step, but a fundamentally different set of priorities is necessary for a mobility transition, one that prioritizes everyone's mobility and health rather than the flow of car traffic.

For long-distance mobility, restriction of short flights in combination with expanding night trains is decisive to reduce energy- and emission intensive flight-km. Frequent flyer levies and landing restrictions for private airplanes tackle especially luxury mobility.

Thoughts on the implementation of a sufficiency strategy

Sufficiency policy has the potential to initiate far-reaching changes and alter existing structures. The implementation of individual measures at municipal level is however an important component in order to make social benefits of measures against overconsumption visible. Examples of success on municipal level can help to create local acceptance and reduce fears. Also test implementations offer opportunities as examples like the city-toll in Stockholm shows [22].

Sufficiency measures are diverse, also in terms of the type of instrument [23][24]. Informed citizens are much more in favour of sufficiency measures than politicians are [25]. Sufficiency policy provides most benefits, if applied strategically at all political levels. The approach needs to be institutionalised to unfold its full potential. For Germany, such institutionalisation can include an overarching sufficiency strategy analogous to the German sustainability strategy, an inter-ministerial working group to coordinate implementation and the thematic expansion of the ministry departments. At European level, the introduction of a sufficiency chapter in the template for national energy and climate plans is a step towards systematically integrating sufficiency [26]. In order to make sufficiency quantifiable, the recording of sufficiency indicators by the European and Nation Statistical Offices is recommended.

Quantifying enough - Multiple benefits and research needs for sufficiency

Assessing the leverage effect of sufficiency on achieving various policy goals in a quantitative way is crucial for adequately addressing the multi-solving nature of sufficiency strategies. Germany's land use target of net zero by 2050 [11] and the resource target of 6-8 t/y/person raw material consumption [27] can be achieved by reducing overall production and consumption levels.

More empirical data of sufficiency policy effects, methods for quantification of multiple benefits, sufficiency suitable sectoral demand models and quantitative integration in energy and climate scenario modelling are required to be able to weigh up and discuss sufficiency on an equal footing with other strategies such as efficiency and renewables.

Distributional effects of energy and climate policy as well as minimum income and more general decent living standards are decisive research areas for fact-based political and societal discussions about strategies of enough.



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Could Voluntary Adoption of Workplace Travel Plans Lead to Tipping Points in Transport Decarbonisation?

Themes 4a and 5b

“Academic contribution”

“Policy/practice contribution”

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Keywords: Decarbonisation, Social Transformation, Game Theory, Transport Demand Management, Small and Medium-sized Enterprises

Extended Abstract

UK surface transport emissions have overshoot the sixth carbon budget by 224 MtC, requiring emission cuts ten times those saved during the COVID-19 pandemic.²³ Emissions can be reduced through measures which increase efficiency or reduce demand, known as Travel Demand Management (TDM) strategies. Improvements in the quantity, quality, and speed of TDM implementation is urgently needed if the UK is to meet its target to reduce car miles by 9% before 2035.² We present preliminary analysis which explores a possible mechanism to achieve this transformation – unlocking a positive tipping point in the adoption of Workplace Travel Plan (WTPs) in the private sector, including Small and Medium-sized Enterprises (SMEs).

Employers can act as a bridge between their employees and broader transport policy goals by providing a social context and communicating norms.³ Employers control the physical and social environments of their employees, shaping their employees’ modal choice. Workplace Travel Plans (WTPs) are long-term TDM strategies developed by organisations to manage their staff’s commutes. They are flexible, cost-effective, (relatively) rapid, and publicly acceptable.⁴⁻⁷ Organisations with WTPs gain a competitive advantage from improved staff productivity, business image, and talent attraction.^{8,9} These benefits could be harnessed to encourage a positive feedback cycle of adoption leading to widespread voluntary adoption of TDM, transforming commutes across the UK.

Currently less than 11% of businesses have a workplace travel plan.⁵ *Ceteris paribus*, this must increase to 56% to achieve the 2035 target¹. In the UK, WTPs are only legally required during planning applications from large organisations and voluntary WTPs remain the norm.¹⁰ While legislation may ultimately be more effective in driving adoption among

firms, increasing voluntary adoption can improve the quality of WTPs across firms of all sizes and build the foundation for formal policy interventions.^{11,12} We apply a framework of

²³ If x is the additional proportion of businesses that need to adopt WTPs to reduce car miles by an additional 9% (and WTPs can reduce car miles by a maximum of 20%) then $9\% = x * 20\% = 0.45$. The total adoption rate is then $11\% + 45\% = 56\%$



interdependent decision-making, from Game Theory, which could inform intervention and policy design to increase voluntary adoption.

Adoption of a WTP incurs immediate, direct, and measurable private costs – it takes time and resources – yet it also generates public and private benefits. WTPs produce several public benefits from reducing car miles such as reduced congestion, accidents, pollution, and emissions.¹³ However, these benefits might only be marginal at first (and largely undetectable to individuals themselves) until a majority of firms adopt them.¹⁴ By considering the public and private costs and benefits of adoption, we can evaluate the adoption decision of a rational firm. Firms may either match each other’s adoption to ‘keep up’ with their competitive advantage, or they may strategically ‘free ride’ on the public benefits of their competitor’s costly efforts.

Analysis

Through desk research we identified the key public and private costs and benefits of adoption to construct the payoffs of adoption under different conditions in Table 1. Table 2 summarise this into qualitative payoffs, to identify a coordination game with strategic complementarity, known as a Stag Hunt game. Mutual adoption leads to the best outcome (high, high), but if others do not adopt then the adopter is worse off. This structure creates multiple equilibria (adopt, adopt) and (not adopt, not adopt), but the optimal outcome is often not reached because of mistrust or mis-coordination, leading to a smaller (but guaranteed) prize. However, Stag Hunts games can show a ‘tipping dynamic’ whereby adoption behaviour stabilises at the cooperative outcome (adopt, adopt).

Table 1. The matrix summarises how the costs and benefits of WTP adoption change based on the choices of other firms. For simplicity, temporal dynamics and firm-specific characteristics are excluded.

		Firm B, Firm C, Firm D, Firm E, etc.	
		Adopt	Does not adopt
Firm A	Adopt	<p>Private (High):</p> <ul style="list-style-type: none"> All firms benefit from improvements to brand image.⁶ All firms benefit from parking & travel cost reductions.⁵ All firms benefit from lower absenteeism, talent attraction and higher retention.^{15,16} All firms bear the cost of adoption, approximately £47 per FTE.⁵ <p>Public (High):</p> <ul style="list-style-type: none"> Reduced emissions & car use.¹⁷ Improved air quality, public health.^{13,18} Improved congestion and road safety.¹³ 	<p>Private (Medium):</p> <ul style="list-style-type: none"> Firm A benefits from improvements to brand image.⁶ Firm A benefits from parking & travel cost reductions.⁵ Firm A benefits from lower absenteeism, talent attraction and higher retention.^{15,16} Firm A bears cost of adoption, approximately £47 per FTE.⁵ <p>Public (Low):</p> <ul style="list-style-type: none"> The reduction in travel demand depends on the share of traffic attributed to the firm. The benefits associated with travel demand are therefore also smaller.
	Does not adopt	<p>Private (Low):</p> <ul style="list-style-type: none"> All other firms bear the cost of adoption, but also gain private benefits. <p>Public (Medium):</p> <ul style="list-style-type: none"> Reduced emissions & car use.¹⁷ Improved air quality, public health.^{13,18} Improved congestion and road safety.¹³ One less firm adopting may result in weaker tipping dynamics.¹⁹ 	<p>Public (Low):</p> <ul style="list-style-type: none"> High congestion.¹³ High parking pressures.¹³ High emissions and failure to meet Net Zero targets.^{2,13}



Table 2. A simple matrix to illustrate how the 'payoff' for adopting a WTP changes dependent on other firms' decision. Payoffs are read left to right.

		Other firms	
		Adopt	Does not adopt
Firm A	Adopt	(High, High)	(Medium, Low)
	Does not adopt	(Low, Medium)	(Low, Low)

This analysis suggests that the voluntary adoption of WTPs can be modelled as a collective action problem. Among SMEs, this problem may be particularly constrained by misperceptions of other's actions due to an underreporting gap.²⁰ Furthermore, the financial costs are concrete, but the benefits can be abstract and difficult to measure. Employees may respond heterogeneously to WTP creating a lottery in expected benefits, which is also aversive.²¹

Future directions

Effective policy design requires an understanding of the determinants of adoption. Our analysis assume rationality, such that if an innovation works technologically and is financially viable, the firm will implement it.²² However, firms are motivated by social, political, and psychological factors like convenience, reputation, social norms, risk reduction, compliance, and intrinsic values.²²⁻²⁴ SMEs are not just economic actors, but social actors too.²² We propose that future work builds a behaviourally informed model of adoption.²⁴⁵

Conclusion

Analysis supports the re-assessment of WTP adoption as a pathway to rapid decarbonisation of commutes, unlocking SME-led contributions to Net Zero. Given that the UK must reduce its total car miles by 9% before 2035 and a WTP can reduce car miles driven by up to 20%, it is worth targeting the estimated² 14 million people who drive to an SME every day.⁵ By exploring under-estimated actors, and dynamics between them, policymakers can unlock tipping points in WTP adoption leading to pro-environmental social transformations.

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²⁴ SME's employ 61% of the UK workforce which stood at 36.9M in December 2024 (approximately 22.5M work in SMEs). In a prior study 62% of employees reported driving to work (i.e., 14M people drive to work at an SME).



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User Behavior Analysis of Vehicle-to-Grid Interaction Based on Behavioral Economics - A Case Study of China

Theme 1, sub-topic 1c) & 1e)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Behavioral economics, Business model, China, User Behavior, Vehicle-to-Grid

Extended abstract

Against the backdrop of advancing Vehicle-to-Grid (V2G) technology, enhancing user participation has emerged as a critical determinant for the sustainability of V2G business models. This study employs a questionnaire survey to investigate domestic electric vehicle (EV) users' actual willingness toward charging and discharging services, with a particular focus on applying behavioral economics theory to dissect the mechanisms underlying user decisions in V2G participation. By identifying the core drivers influencing user behavior from dimensions such as behavioral preferences and economic considerations, this research aims to provide targeted insights for improving V2G user engagement, thereby facilitating efficient aggregation of EV resources, effective transmission of market value, and ultimately strengthening the attractiveness and sustainability of V2G business models.

Rooted in behavioral economics, this study conceptualizes EV users' V2G participation as a bounded rational decision-making process, integrating insights from prospect theory and nudging mechanisms to extend the traditional Theory of Planned Behavior (TPB). Key behavioral parameters—including risk perception (e.g., battery degradation concerns), loss aversion (e.g., sensitivity to battery aging costs), and time preference (e.g., charging duration trade-offs)—are extracted to construct an expanded model that captures the psychological and economic drivers of user behavior. Guided by this model, a structured questionnaire was designed to elicit users' genuine preferences regarding V2G services. A total of 267 valid responses were collected from a city in China, and subsequent analyses identified user preferences and concerns in V2G participation, forming the basis for evidence-based recommendations to incentivize V2G engagement.

The behavioral economics-informed analysis of user charging/discharging patterns reveals the following key findings:

(1) Information Asymmetry and Bounded Rationality: Behavioral economics highlights that limited information constrains rational decision-making. Survey results indicate a significant knowledge gap: nearly half of EV owners exhibit low familiarity with V2G technology, its benefits, policy frameworks, and pilot initiatives. This information asymmetry directly impedes V2G adoption, as users cannot adequately evaluate its utility.



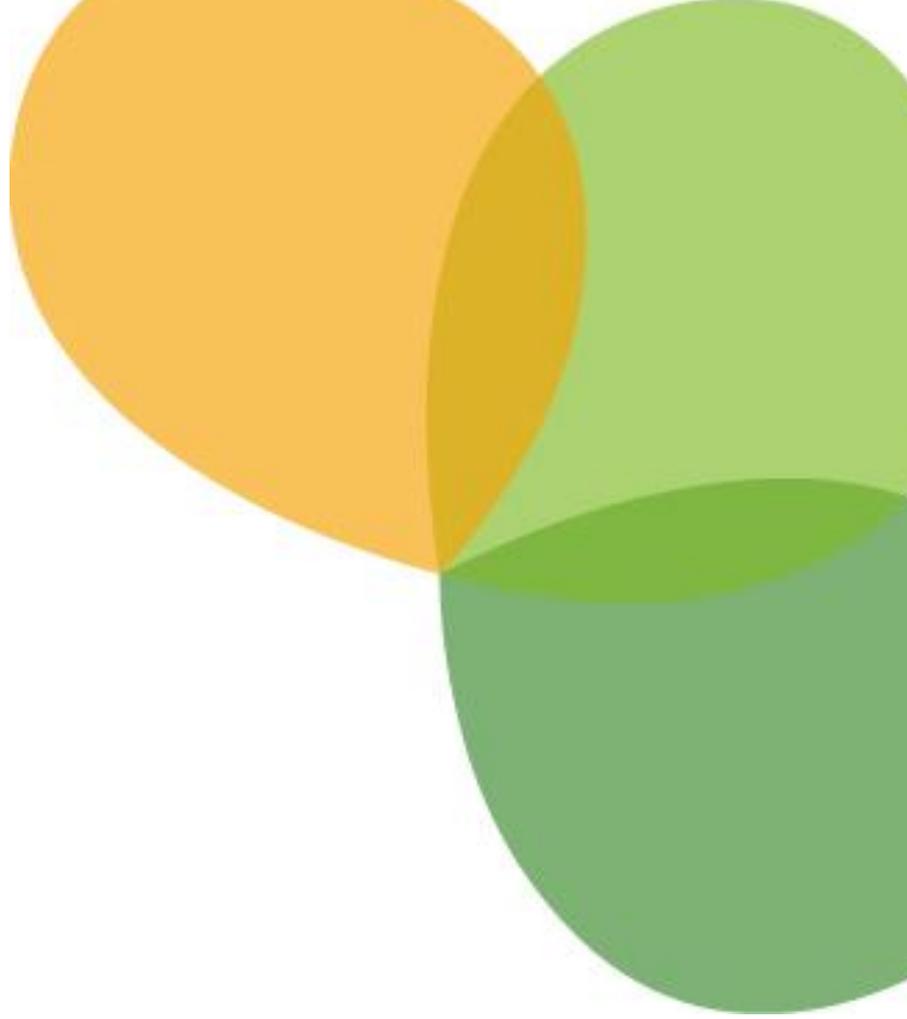
From a behavioral economics perspective, targeted information provision—via multi-channel campaigns (e.g., authoritative publications, social media, and industry workshops)—is critical to reducing uncertainty and enabling informed choices. Stakeholders such as automakers, grid operators, and policymakers should emphasize V2G's dual value in energy management and grid support, framing messages to align with users' risk-averse tendencies.

(2) Habit Formation and Heuristic Decision-Making: Behavioral economics emphasizes that repeated behaviors solidify into habits, shaping heuristic choices. The survey identifies distinct charging/swapping routines: most users recharge when remaining capacity is 20%–40% (with 20%–30% being the modal range), exhibit strong loyalty to familiar stations, and predominantly charge in residential communities—reflecting habit-driven inertia. Temporal patterns also emerge: 1–2 weekly charging sessions, typically after 20:00, align with users' time-use heuristics. Slow charging is preferred over fast charging, as trade-offs between time costs and monetary expenses (a core behavioral economics construct) favor slower, lower-cost options, albeit constrained by vehicle specifications. Pain points such as suboptimal station's location and long wait times trigger loss aversion, further reinforcing resistance to behavioral change.

(3) Risk Perception and Preference Heterogeneity: Central to behavioral economics is the role of perceived risks in decision-making. In this study, battery degradation emerges as the primary barrier, with users demonstrating high loss aversion toward potential aging costs—consistent with prospect theory's prediction that losses loom larger than gains. In terms of V2G participation parameters, users' bounded rationality manifests in preferences for daily connection durations under 4 hours and minimum post-discharge capacities of 30% or 40%, reflecting risk-averse thresholds to avoid "losses" in usability. To mitigate these behavioral barriers, behavioral economics suggests designing diversified contracts that accommodate heterogeneous preferences, thereby reducing perceived risks and aligning V2G participation with users' intrinsic utility functions.

In conclusion, this study leverages behavioral economics to unpack EV users' V2G-related behaviors, highlighting information asymmetry, habit persistence, risk aversion, and preference diversity as key determinants. The findings underscore the need for strategies grounded in behavioral insights: enhancing knowledge dissemination to reduce uncertainty, optimizing infrastructure to alleviate loss aversion from operational inefficiencies, addressing battery degradation concerns through technological and contractual safeguards, and offering flexible participation schemes to match heterogeneous preferences. By aligning V2G design with users' behavioral patterns and psychological drivers, these recommendations can strengthen the business model's viability and accelerate its sustainable integration into energy ecosystems.





POSTERS



Who has the socio-technical capacity and willingness to reconfigure their social practices?: Insights from a Swiss survey

Theme 1, sub-topic a

“Academic contribution”

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Keywords: Demand-side flexibility, household energy use, automation, energy communities, experimental survey

Extended abstract

In the context of ongoing energy crises and the expanding role of renewable energy in the power mix, demand-side management (DSM) programs that both lower and increase the flexibility of household energy use are becoming increasingly important. To realize the full benefits of these programs, it is essential that households and energy users engage actively in their implementation. However, the literature demonstrates significant disparities in socio-technical (in)capacities such as the ability and resources to engage with the new technologies (e.g. technical expertise, digital alienation¹ or to modify their energy use i.e. reconfigure their social practices (material arrangement (ownership of smart appliances), competence (skills, know-how), and norms and images) that hugely reflect complex identities and social contexts of citizens (e.g. intersectionality)^{2,3}. Currently, an economic framing exists in DSM solutions



offered by utility companies that sees citizens as consumers, concentrated on the provision of economic signals (e.g. tariffs), often coupled with technological interventions to facilitate the transmission of these signals with the assumption of economic drivers and rational decision-making^{4,5}. The imagined lay person for this particular objective is usually a representation affected by unconscious bias about who the user is: “usually white, male, privileged, well-off, and young geeks and tech-savvies who gladly take the roles of grid operators”, leading to the development of DSM programmes that exclude or simply do not appeal to many other citizens⁶. Certain groups’ perspectives and needs are rendered invisible or disadvantaged in the process and programmes offered, they also might bear greater manual or cognitive burdens if the household is unable to afford smart home equipment^{7,8}. Therefore, (new) social inequalities may emerge and persist in relation to DSM. While there has been a significant amount of research attention on energy justice considerations related to low-carbon transitions⁹, work explicitly considering the justice implications of on ‘demand side management’ by citizens individually and collectively specifically has still been somewhat limited given the scale of expectations in this area³. These approaches are increasingly and extensively critiqued by scholars as they overlook the social and political engagements and role of citizens/communities, undermining more profound and inclusion of citizens as crucial elements in the transformation of the system¹⁰.

Against this background, we ask the following research questions:

- What are the diverse profiles manifested in Swiss home electricity users across different socio-demographic profiles?
- What are the different capacities, aspirations, acceptance of DSM programmes manifested in these profiles?

Our main aim is to show multiple ways of engaging people (social, political), a percentage representation of these profiles across different socio-demographic distributions.

Methodology: A survey was conducted with Swiss households (n=1,378 responses). The survey is structured into seven thematic blocks to gain a comprehensive understanding of household energy flexibility. It examines both the technical and social capacities of households to offer flexibility in energy consumption or production, exploring technological readiness and behavioural willingness. It also identifies barriers—both perceived and actual—to adopting flexible practices. The survey assesses attitudes toward collaboration in energy initiatives and explores participants’ values and interests related to energy. Additionally, it investigates how extreme events influence energy use and support needs. Finally, it collects socio-demographic data to analyse how different characteristics manifest across different social groups and profiles. The survey data was analysed using a k-means clustering approach, following a structured four-step process. First, relevant variables were selected, and the dataset was prepared for analysis. Then, Factor Analysis of Mixed Data (FAMD) was applied for dimensionality reduction, allowing for the integration of both numerical and categorical variables. Based on the reduced dimensions, k-means clustering was performed to identify distinct groups within the data. Finally, detailed profiles were generated for each cluster to interpret and characterize the different patterns of energy flexibility among respondents.

Results: This k-means clustering identified six distinct clusters, each revealing different levels of socio-technical capacity, and socio-environmental motivations. These personas highlight the diversity of energy users and the need to design demand-side management (DSM) strategies tailored to their values, capabilities, and circumstances. The first cluster is the traditionalists, which represents the majority, demonstrate moderate solar panel adoption (43%) and some experience with smart energy devices. Their social capacity is limited—they tend not to actively



adjust routines for flexibility. While they exhibit moderate energy literacy and digital competence, they are not strongly motivated by environmental or social concerns. Economic awareness is present but tends to translate into passive behaviour. Second cluster is the Tech-Savvy Adopters (8%) shows the highest solar panel adoption (59%) and strong ownership of smart energy devices. They actively schedule appliance usage and heating/cooling based on efficiency. They are digitally literate, environmentally motivated, and responsive to social norms. Mostly comprising middle-aged male homeowners with high incomes and tertiary education. The third cluster is the conservative energy users, which is a smaller segment, shows moderate solar adoption (42%) but relatively low smart technology usage. While they do manage appliance use to some extent, they are reluctant to compromise on comfort. They possess good energy literacy but lower digital confidence. Although environmentally aware, their behaviours do not consistently reflect this. Cost is a concern, but active energy management is lacking. The fourth cluster is the passive consumers (37.4%), this large group has the lowest solar adoption (22%) and minimal use of smart energy systems. Their behaviours show little flexibility, and digital competences are below average. They are not significantly influenced by social norms and show limited environmental motivation. Economic awareness exists but does not result in active engagement. The fifth cluster is the balanced pragmatists (1.37%). This niche group shows moderate solar adoption (47%) and some even use of electric vehicles. They manage energy use pragmatically, according to daily routines. Digital literacy is strong, but social and environmental drivers play a modest role. Finally, though the smallest cluster, the sustainability champions are the most committed to sustainable energy practices, with high adoption of heat pumps and renewables. They actively engage in energy management, have high digital and energy literacy, and are deeply motivated by environmental concerns and social responsibility. Typically, younger male cooperative members with tertiary education are in this profile.

Conclusion : These findings contribute to the ongoing discourse on the need to redesign demand-side management (DSM) programs to account for the diverse user profiles that exist within the population. To ensure inclusive participation and successful enrollment, DSM initiatives must incorporate multiple interconnected processes—such as empowerment, engagement, targeted communication, and the co-design of solutions—that reflect the varying capacities, motivations, and preferences of energy users. The six clusters reflect the complexity and diversity of energy users, making it clear that “one-size-fits-all” DSM strategies are insufficient. Inclusivity requires aligning DSM programs with the values, capacities, and contexts of each group. Indeed, the tech-Savvy Adopters and Sustainability Champions are ready for cutting-edge DSM tools—dynamic pricing, peer-to-peer trading, or participation in energy communities. On the other hand, traditionalists and conservative energy users are more cautious. They may respond to programs that requires trust-building and user-friendly design are key. Passive Consumers risk exclusion without targeted support. Interventions here must focus on accessibility—through digital upskilling, translated materials, low-tech interfaces, and trusted local intermediaries.

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Green production, great solution? - Understanding Public Preferences for Green Hydrogen Production in Germany

Theme 3, sub-topic 3b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Green hydrogen, Social acceptance, Renewable energies, Energy transition, Decarbonisation

Extended abstract

Introduction

Although green hydrogen (i.e. hydrogen produced with renewable electricity) is internationally considered a key component of decarbonisation and the energy transition [1], many green hydrogen projects are either not being implemented at all or are only being implemented slowly and with significant delays [2]. Of 190 green hydrogen projects announced globally in recent years, so far only 7% have been implemented as planned [2]. The main reason for this is that the implementation of green hydrogen projects remains prohibitively expensive, and massive global subsidies, estimated at US\$1.3 trillion, would be required to realise all announced green hydrogen projects [2]. In addition, there is often a lack of willingness to pay high prices for green hydrogen on the demand side, while on the supply side, uncertainties persist regarding future subsidies and regulatory frameworks [2, 3].

Nevertheless, various countries, including Germany, strongly support a market ramp-up for green hydrogen (production) to combat climate change. Since crucial sectors of the German industry (iron and steel, cement, and chemical industries) cannot be directly electrified, the German National Hydrogen Strategy envisions using green hydrogen in these industries as a mean of long-term decarbonisation [8, 9], not least since green hydrogen results in significantly lower greenhouse gas emissions compared to hydrogen derived from fossil fuels [10]. Thus the German National Hydrogen Strategy also aims to scale up the hydrogen economy, including the national production of green hydrogen [8, 9]. In addition to technical and economic challenges that policymakers and industry must address, the success of this transition also hinges on public perception, especially when green hydrogen production facilities are to be constructed near residential areas. Despite the relevance of this issue, little empirical evidence



exists on how the German population perceives specific characteristics (participation opportunities for citizens, safety risks, financial benefits, landscape impact, origin of renewable electricity) of such green hydrogen projects. At the same time, an optimal design of green hydrogen projects is essential because it increases the likelihood that citizens will accept such projects.

Study Design and Attribute Selection

To fill this gap, a nationwide online survey with a discrete choice experiment was conducted in Germany with a final sample of 1,203 respondents. In the choice experiment, participants were presented with a series of hypothetical scenarios describing green hydrogen production projects. Each scenario was composed of a set of attributes with varying levels, developed based on previous research on the acceptance of renewable energies by Langer *et al.* [11], Plum *et al.* [12] and van Rijnsoever *et al.* [13]. The final set of five attributes and their levels is shown in Table 1.

Table 11: Design of the choice experiment

Attribute	Levels	Source
Participation	No participation Alibi participation Information Consultation Cooperation Financial participation	[11]
Origin of renewable electricity for green hydrogen production	Local production on-site Own federal state Germany Europe Outside of Europe	[12], own supplements
Fire or explosion risk	low medium high	Expert interviews
Impact on the landscape's appearance or visual impact	low medium high	[13]
Personal, annual heating cost savings	0 € 100 € 250 € 500 €	Expert interviews

Each respondent evaluated ten choice sets, each consisting of three green hydrogen project alternatives and a none-option, enabling the capture of opt-out behaviour. Figure 1 shows an example of a choice set from the online survey.



Which of the combinations described here for local production of Green Hydrogen and renewable energy near your place of residence would you be most likely to accept? Or would you choose not to accept any of the described combinations? Please click on "Select" for each and then click "Next."

(1 out of 10)

Origin of renewable electricity for hydrogen production	Europe	outside of Europe	Germany
Fire or explosion risk of the facility	high	medium	low
Information or participation opportunities for citizens	Alibi participation	Information	Consultation
Influence of renewable energy installations on the landscape in my immediate vicinity	low	high	medium
Your personal annual heating cost savings with the help of hydrogen as part of the energy transition	250€	0€	100€
	Select	Select	Select

I would not choose any of these alternatives.

Select

Figure 33: Example of a choice set in the choice-based conjoint experiment

Methodology: Hierarchical Bayes Estimation

The choice experiment was analysed via Hierarchical Bayes (HB) estimation in Sawtooth Software [14] to identify the preference structures of German citizens toward different configurations of green hydrogen production facilities. HB allows for robust individual-level part-worth utilities, drawing on both the respondent's choices and overall population priors. Compared to traditional estimation techniques like multinomial logit, HB captures unobserved heterogeneity more accurately and is particularly suited for understanding variation in public preferences for infrastructure projects.

Utility coefficients were zero-centered within respondents to ensure comparability, and attribute importance scores were derived from the range of utility values across levels per attribute.

Key Results and Interpretation

The attribute with the highest importance for survey participants identified in the HB is fire or explosion risk (32%), followed by the origin of renewable electricity for hydrogen production (25%). In contrast, the least important attribute for the survey participants is the visual impact of the required renewable energy installations on the landscape (10%). Figure 2 illustrates the average importances of attributes in the Hierarchical Bayes estimation.

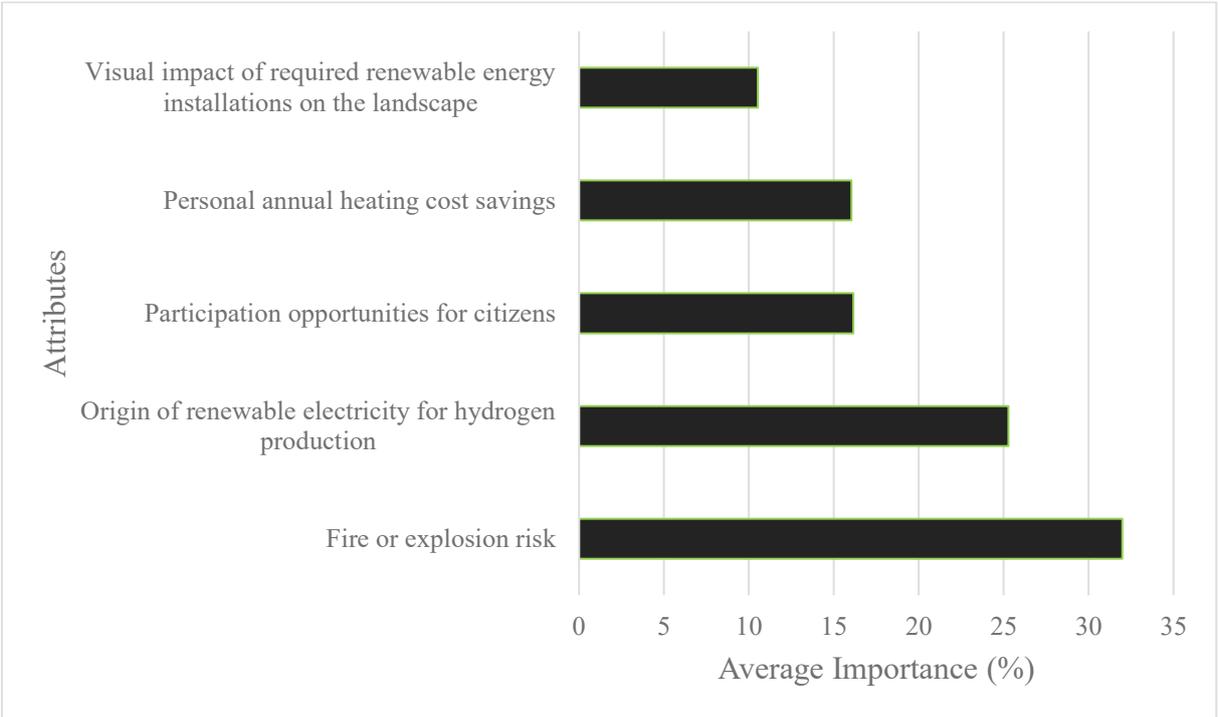


Figure 34: Average Importances of Attributes in the Hierarchical Bayes Estimation (n=1,203)

- Origin of renewable electricity for green hydrogen production**
 This attribute reflects preferences for the location of the renewable electricity facilities needed to produce green hydrogen. The utilities show a clear preference for local production on-site (utility: +38.29). In contrast, preferences are strongly negative for outside Europe (-65.32). Respondents strongly favour local and national electricity sources, likely due to perceived environmental, economic, or reliability benefits.
- Fire or explosion risk of the facility**
 For this attribute, the utilities indicate a strong preference for low explosion risk (+66.38) and strong aversion to high risk (-78.68). Safety of production sites is a top priority for respondents. High-risk facilities are clearly undesirable, while low-risk ones are strongly preferred.
- Participation opportunities for citizens**
 This attribute includes various levels of citizen involvement. Financial participation (+18.49) is most positively valued, while alibi participation (-38.71) is most negatively perceived. Respondents value meaningful and active participation, especially in financial and cooperative forms. Token or absent participation is viewed negatively.
- Visual impact on the landscape**

Preferences here show a clear dislike for high impact on the landscape (−23.36), while low impact (+13.28) is positively rated. Visual and environmental impacts matter. Respondents prefer installations that minimally affect the surrounding landscape.

- **Annual heating cost savings**

This economic attribute shows increasing utility with higher savings: €500 (+22.41) and decreasing utility with no possible savings: €0 (−34.41). Financial incentives are important and preferences follow the economic principle.

Table 2 provides an overview of the average utilities of the individual attribute levels.

Table 12: Average utilities of the attribute levels (n=1,203)

Attributes	Levels	Average Utilities	Standard Deviation
Origin of renewable electricity for green hydrogen production	Electricity production: local on-site production	38.29	44.39
	Electricity production: from the same federal state	29.53	28.65
	Electricity production: Germany	17.46	16.86
	Electricity production: Europe	-19.96	32.17
	Electricity production: Outside Europe	-65.32	47.37
Fire or explosion risk of the facility	Risk: low	66.38	50.85
	Risk: medium	12.29	20.72
	Risk: high	-78.68	48.99
Participation	No participation	-18.24	22.58
	Alibi participation	-38.71	26.42
	Information	11.13	17.59
	Consultation	12.36	24.15
	Cooperation	14.98	16.58
	Financial participation	18.49	21.95
Visual impact on the landscape	Landscape impact: low	13.28	21.23
	Landscape impact: medium	10.08	12.11
	Landscape impact: high	-23.36	24.47
Annual heating cost savings	Savings: €0	-34.41	39.22
	Savings: €100	-3.34	18.55
	Savings: €250	15.35	19.91
	Savings: €500	22.41	36.62
None option		-14.25	166.27

Conclusion



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Based on the Hierarchical Bayes (HB) estimation results from the conjoint analysis study on green hydrogen, several clear conclusions can be drawn regarding public preferences and priorities.

The most influential factor in decision-making was the fire or explosion risk of the green hydrogen facility, with respondents showing a strong preference for low-risk installations and a clear rejection of high-risk scenarios. This highlights the central importance of safety of production facilities for public acceptance of hydrogen technologies.

Closely following in importance was the origin of the electricity used for hydrogen production. Participants strongly favoured local and regional sources, with preferences decreasing significantly for electricity generated outside of Europe. This suggests that local value added, better perceived control or sustainability of energy sources play a key role in shaping attitudes.

Citizen participation opportunities also emerged as a meaningful factor. Respondents valued genuine forms of involvement—especially financial participation and cooperation—while symbolic or absent participation was viewed negatively. This indicates a desire for transparency, influence, and shared benefits in energy projects.

Economic considerations, such as annual heating cost savings, were also relevant. Higher savings were clearly preferred, though this attribute was slightly less influential than safety and energy origin. This suggests that financial incentives matter, but they are not the sole driver of acceptance.

Finally, the visual impact on the landscape was the least important attribute overall. Respondents preferred installations with minimal visual or environmental disruption, indicating that aesthetic and ecological concerns should not be overlooked.

In summary, the HB results reveal a nuanced picture of public preferences. The insights of this study can guide policymakers and project developers in designing hydrogen infrastructure that aligns with public expectations and fosters broad support. By considering these study findings, future green hydrogen projects are more likely to be accepted by citizens and, through the ramp-up of green hydrogen production, facilitate the transition towards a more sustainable energy future in Germany and beyond.

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Adopting Smart Home Charging for Electric Vehicles: A Stage-Based Socio-Psychological Perspective

Theme 1, sub-topic 1a) Contributions of multidisciplinary approaches to behaviour and social practices

- “Academic contribution”
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Keywords: Demand flexibility, Electric vehicles, Smart charging, Stage model, Behavioural change, Psychology

Extended abstract

Efforts to meet rising electricity demand through large-scale grid expansion have faced a bottleneck, mainly due to high costs and slow implementation processes. In response, demand-side flexibility is proposed as a more cost-effective and time-efficient alternative [1], [2]. This approach shifts part of the responsibility from suppliers to consumers by encouraging



electricity use during low-demand, off-peak hours, typically communicated through price signals [3]. It assumes that consumers behave as rational actors who know when and how to adjust their usage [4]. However, the concept of bounded rationality challenges this view, noting that individuals make decisions under constraints of limited cognitive capacity, information, and time [5]. As a result, consumers may struggle to interpret price signals and make optimal adjustments. This can lead to suboptimal decisions (i.e., shifting all usage to the same off-peak period, potentially creating new peaks) rather than optimal ones (i.e., distributing usage across multiple off-peak periods).

Smart home charging for electric vehicles (EVs) represents a key innovation that enhances demand-side flexibility while reducing the cognitive burden on consumers. Imagine returning home, plugging in your EV, and knowing it will automatically charge at the most cost-effective and energy-efficient times. Smart home charging offers daily convenience for EV drivers while supporting a more stable electricity grid. By shifting charging time to off-peak hours and enabling the integration of renewable energy, it helps balance supply and demand and supports the decarbonization of energy system [6]. However, despite its technical and environmental potential, widespread adoption has yet to be achieved. This suggests that successful integration depends not only on infrastructure and technology but also on understanding the socio-psychological factors influencing consumer adoption [7].

This study will explore the **socio-psychological factors** influencing the adoption of smart home charging among EV drivers in Sweden, using the Stage Model of Self-Regulated Behavioural Change (SSBC) as its theoretical framework. In this context, adoption of smart home charging is viewed as a behaviour that unfolds across multiple stages, rather than as a one-time decision, with each stage shaped by distinct factors that may either motivate or hinder progress toward adoption. Sweden offers a highly relevant context, given its high EV penetration and high share of renewable energy [8], [9]. The SSBC conceptualizes behavioural change as a four-stage process: **pre-decision**, **pre-action**, **action**, and **post-action** [10]. Progression through these stages is determined by three types of intentions: goal intention (deciding to change), behavioural intention (deciding what to do), and implementation intention (planning how to do it). These intentions are influenced by constructs from the **Theory of Planned Behaviour (TPB)** [11], the **Norm Activation Model (NAM)** [12], as well as self-efficacy and planning ability.

The SSBC has been applied in areas such as sustainable transportation [10], purchase of EVs [13], and moving into energy-efficient home [14], making it well-suited for examining the adoption of smart home charging for EVs. The following hypothetical scenario illustrates how the SSBC captures the distinct factors drivers might face at different stages of adopting smart home charging for EVs. These factors influence whether they remain at their current stage, regress to an earlier one, or progress toward adoption:

- **Pre-decision stage:** Drivers charge their EVs at random or peak hours, with limited awareness of the grid or environmental impact and little sense of responsibility to change. Some remain in this stage, while others begin to form a goal intention to change their charging habits.
- **Pre-action stage:** Drivers consider smart home charging as a viable option and evaluate factors such as installation and maintenance costs. These factors shape their attitudes and perceived ability to adopt. Some remain uncertain or regress, while others develop a behavioural intention to adopt.



- **Action stage:** Drivers take concrete steps, such as purchasing and installing a smart charger and using smart charging apps. Technical issues or unexpected costs may lead to stagnation or regression, while others progress by forming an implementation intention, such as scheduling regular overnight charging.
- **Post-action stage:** Drivers consistently use smart home charging as part of their daily routine.

While the SSBC describes behavioural change as a sequence of stages unfolding over time, this study will adopt a cross-sectional approach to compare how motivations and barriers manifest among EV drivers at different stages of adoption. This design suits the exploratory nature of this study, as it provides initial insights into whether the model's proposed variables are relevant and distinguishable across these stages. Data will be collected using an online questionnaire based on SSBC constructs. Participants will be EV drivers in Sweden, recruited through an online portal during the summer of 2025.

This study is expected to yield implications for both theory and practice. Firstly, it contributes to the growing theoretical discourse on the value of interdisciplinary approaches to addressing sustainability challenges related to energy efficiency and climate mitigation. By examining the socio-psychological factors influencing the adoption of smart home charging for EVs, this study offers a more holistic perspectives that complements technical solutions in supporting wider adoption. Secondly, understanding the distinct motivations and barriers faced by drivers at different stages of adoption can inform more targeted interventions. For drivers in earlier stages, targeted messaging can be delivered via email, text messages, or social media. The content can focus on reducing uncertainty and increasing motivation by providing clear installation guidance, sharing testimonials from other drivers, highlighting long-term financial and environmental savings, and addressing common misconceptions. For drivers in later stages, interventions can focus on reinforcing established routines by offering personalized rewards for achieving environmental goals, providing tailored in-app feedback on energy usage and environmental impact, and sending timely reminders for maintenance or software updates.

In conclusion, smart home charging for EVs offers a viable solution by enabling demand-side flexibility while reducing the cognitive burden on drivers. This study examines the socio-psychological factors influencing its adoption, and how these factors may vary across different stages of adoption. The insights gained may inform stage-specific interventions to support adoption, ultimately contributing to improved energy efficiency and the decarbonization of the energy system.

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Beyond Behaviour: Structural Prerequisites for Energy Sufficiency in Türkiye

Theme 2, sub-topics 2b and 2c
Theme 5, sub-topics 5a and 5b

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy sufficiency, Energy poverty, Structural inequality, Just transition

Extended abstract

Over the past decade, the concept of *energy sufficiency* has emerged as a critical dimension of the sustainable energy transition in Europe. Initially developed through academic and civil society discussions, it is now increasingly reflected in mainstream policy frameworks. Energy sufficiency refers to a condition in which people’s basic needs for energy services are met fairly, while ecological boundaries are respected [1]. In contrast to energy efficiency, which aims to reduce the energy input required to deliver the same service, sufficiency challenges the nature, volume, and necessity of those services. It asks not only how energy is used, but how much is used and whether that use is truly necessary [2], [3], [4]. This framing marks a shift away from purely technological solutions and toward a broader socio-technical rethinking of demand.

This shift reflects the growing recognition that demand-side action is as essential as decarbonising the energy supply. Without measures to reduce absolute demand, efficiency gains are often undermined by rebound effects, where improved performance leads to increased overall consumption [2]. In this context, sufficiency emerges as a critical complement to energy efficiency, helping to sustain and deepen the impact of efficiency measures by addressing the volume and necessity of energy services themselves. As Sachs has noted, “*While efficiency is about doing things right, sufficiency is about doing the right things*” highlighting the normative dimension of this approach [5]. Sufficiency has been recognised in the IPCC’s Sixth Assessment Report as a key component to reach climate neutrality by 2050, and is highlighted as a distinct mitigation strategy that aims to avoid unnecessary demand while safeguarding well-being [3]. Wiese et al. estimate that sufficiency policies could account for 40-50% of Europe’s potential final energy demand reduction by 2050 [6].

However, the successful implementation of sufficiency principles depends not only on individual choices, but also on the structural conditions that enable or constrain those choices. Bertoldi emphasize that sufficiency is not solely about behavioural change. To be effective and fair, it must be supported by enabling infrastructure, regulation, and access to efficient energy services [2]. This study builds on that insight by operationalising the concept of sufficiency through an exploratory data analysis in Türkiye. Using national microdata, it explores how



housing problems and basic service interruptions relate to life satisfaction and perceived hope for the future.

This study draws on Türkiye’s 2022 Life Satisfaction Survey (LSS), a nationally representative microdata set conducted by the TurkStat. The survey collects detailed information on life satisfaction, public services, social pressure, and future outlook, based on a sample of 4,736 households selected via two-stage stratified cluster sampling across urban and rural areas.

Figure 1 shows the distribution of household-level life satisfaction scores, rated on a scale from 0 (not satisfied at all) to 10 (completely satisfied). The distribution is approximately symmetrical, with both the mean and median values centred at 5.5.

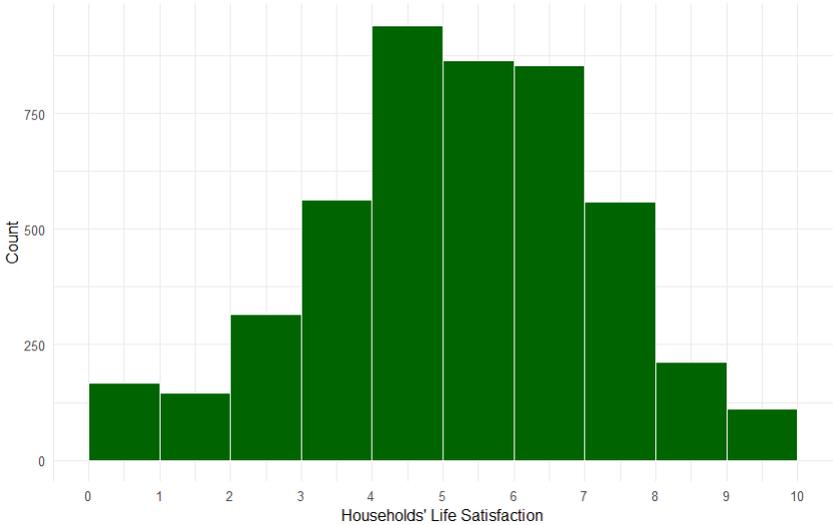


Figure 35. Histogram of Households' Life Satisfaction

Figures 2 and 3 illustrate the prevalence of structural housing problems and utility service interruptions reported by households.

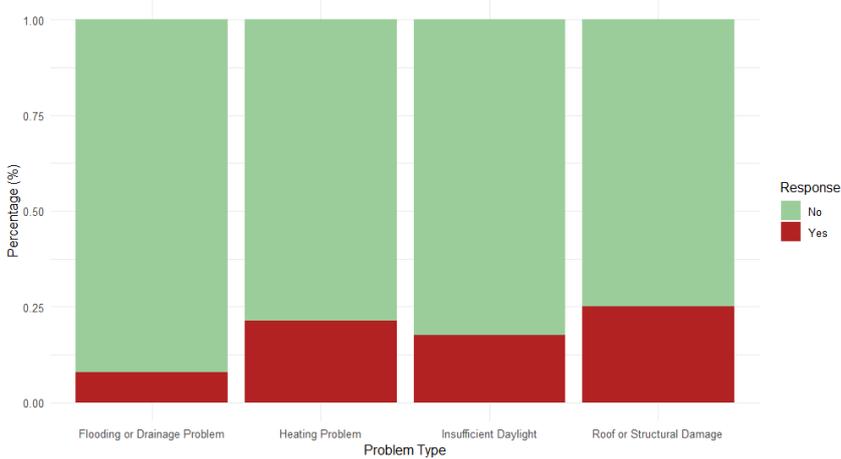


Figure 36. Structural Housing Problems

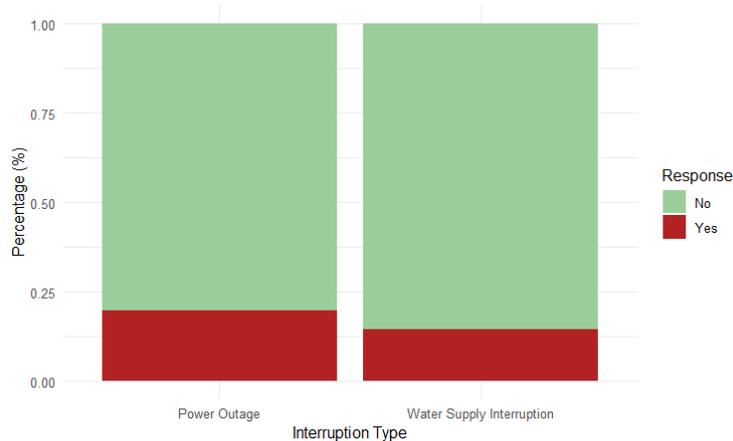


Figure 37. Utility Service Interruptions

As shown in Figure 2, between 17% and 25% of households face significant issues such as heating problems, insufficient daylight, and roof or structural damage. While flooding problems are less common, they are still reported by around 8% of households. Figure 3 indicates that nearly 20% households experience frequent power outages, while 15% report interruptions in water supply. These conditions indicate that a substantial share of the population lives in residential environments that fall short of providing basic comfort and reliability, challenging the sufficiency of the built environment.

Figures 4 and 5 illustrate how structural housing problems and utility service interruptions are associated with differences in household life satisfaction. Households that report such problems tend to have lower median life satisfaction than those that do not. Although some variation exists within each group, the downward shift in median satisfaction indicates a link between poor housing conditions and reduced life satisfaction. Both power outages and water supply interruptions are associated with lower median life satisfaction scores among affected households. Although the differences appear less pronounced than those observed for structural housing problems, the pattern remains consistent: households that experience disruptions in basic utilities tend to report lower life satisfaction compared to those without such interruptions.

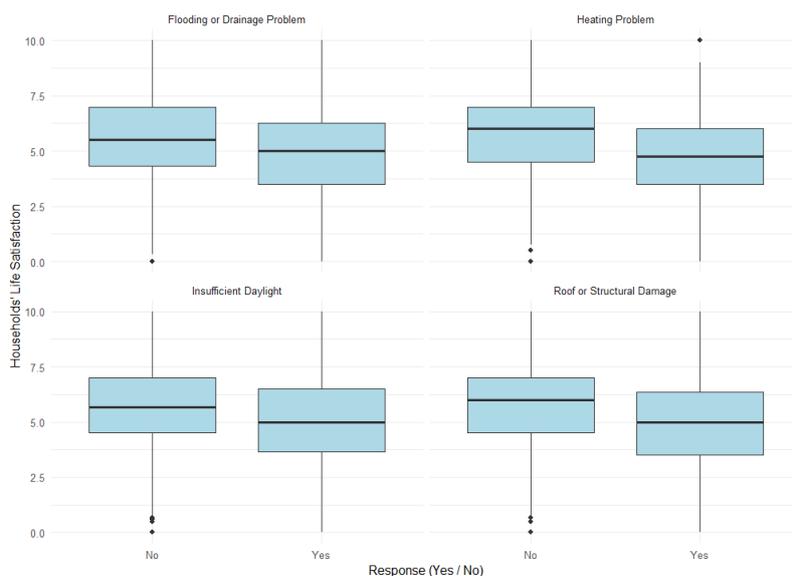


Figure 38. Life Satisfaction by Structural Housing Problems

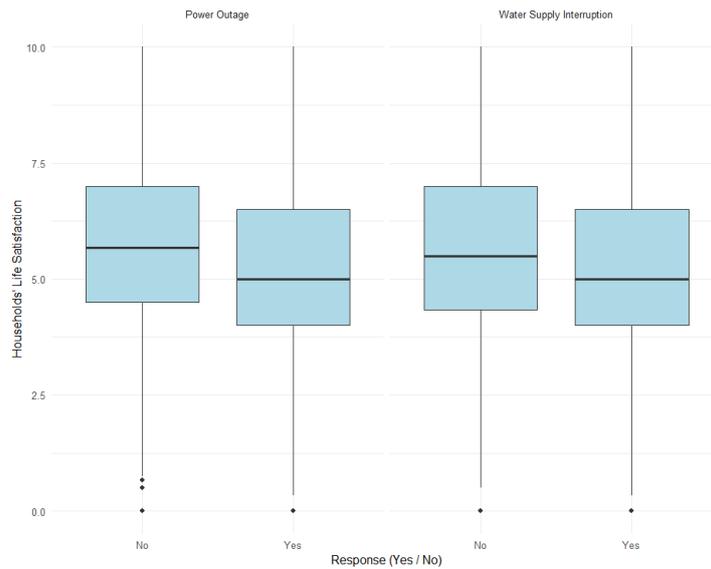


Figure 39. Life Satisfaction by Utility Service Interruptions

Figure 6 illustrates the distribution of future outlook (hopefulness) among individuals living in households with or without various housing and utility-related problems. Across all problems considered, a consistent pattern emerges: individuals exposed to structural deficiencies and those experiencing utility service interruptions are more likely to report a lack of hope for the future. The difference is particularly pronounced for households with heating problems and insufficient daylight, where nearly half of the respondents fall into the "Not Hopeful" group. In contrast, individuals in households not facing these issues report significantly higher levels of hope. Although the gap is slightly narrower for utility service interruptions, the negative association with future outlook remains evident.

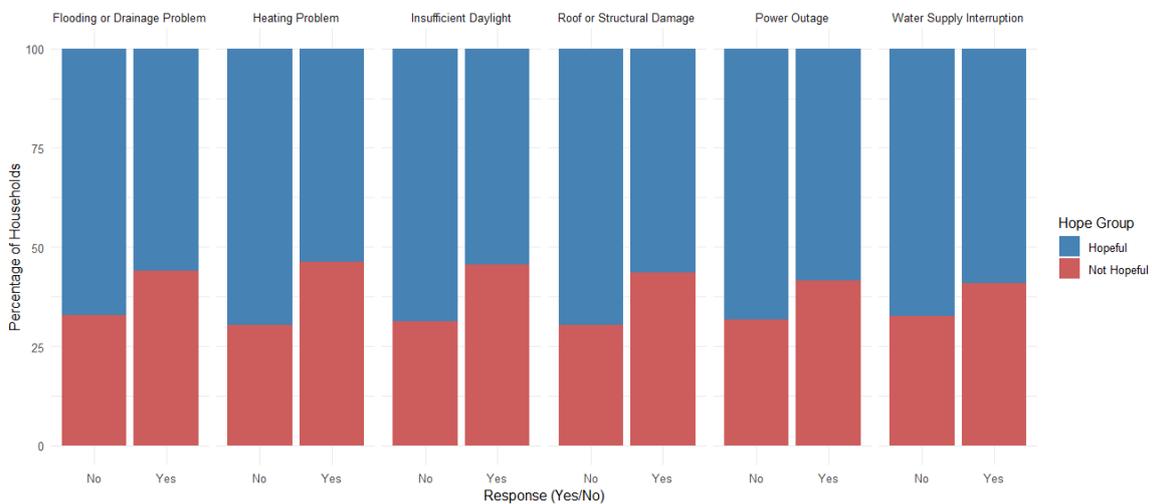


Figure 40. Hope for the Future by Type of Housing Problems and Utility Interruptions

Energy poverty also remains a key barrier to ensuring fair and inclusive transitions in energy and climate policy and poses a significant challenge to the implementation of sufficiency practices. It not only limits access to adequate energy services but also reflects deeper structural and economic vulnerabilities. To better capture these intertwined challenges, this study adopts proxy. Households are classified as “energy poor” if they report either heating problems or roof/structural damage and also indicate that their income is “hardly sufficient” to meet

households' needs. Based on this definition, 24% of households in the sample fall into the energy-poor category. As shown in Figure 7, energy-poor households report substantially lower life satisfaction compared to others. Similarly, Figure 8 reveals a clear association with future outlook: while the majority of non-energy-poor individuals remain hopeful, energy-poor individuals are significantly more likely to feel pessimistic about future.

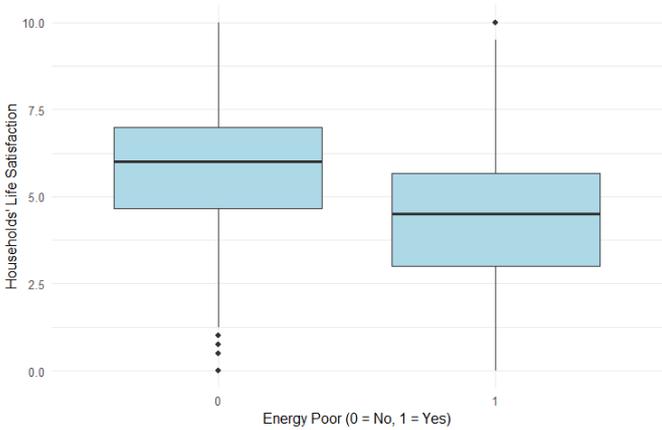


Figure 41. Life Satisfaction by Energy Poverty Status

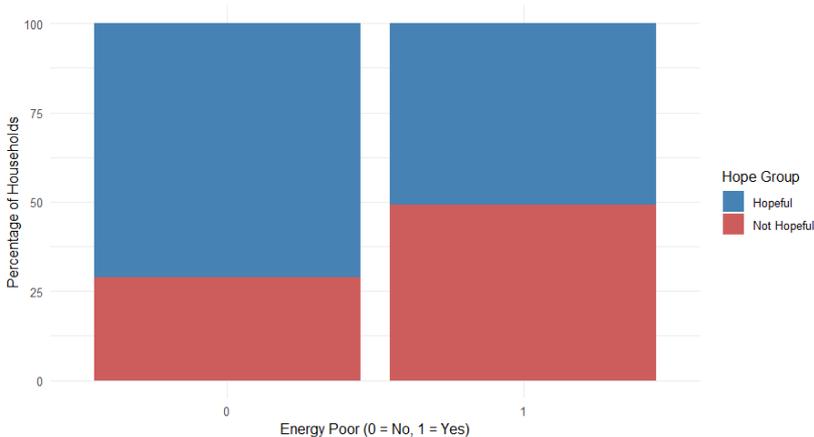


Figure 42. Hope for the Future by Energy Poverty Status

This study highlights the significance of structural housing problems and basic infrastructure deficiencies as critical factors shaping households' life satisfaction and outlook for the future. While sufficiency is increasingly highlighted as an essential pillar of climate mitigation, it cannot be realistically promoted in settings where many households still face inadequate living conditions. The findings imply that without addressing these fundamental deficits, expecting widespread behavioural shifts may be overly optimistic. Households struggling with heating problems, insufficient daylight, or frequent service interruptions are not only materially constrained but also report lower life satisfaction and diminished hope, potentially undermining their capacity or willingness to adopt sufficiency practices.

Although sufficiency aims to empower individuals to consume less while maintaining well-being, it must be supported by structural improvements, accessible services, and a broader enabling environment. Behavioural action alone may not deliver meaningful change if individuals lack the financial means, physical conditions, or psychological resilience to participate.

This study focused only on housing and infrastructure-related indicators within the national LSS microdata and does not claim that these conditions are the sole determinants of dissatisfaction or pessimism. Rather, it highlights that such factors may play a substantial role and deserve closer attention in sufficiency-oriented policymaking.

The results presented here reflect preliminary insights. Authors will expand on these findings through statistical analysis to evaluate whether these relationships remain significant. Given the availability of comparable Eurostat datasets, this study is replicable in other European countries, allowing for broader cross-country validation and policy relevance.

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AENEAM: Agri-Food Efficiency with New Energy Audit Measures

Theme 4, sub-topic 4a) and 4b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Audits, Acceleration Programme, Pilot

Extended abstract The food sector is a major consumer of energy, with the amount of energy required to cultivate, process, pack and bring food to European citizens’ tables accounting for 17% of the EU’s gross energy consumption in 2013 – equivalent to about 26% of the EU’s final energy consumption in the same year [1]. The food industry in the EU-27 is largely dominated by small and medium-sized enterprises (SMEs). The war in Ukraine and the COVID-19 pandemic added to the existing pressure that climate change puts on our food production systems, forcing food manufacturers to continuously mitigate and adapt.

SMEs [2] face several internal barriers to the uptake of energy efficiency measures, including (1) the lack of awareness and commitment from top management, and (2) lack of time and/or internal skills. Other barriers may arise from: a reluctance to invest in building energy efficiency improvements from SMEs leasing or renting their buildings; potential disruption of day-to-day routines; and deviation from standard practices. An external barrier SMEs often face is the limited financing solutions available to them, as they often do not have access to capital markets, and banks and other financial institutions are often reluctant to provide loans due to the perceived risks. Rapid expansion of technologies and solutions that drive more efficient energy use across the economy are necessary to keep global climate commitments – governments need to take the lead in the mobilisation of the required increase in investment [3].

The EU LIFE project *AENEAM* project seeks to address these issues and aims to accelerate the transition of the agrifood industry towards a sustainable growth model, by increasing the uptake of recommended measures from energy audits. The project is underway in the four countries of the project (Spain, Poland, Italy and France), represented by the Asociacion de la Industria Navarra, Nasuvinsa, AUiPE AG, Klaster Spozywczy Poludniowej Wielkopolski, CSMT, Confindustria Brescia, the Critt Agroalimentaire Sud, and Innov’Alliance.

The project encourages companies (from NACE codes C10 and C11) to undergo energy audits and subsequently implement the recommendations from these audits – and participate in a “local pilot” grouping companies for joint solutions.



AENEAM aims for a comprehensive approach to achieving energy efficiency, with several specific objectives:

1. To promote the development of an innovative acceleration programme tailored to the involved companies, with high impact monitoring and steady network immersion. The acceleration programme serves for capacity building, with a systematic approach to knowledge and skills development to ensure that companies have the internal expertise to effectively implement change and improve performance of measures.
2. To design and deploy the “local pilots”, offering operational support to groups of companies, identifying synergies and complementarities for energy efficiency solutions. Three pilots will be deployed across the partnership: energy communities within an industrial area, demand aggregation and set-up of an energy purchasing group, investigation into the deployment of renewable energy sources.
3. To set up specialised workshops for re-skilling, as part of the acceleration programme to enhance the skills of energy technicians; to foster the development of a green impact strategy for improved corporate energy culture and communication; to propose business plans for the implementation of recommended measures; to facilitate access to investors and public funding.
4. To engage the key actors and establish a stakeholders’ network, fostering not only a favourable energy audits ecosystem, but also to complement support to the involved agrifood SMEs and multiply the effect of the proposed measures, reaching other sub-sectors and contributing to the sustainability of the programme.
5. To promote a range of operational services to the companies involved, with direct support to undertake the proposed or selected measures from the energy audit recommendations; to identify funding schemes; to promote the use of digital solutions, including energy management systems (EMs) based on ISO 50.001.

The project has calculated energy savings and related impacts, based on the expected results of the activities of the project, assumptions of involvement of companies in these activities, and assumptions about their annual energy consumption. Companies selected for participation were sought on the basis of specific minimum average primary energy consumption rates (4.5 GWh for companies involved in the energy audits and local pilots, and 1.63 GWh for companies in the acceleration programme and workshops). The project took several publications, studies and statistics into account to calculate the estimated energy savings relevant for each type of energy efficiency measure undergone in the project, outlined below:

Table 1: Estimated primary energy savings per type of energy efficiency measure

Type of Energy Efficiency Measure	Estimated energy savings	Relevance to companies	Ref.
Audits	4.10 %	All companies involved	[4]
ISO 50.001	5.50 %	All companies involved	[5][6]
EMS	5.00 %	All companies involved	[7]
Adoption of energy efficiency technologies and renewable energy	4.10 % 2.00 %	Companies involved in the application of recommended measures Companies involved in the acceleration programme workshops	[8]
Local pilots	8.24 GWh	Companies involved in the local pilots	[9][10][11] [12][13][14][15]

The project has calculated the following estimated primary energy savings for companies involved in the following project activities:

Table 2: Primary Energy savings per year triggered by the project (GWh/year) based on assumption of N° of companies involved in the project activities, by type of energy efficiency measure

Type of Energy Efficiency Measure	Type of involvement	N° of SMEs	Primary Energy savings (GWh/year)
Audits	Selected companies to undergo energy audits	80	14.76
	Networking with stakeholders	300	20.01
	Companies attending training and workshops	200	13.34
	TOTAL	580	48.12
ISO 50.001	Selected companies to undertake ISO 50.001 implementation	8	1.98
	Companies attending training and workshops	150	13.42
	TOTAL	158	15.40
EMS	Selected companies to undertake EMS implementation	8	1.80
	Companies attending training and workshops	40	3.25
	TOTAL	48	5.05
Adoption of energy efficiency technologies and renewable energy	Selected companies to undertake measures recommended from energy audits	12	2.21
	Companies attending training and workshops	150	4.88
	Companies attending exchange of experiences workshops	150	4.88
	TOTAL	312	11.98
Local pilots	Companies involved in the local pilots	24	8.24
TOTAL			88.79

As a result of these project activities and objectives, the AENEAM project expects the following impacts:

Table 3: Expected impacts triggered by the project

	ProjectEnd Value	5 years beyond Project-End Value
Primary Energy savings triggered by the project (GWh/year)	88.79	217.25
Final Energy savings triggered by the project (GWh/year)	61.66	150.87
Reduction of GHG emissions triggered by the project (kt CO ₂ /year)	13.06	31.95
Cumulative investments in sustainable energy triggered by the project (million €)	6.33	14.81



Real-life implementation sites carried out by the project (N° sites)	4	4
Market stakeholders trained with increased skills and competencies on energy issues (N° stakeholders)	150	300
Company staff with improved skills/knowledge (N° persons)	600	1200
Number of stakeholders reached through media and events throughout the project (N° stakeholders)	2000	3000
Companies benefitting from direct support (N° companies)	104	

The resources produced throughout the project (recordings from workshops and trainings, green communication plans, good practices and database of Best Available Technologies, technical deliverables) will be disseminated and made available on the project's website, with it maintain three years beyond the project's timeline. The goal is to foster the project's long-term sustainability and facilitate the appropriation of its resources and methodologies for replication.

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Household Energy Waste: Insights from UK household observatory data

Theme 1, sub-topic 1a, Theme 5, sub-topic 5a

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Household energy, Energy efficiency, Sufficiency, Waste, Smart meters

Extended abstract

Introduction

The UK has invested in a longitudinal observatory to deliver data and insights into energy use in households. The programme began with the Smart Energy Research Laboratory (SERL), which from 2019 onwards has enrolled 13,500 households who use electricity and natural gas as their main energy sources. All households have smart meters, and SERL has access to half-hourly data. In addition to a mandatory survey administered on joining, households have been asked to complete additional surveys. The anonymised data is available to researchers with an approved project, and annual data summaries [1] are available to all (www.serl.ac.uk).

This activity has been continued via the ‘Energy Demand Observatory and Laboratory’ (EDOL) programme (2022-27). Selecting from the SERL household sample, which currently numbers 11,600 because some households have left the project (e.g. on moving home), EDOL will install monitoring equipment in 2,000 households. Indoor temperature and humidity will be recorded and 10-second metered electricity data collected. Measurement of air quality and occupation patterns may also be trialled. Monitoring equipment installation will commence shortly. Alongside this ‘observatory’, smaller scale ‘laboratories’ seek to investigate specific technologies and policy relevant questions. A household survey has been undertaken in 2025 and further surveys are planned for 2026 and 2027 (www.edol.ac.uk).

A central EDOL research aim is to “enable and strengthen foundational scientific understanding of how and why energy is used in homes through data-rich sociotechnical research”. This aim also applies to energy waste in homes. Understanding energy waste is important; identifying the magnitude, characteristics and causes of wasted energy highlights opportunities for energy saving which will benefit households, the energy system and the environment. Reducing energy waste and energy demand will also reduce the cost of system transition to a net zero energy system [2].

This extended abstract outlines how existing and planned EDOL data can be used to investigate energy waste, and what additional data may be required.



What do we mean by energy waste?

Energy waste in households can be understood as a technical measure of inefficiency – e.g. in an appliance, heating system or building fabric, which can be measured in terms of kWh / service delivered or rate of heat loss. Many improvements have come about because of a policy focus on increasing efficiency, with average UK household use reducing by one quarter since 2000 [3].

Energy waste can also arise from the ways in which homes and technologies are controlled and used. To investigate this, householders can be asked about energy conservation behaviours (see Table 1). However, these questions may need to change. For example, the UK plans to move from predominantly gas central heating (used by 85% of households) towards electric heat pumps. Heat pumps work best delivering continuous low temperature heat – and this means questions like “When you leave the house, do you turn down your thermostat or turn off your heating?” may no longer be relevant. What constitutes energy waste, particularly for space heating (the biggest use of residential energy in Northern Europe), is likely to change.

Beyond technologies and behaviours, understanding of waste and wastefulness intersects with related ideas of enough-ness, sufficiency, comfort, luxury or excessive consumption – with exploration of these concepts being an active research topic [4].

EDOL is developing work on conceptualising energy waste at all scales of the energy system including differentiating technical inefficiency from waste associated with household behaviours, practices or habits. This is helping to inform future data collection and interpretation of existing data.

Relevant data collected in EDOL

In relation to technical (in)efficiency, EDOL links to data on the efficiency of buildings’ fabric and heating systems, via Energy Performance Certificates, where available. Data about heating systems, smart controls and insulation measures was collected in an initial recruitment survey and again in the 2025 survey, which also asked about acquisition of new ‘energy saving’ technologies, e.g. heated airers (for drying clothes), air fryers (efficient small ovens). EDOL has no data about the efficiency of individual energy-using technologies.

The 2025 survey asked a number of well-established questions around behaviours related to appliances, hot water and heating (

Table 13). Questions about behaviours to keep homes cool in summer have been included for the first time. These are of increasing concern as UK temperatures rise due to climate change.

Table 13: Number and type of questions in 2025 EDOL survey related to behaviours and thermal comfort

Theme of question	Number of questions	Types of energy use impacted
Frequency of behaviours ‘to save energy’	9	Hot water use, cooking, clothes washing and drying, lighting
Frequency of particular behaviours in winter (energy saving not mentioned)	7	Space heating
Thermal comfort, affordability in winter	3	Space heating
Ventilation practices in winter	1	Space heating
How often data about energy use via smart meter / other device is consulted	1	All
Frequency of behaviours to keep the home cool in summer (energy saving not mentioned)	8	Cooling fans, mechanical ventilation and cooling (and passive measures).



Preliminary survey data

Preliminary data from the EDOL 2025 survey, answered by 3,806 households from the SERL cohort, is now available to the research team. It has not yet been fully quality checked or linked to the smart meter data.

85% of households report making either ‘a great deal’ or ‘some’ effort to reduce the amount of energy used (Figure 43). This shows a notable increase in effort from the baseline SERL survey in 2019, and almost as much effort as reported in the 2023 ‘cost of living’ survey (5,400 respondents) carried out at time of very high energy prices [5].

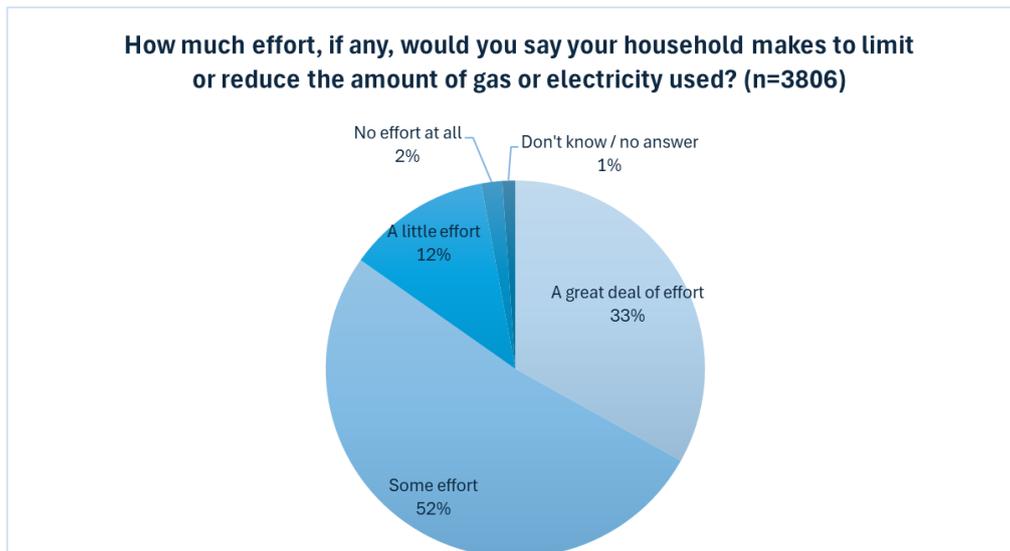


Figure 43: Responses to survey question about efforts to limit energy use

Discussion and conclusions

Smart meter energy data alone cannot determine whether energy is being wasted, although unusually high energy use, particularly if normalised for EPC, m² and household numbers (key determinants of energy use), would suggest this is likely.

The new data on internal temperature will be very important for insights on energy used for space heating. The general UK guidelines for 18-21C as a ‘healthy’ temperature in living rooms will give a starting point for investigating over-heating as a form of energy waste.

Surveys can collect detailed self-reported data on efforts to save energy. While useful, these data are subject to the normal social desirability bias. The phrase ‘energy waste’ is not used in the EDOL or SERL surveys. An expert workshop at the 2024 ECEEE conference suggested that because of its strong emotional resonance, it should be only used very carefully with research subjects and in public communication – suggesting a need for further exploration of this phrase and its meanings.

Planned workshops will explore what different groups of people understand by ‘energy waste’. This will include exploring energy waste within specific practices such as cooking, heating, ventilation, EV charging. Insights from this work will add to EDOL’s conceptualisation of energy waste, design of future survey questions and interpretation of existing data.

EDOL has the opportunity to explore energy waste in more detail by linking these types of data, and to act as a starting point for future research and debate. Ongoing research will shape a more nuanced understanding of energy use — helping to inform better policies, guide household engagement, and ultimately support a fair and effective transition to net zero.



Acknowledgements

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Investigating sufficiency and its potential for decarbonisation pathways: Insights from an interdisciplinary research project

6a), 6b), 5a), 5b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Sufficiency, Lifestyles, Decarbonisation pathways, Interdisciplinarity, Scenarios

Extended abstract

Introduction

This contribution aims at presenting the results of an interdisciplinary European research project on sufficiency, understood as a process of socio-technical change allowing for the creation of the social, infrastructural, and regulatory conditions for changing individual and collective lifestyles in a way that reduces energy demand and greenhouse gas emissions, and simultaneously contributes to societal wellbeing.

The purpose of the project was to empirically refine the concept of sufficiency, from both social science and humanities (SSH) and energy and climate modelling (ECM) perspectives. We build on Sahakian and Wilhite’s [1] theory of energy consumption as social practices to investigate sufficiency as the triad of habits, infrastructures, and societal framework, and we assess its potential contribution to decarbonisation pathways in modelling scenarios [2]. This research has been conducted between 2021 and 2024 in five European countries (Denmark, France, Germany, Italy, and Latvia) and India.

In this communication, we wish to focus on the outputs of the interdisciplinary dialogue between SSH and ECM in order to unveil the complexity of defining sufficiency and the challenges of making impact assessment and prospective consistent with the social realm.

Theoretical framework

Sufficiency, defined as a voluntary reduction in resource consumption that maintains quality of life while staying within the planet’s boundaries [3, 4], is increasingly understood as a key driver in decarbonisation pathways [5, 6]. Since households account for between 60 and 70 percents of global greenhouse gas (GHG) emissions [7, 8], altering lifestyles holds a crucial potential to cut down GHG emissions [9]. Sufficiency has thus often been described as a shift towards less resource-intensive daily practices [10]. Yet, energy and climate scenarios often overlook the embeddedness of individual practices within social structures, the formation of



social practices and lifestyles, the diversity of social differentiations through consumption, and the complexity of lifestyles. The purpose of this project was to help narrow the gap between both approaches.

Methodology: A step-by-step interdisciplinary approach to the notion of sufficiency

Our interdisciplinary methodology consists of different steps including a comprehensive review of decarbonisation scenarios, the recollection of 40 initiatives, 90 semi-structured interviews with participants to sufficiency initiatives, a quantitative study based on a representative panel of 8760 individuals²⁵, 60 in-depth interviews with ordinary citizens drawn from this panel, and the study of 8 “sufficiency scenario assumptions”. By “sufficiency scenario assumption” we mean the projected changes for a given sufficiency lever (e.g. shared housing) on a set of sufficiency indicators (e.g. square meters per capita), from a starting point to a target year, including a characterisation of the pace of change with a defined time step. We use both inputs from the ECM within SSH research and inputs from the SSH within ECM research to improve the quantification of projected changes towards more sufficient lifestyles at the national level.

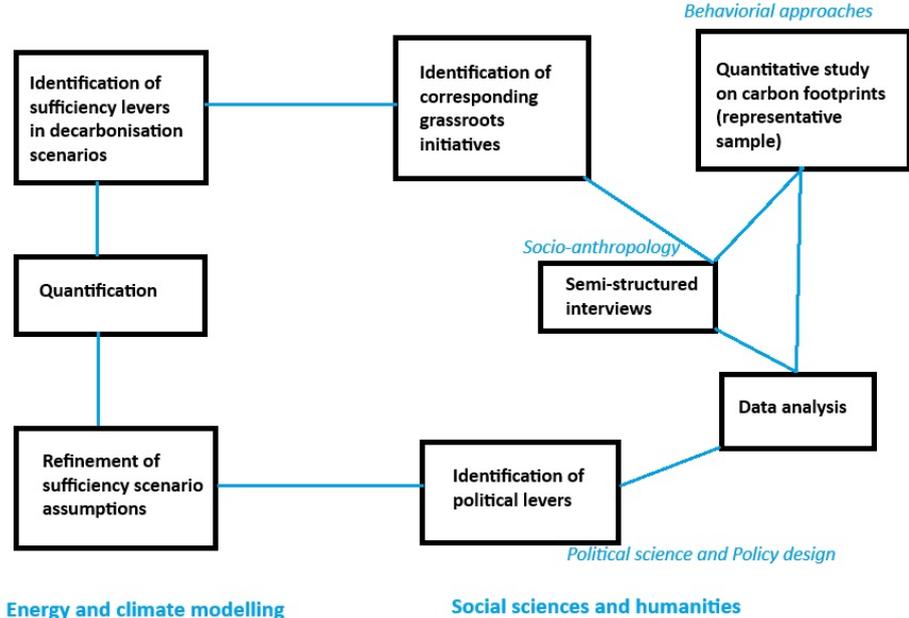


Figure 44. The interdisciplinary methodological design

Results

1) Sufficiency levers seen from the SSH

Our research has shown that the adoption of more sufficient energy practices needs several conditions to occur. The availability and accessibility (both geographical and financial) of alternatives to the mainstream, carbon-intensive options for consumption are key conditions, but the institutional and legislative environment is often ill-adapted. As a consequence, the offer for low-carbon alternatives is insufficient and inconsistent in most territories, not allowing for, even preventing, the development of a “low-carbon lifestyle”.

²⁵ Representative sample of approximately 1,800 p. per country

In addition, a low-carbon lifestyle necessitates resources in order to ensure that wellbeing is preserved. Indeed, while low-income consumers have tried to decrease their energy consumption through sacrifices in terms of comfort, high-income consumers have been able to adapt to increased energy prices by improving their equipment. Sufficiency-oriented individuals recruited within the initiatives, on the other hand, often benefit from more free time, peer support and lack of economic stress. In addition, adopting a sufficient lifestyle can be demanding, especially for women and at certain periods of life (e.g., parenthood) and enter in competition with other norms (e.g. being productive at work, being socially included), with few rewards in the current social context.

2) Quantification of sufficiency seen from the ECM

Our exploratory work highlights the importance of considering social determinants in the transformation of lifestyles towards sufficiency to improve the design and implementation of decarbonisation pathways. Integrating SSH knowledge into sufficiency prospective studies on energy and climate also makes it possible to question the balance between feasibility and ambition from a social point of view, and to build a more detailed justification of the related projections.

Besides, a fine understanding of barriers and enablers at play allows, by identifying the targets more clearly, to better define the policy objectives and thus to design more tailored and effective policy instruments. This work suggests a way of better integrating and articulating policies and measures for the short, medium and long term. Since it forces to describe precisely the social and political dynamics at work throughout the trajectory, it can also contribute to elaborating more relevant narratives and to making sufficiency policies more tangible.

In a nutshell, using insights from SSH in ECM can make scenarios more robust, consistent, fit for public discussion and useful for policymaking.

Discussion and conclusion: The challenges and promises of interdisciplinarity

Our work highlights the challenges and promises of bettering the interdisciplinary dialogue between SSH and ECM for prospective studies.

From a SSH perspective, it proved difficult to transpose the theoretical levers in the social realm and find corresponding social practices to study their formation. In addition, we found that “native” definitions of sufficiency and the practices associated with it do not align with the abstract, theoretical definitions of sufficiency. It encompasses a diversity of material and energy cultures across countries and social groups. We also found that sufficiency levers are not equally distributed among social groups, which raises issues of social justice [11].

Several difficulties were encountered with the ECM work carried out. First, one has to face a crucial lack of data regarding historical practices and adequate surveys on effective and desired practices. Differentiating subpopulations for each sufficiency lever studied is also complex, especially when it comes to intersectionality. Finally, the work carried out turned out to be too cumbersome to be replicated for every single lever to consider in a sufficiency-based pathway.

Our work highlights the relevance of going deeper into certain levers and corresponding social practices, especially for sufficiency scenario assumptions that are causing social or political debate, and to integrate a policy strategy that articulates multiple temporalities (short, medium and long term).

In conclusion, interdisciplinary research work is important to reinforce the political credibility of sufficiency scenarios. It should be deepened through a continued dialogue across SSH and prospective studies (i.e. techno-economic energy and climate research). It could serve as a basis



to discuss how future sufficiency-based scenarios could be improved by using data from SSH, but also to challenge the overly technical and theoretical approaches of sufficiency.

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Rethinking the Boundaries of Energy Justice in Demand-Side Flexibility across Europe: A Critical Review

Theme 2, sub-topic 2b)

“Academic contribution”

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Keywords: Energy justice, demand-side flexibility, critical interpretive policy analysis, discursive power, European countries

Extended abstract

As the transition towards decarbonised energy systems accelerates, demand-side flexibility (DSF) has become a key strategy for integrating variable renewable energy sources and promoting more sustainable energy consumption behaviors [1]. When combined with education and accessible technologies, flexible mechanisms have the potential to reduce overall energy use, beyond merely shifting loads in response to real-time grid needs [2]. These strategies are often framed as win-win solutions, enhancing grid stability while empowering consumers [3]. However, they tend to prioritise technological and market-based incentives, often overlooking everyday motivations and barriers that shape consumer behavior [4,5] and influence individuals' ability to participate in and benefit from DSF initiatives [6]. Reducing energy demand requires not only technical solutions but also societal and lifestyle changes that can raise important questions of energy justice, particularly for vulnerable and marginalised groups, in the design and implementation of DSF [7,8].

This research responds to this gap by bringing a critical interpretive perspective to the societal challenges and ethical dimensions of DSF. As part of the Consumer energy Demand Flexibility (CoDeF) project, this study explores the question: How do dominant narratives shape the way in which energy users, scientists, and actors in policy making understand and experience energy justice in the context of DSF? More specifically, it analyses user, academic, and policy discourse to investigate who DSF is designed for, by whom, and for what purpose. It critically examines the instruments used to promote DSF, such as time-based tariffs, dynamic pricing, smart metering, and demand-response programs, and the extent to which justice is considered in relation to these instruments. Using an intersectional lens, the research explores how energy justice is conceptualised. It pays particular attention to the assumptions behind prevailing narratives, which often simplify identities, overlook diverse needs, and exclude certain perspectives.

Adopting a qualitative, critical and interpretive approach, this study includes a systematic literature review as a key methodological tool to evaluate and expand the way in which energy justice is framed and operationalised within DSF debates. This review helps identify which narratives are under or overrepresented, and what issues are included or excluded from policy agendas, highlighting gaps between scientific research and practice. Particular attention is given



to less visible expressions of power, examining how these dynamics influence energy consumption behaviors and how they may lead to or reinforce injustices within the energy system.

The analysis draws on a comparative case study of three European countries: the Netherlands, Norway and Italy. In all of these countries, DSF is recognized as an important instrument for aligning future energy consumption better with availability of energy at different moments in time, however, the cases differ in geographic, demographic, socio-economic, and cultural contexts and hence, may give rise to and be influenced by different DSF narratives and understandings of justice. In addition to that, the Netherlands and Norway are part of the CoDeF project consortium, while Italy is the main author's native country, facilitating further empirical research with local stakeholders.

Accordingly, the next phase will involve empirical research using participatory methods such as interviews and focus groups with key stakeholders, including researchers, policymakers, energy providers, consumers, and relevant associations and organizations involved in flexible energy systems. Participants will be selected based on their expertise, influence, and engagement in DSF-related initiatives. The goal is to better understand the intentions of those setting the “rules of the game” as well as the lived experiences, intentions and perceived burdens of those affected by these interventions. The ultimate goal is to develop fine-grained, contextspecific policy recommendations that support the co-creation of more inclusive and diverse approaches to addressing energy (in)justice.

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Building designers' attitudes towards reuse of materials in construction

Theme 1,2,5, sub-topic 1a), 2a), 5c)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Sufficiency, Circularity, Construction, Behaviour, Building sector, Reuse

Extended abstract

- INTRODUCTION

The construction industry's faces urgent challenges to reduce its significant contribution to global waste and environmental degradation. Going beyond circular economy and shifting towards more sufficient building practices, such as adaptive reuse of the existing building stock and reuse of materials and building components, play a crucial role to achieve climate goals and restore balance with planetary boundaries. In recent years, several online reuse marketplaces and digital tools, such as digital building logbooks (DBLs) have emerged within the scope of circularity in the built environment, aiming to facilitate circularity and traceability. However, their efficacy in promoting reuse depends on widespread adoption and their ability to offer value without additional burdens. The successful implementation of reuse practices depends on the attitudes and perceptions of building designers and their considerable influence over material selection and design decisions. Understanding designers' attitudes toward material reuse is fundamental to unlock the full potential of an online reuse marketplace and address barriers to and enablers of behaviour change. This study examines how tacit knowledge shapes designers' attitudes toward material reuse and how these attitudes can support sufficiency and broader social practice evolution.

- METHODOLOGY

An interactive workshop with 11 Belgian building designers explored perceptions of reuse using generative techniques (collage and narrative). Using generative techniques, participants were prompted to express their perceptions of material reuse through collages, accessing their unconscious knowledge and bypassing conscious biases. The results were analyzed and classified considering the three main components of attitude (affective, behavioral, and cognitive) [1], the expressed emotions [2], and the main values (biospheric, altruistic, and hedonic)[3,4] highlighted by participants, through content and thematic analysis.

- RESULTS

Results revealed that designers' attitudes are deeply rooted in self-transcending values (biospheric and altruistic), with hedonic values playing a significant supporting role. The affective component showed high levels of joy, optimism, and anticipation toward reuse. Participants framed reuse as an opportunity for creativity, transformation, and beauty, linking hedonic enjoyment with pro-environmental practices. This underscores that sufficiency



practices can be attractive and pleasurable rather than restrictive, which is essential for encouraging behaviour change. Fear and apprehension were also present, reflecting uncertainties about material quality and process complexity.

Designers saw reuse as a creative action requiring experimentation and reinterpretation. They view incorporating reused materials as a creative challenge and an opportunity for transformation and value creation, emphasizing that reused materials should guide the design process through their cultural, aesthetic, and narrative attributes. Actions were framed around "designing from reuse," highlighting a shift in social practices towards sufficiency by starting design processes from available materials rather than treating them as mere substitutes. This shift supports sufficiency principles in design, production, and distribution by reducing dependence on new resource extraction and encouraging prolonged material lifecycles.

Cognitively, barriers included knowledge gaps, uncertainties, and perceived financial and time constraints. However, designers also identified enablers: improved data transparency, policy support, collaborative platforms (marketplaces), and creative freedom. Importantly, designers expressed a strong external locus of control, emphasizing systemic changes over individual responsibility, which suggests the need for multi-level interventions combining personal, professional, and policy drivers.

- IMPLICATIONS FOR MAINSTREAMING REUSE IN CONSTRUCTION

These findings contribute to the understanding of behaviour change in environmental contexts by illustrating how designers' value structures and emotional responses shape social practices. This research identifies four key strategies to empower designers to embrace material reuse effectively:

1. Tailoring information to users' values, particularly hedonic values, to highlight the pleasurable aspects of reuse.
2. Providing historical feedback that reinforces positive actions like adaptive reuse and featuring the story and heritage values of reused materials.
3. Offering group-based feedback, such as accounting for CO₂ savings achieved collectively through the reuse platform, and social comparison feedback to benchmark designers' reuse efforts against their peers.
4. Reducing cognitive effort by making reused materials the default scenario in design tools and avoiding information overload by providing value-tailored information.

Integrating these strategies will help overcome barriers and unlock the full potential of digital tools and online reuse marketplaces, thus contributing significantly to mainstreaming sustainable consumption in the construction industry and promoting sufficiency-oriented practices for a circular society.

- CONCLUSION

In conclusion, these findings underscore the importance of addressing designers' values rather than attempting to change them. By aligning reuse with beauty, creativity, and pleasure, and highlighting what designers are already doing well, interventions can enhance engagement without adding perceived hassle. Reducing complexity and providing transparent, value-focused information are key to making reuse the easy and appealing choice. Future studies should validate these insights more broadly to support inclusive, sufficiency-oriented practices and accelerate the transition toward a more circular built environment.



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Exploring Vulnerability in the Context of Renovations for Low-income Homeowners: Insights from an Empirical Study

Theme 2, sub-topic 2b)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Vulnerability, Energy efficiency, Decarbonisation, Renovations, Policy support

EXTENDED ABSTRACT

Scope and objective

Energy renovations are crucial for reducing CO₂ emissions in the building sector as renovated spaces generally require less energy for heating and cooling or utilize more sustainable or efficient energy sources. Energy renovations can also have positive implications for households: they can lead to reduced energy costs and can improve the quality of the living space (e.g. people might experience less discomfort from cold). This is especially relevant for vulnerable groups, for instance for low-income households. However, there are different barriers to energy renovations for homeowners, for instance renovations call for financial resources and knowledge. To mitigate these barriers, governments can implement targeted policies.

In this study, two potential policies supporting low-income homeowners in the context of energy renovations are investigated: (1) government funding for energy renovations, such as improving insulation or changing heating systems for homeowners based on household income (2) offering (additional) one-stop shops. These policies can reduce vulnerability in the context of energy inefficient dwellings as they support renovations.

In this study, vulnerability is understood as being at risk of living in an energy inefficient dwelling (exposure) while not having the resources to improve their situation, i.e. conduct energy renovations (adaptive capacity). Additionally, preexisting disadvantages in the housing sector (sensitivity) are considered as they can add to the stress experienced by living in an inefficient dwelling. This three-dimensional understanding of vulnerability including (i) exposure, (ii) adaptive capacity and (iii) sensitivity is based on a conceptualization stemming from climate change adaptation research, which has been more recently applied to the context of energy transition [1, 2, 3].



Using Germany as a case study, the following research questions are addressed in this study: (1) How are the different dimensions of vulnerability related to each other? (2) How are exposure and adaptive capacity related to perceptions of the two supportive policies?

Methodology

The analysis utilizes survey data collected for Germany within the EU Horizon–funded HouseInc project (ID# 101132513) [4] with N = 883 in 2025. The analyses focus on investigating homeowners only. Each respondent was presented with one of the two policies only. Hence, the sample size for the regression analyses is lower.

To explore our research questions, correlations and linear regression models are conducted, employing several variables to operationalize the three dimensions of vulnerability. In this context, exposure refers to whether the respondent currently lives in an energy-inefficient home, measured through (1) a subjective evaluation of the energy performance of the dwelling and (2) the building condition considering construction date and previous renovations. For adaptive capacity, we consider (1) income, (2) whether someone owns their dwelling without a mortgage as indicator for wealth, as well as subjective evaluations of the ability to renovate, including (3) feeling capable to afford renovations and (4) feeling capable to gather the necessary knowledge and information for renovations. Sensitivity encompasses pre-existing disadvantages in the housing sector, including groups identified in existing literature as prone to housing inequality: younger and older adults, respondents with migration history, having a chronic disease or longstanding illness or being a single parent.

Main results

To understand how the vulnerability dimensions are related to each other, correlations were calculated. In general, effect sizes of the correlations are very small or small. In the following, only small effects are discussed (effect > |0.1|).

Regarding the relationship between sensitivity and exposure, results indicate that having a chronic disease or longstanding illness is positively correlated with lower estimated energy performance. For the relationships between sensitivity and adaptive capacity, the results indicate that younger age, older age as well as having a chronic disease or longstanding illness are correlated with variables capturing adaptive capacity.

For correlations between adaptive capacity and exposure, results suggest that respondents with lower income tend to live in energy inefficient dwellings. Both variables measuring the perceived capacity to renovate are negatively related to exposure: individuals who state to live in energy inefficient dwellings also report lower levels of perceived capacity to renovate.

Table 14: Correlations between sensitivity and exposure/ adaptive capacity and between adaptive capacity and exposure

Variable	Exposure		Adaptive capacity			
	Low estimated energy performance	Living in old, unrenovated dwelling	Income	Own dwelling without mortgage	Perceived capacity: affordability	Perceived capacity: knowledge
<i>Sensitivity</i>						
Younger age (below 35)	-0.05	-0.07*	-0.00	-0.05	0.11*	-0.02
old age (65+)	0.09*	0.09*	-0.28*	0.27*	-0.05	-0.03
Having been born abroad	-0.04	-0.04	0.02	-0.08*	0.01	-0.06

Having a chronic disease or longstanding illness	0.12*	0.04	-0.16*	0.01	-0.17*	-0.12*
Being a single parent	0.04	0.00	-0.07*	-0.06	-0.02	-0.03
<i>Adaptive capacity</i>						
Income	-0.25*	-0.17*	-	-	-	-
Own dwelling without mortgage	0.01*	0.08*	-	-	-	-
Perceived capacity: affordability	-0.26*	-0.20*	-	-	-	-
Perceived capacity: knowledge	-0.19*	-0.09*	-	-	-	-

Note. N = 883, except for income: N = 816. * p<0.05. Significant effects printed in bold.

The regression models address whether the different variables operationalizing exposure and adaptive capacity are related to perceptions of the two policies aiming to support energy renovations especially for low-income households: (1) government funding for renovations dependent on income and (2) one-stop shops.

Table 15: Results of linear regression models of the vulnerability variables (exposure and adaptive capacity) on policy perception of the two policies (dependent variables).

	<i>Dependent variables:</i>	
	Support: Government funding	Support: One-Stop-Shops
Low estimated energy performance	0.023 (0.025)	-0.001 (0.023)
Living in old, unrenovated dwelling	0.002 (0.154)	-0.098 (0.119)
Income	-0.019 (0.016)	-0.011 (0.014)
Own dwelling without mortgage	-0.119 (0.095)	-0.094 (0.089)
Perceived capacity to afford to make energy renovations	0.150** (0.046)	0.170*** (0.042)
Perceived capacity gathering knowledge	0.049 (0.049)	0.116* (0.046)
Constant	2.697*** (0.240)	2.353*** (0.223)
Observations	415	401
Adjusted R ²	0.026	0.078
F Statistic	2.830* (df = 6; 408)	6.622*** (df = 6; 394)

Note. Results for linear regressions, unstandardized coefficients, standard errors in parenthesis; * p < 0.05, ** p < 0.01, *** p < 0.001

The results suggest that higher perceived capacity to afford energy renovations is related to higher support of both policies. Similarly, higher perceived capacity to gather knowledge and information is positively related to support of one-stop shops. The models explain only a small share of the variance of the dependent variables. Thus, in a further step control variables will



be included in the models. Potentially, the results will be extended to include additional countries to be able to investigate cross-country validity of the results.

Conclusion

This study explored the relationship between several variables capturing different dimensions of vulnerability to energy inefficiency among homeowners in Germany, only finding small effects. Regarding the sensitivity variables, the results indicate correlations for having a chronic disease or longstanding illness as well as for age with the other vulnerability dimensions. In addition, several correlations between exposure and adaptive capacity were found. Further, the relationship between vulnerability and policy support for two renovation policies were investigated. The results highlight the importance of perceived capacity to renovate for perceptions of the renovation policies.

This paper contributes to existing literature by conceptualizing different dimensions of vulnerability in the context of energy inefficiency of dwellings and adds to research on policy perceptions by underlining the importance of perceived capacity in the area being targeted by the policies.

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Extended Abstract: Addressing Energy Poverty through Care: An Austrian Case Study on Gender, Literacy, and Vulnerability

Theme 2, sub-topic 2b) (12 font size)

“Academic contribution”

“Policy/practice contribution”

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Keywords: energy community, energy poverty, energy literacy, inclusive energy transition, gender-sensitive approaches, gender equality

Extended abstract

1.0 Introduction

Climate change and the current energy crisis pose multifaceted challenges to society, with adverse effects unevenly distributed across the population. Socioeconomically disadvantaged groups, particularly those with low incomes and insecure housing, are disproportionately affected by energy poverty due to limited resources and inefficient housing [1]. Additionally, gender shapes vulnerability to energy poverty, as structural inequalities related to income, care responsibilities, housing security, and domestic power dynamics often intersect with energy poverty [2, 3]. Ensuring a socially just energy transition requires the active inclusion of vulnerable groups and recognition of the diverse social and gendered dimensions of energy poverty [2, 4].

A central challenge lies in identifying and reaching those experiencing energy poverty [5, 6]. Social institutions, through their often trusted relationships with vulnerable groups, can serve as key intermediaries in this context [7]. Drawing on our case study, this contribution explores how they can support a just energy transition. *Schweizer Haus Hadersdorf* (SHH) is a non-profit inpatient and outpatient therapy facility for addiction disorders, located at Mauerbachstraße 34, 1140 Vienna and serves as a practical example where energy poverty and energy literacy is both experienced and addressed towards the patients. Furthermore, the case study also explores the role of the Austrian charitable association *Evangelischer Waisenversorgungsverein Wien* (EWV) as the property owner of the facilities where SHH



operates. The following abstract explores the case study and presents insights from the early stages of the project implementation.

2.0 Institutional setting of the case study: EWV and SHH

The case study involves two interconnected social institutions: the *Evangelischer Waisenversorgungsverein Wien* (EWV) and the *Schweizer Haus Hadersdorf* (SHH). EWV is a charitable, church-affiliated association supporting children and adolescents in difficult life situations through socio-pedagogical care, educational programs, and secure living conditions. The association's primary funding comes from property holdings, most of which are rental apartment buildings. One exception is the property at Mauerbachstraße 34, 1140 Vienna where SHH, a therapy facility, is located. In response to the energy crisis and Austria's commitment to phasing out fossil fuel heating, EWV promotes the energy transition across its portfolio, including SHH. In line with its social mission, particular emphasis is placed on sustainable and socially responsible strategies, with SHH serving as a practical site for implementation.

SHH is a non-profit inpatient and outpatient therapy facility for addiction disorders, offering medium-term therapies, psychiatric treatment, and social work support. In addition to the outpatient hospital and the administration, all the residential communities for inpatient treatment are also located there. During inpatient therapy, the patients live in small residential groups, one of which is for women. In the smallest group home, four patients live together, in the largest group home, eight people live together. Most of the rooms are double rooms, but there are also a few single rooms. All living groups have a spacious kitchen for communal activities and were recently renovated.

Around one third of patients are addicted to illegal substances, while two thirds struggle with alcohol dependency. This group often faces multiple forms of energy poverty. Financial constraints expose them to high energy cost burdens, and inadequate housing performance increases health risks. Poor insulation and limited access to effective heating intensify these effects. Many patients also lack energy literacy and may experience mental health conditions that both contribute to and result from energy poverty. Among SHH's seven branches in Vienna, the central location in the 14th district serves as the focal point for implementation. Schweizer Haus Hadersdorf (SHH) is also operating *Gesundheitsgreisslerei*. located in Vienna offering outpatient therapy by women for women.

3.0 Framework for practice

3.1 Strengthening energy communities and combating energy poverty

Within the case study, two key measures are implemented. First, preparatory work will support a socially inclusive, solidarity-based energy community by involving EWV buildings—primarily SHH—and actively engaging SHH patients as vulnerable user group. The initiative is supported by the Austrian Renewable Energy Expansion Act (2021) [7] and seeks not only to enable shared use of renewable energy but also to foster social cohesion, knowledge exchange, and collective action toward a more sustainable future. Knowledge-transfer and awareness-raising workshops are conducted to engage both patients and staff in energy-saving practices, the concept of energy communities, and broader questions of climate change and the energy transition.

3.2 Integrating a gender-dimension

Second, gender-sensitive capacity-building measures are being introduced, addressing the cross-cutting issues of energy advice and social welfare support. These measures, including the provision of information materials and the implementation of train-the-trainer seminars, are



designed to strengthen the competencies of energy consultants, social workers, healthcare professionals, and relevant stakeholders. They aim to foster closer integration of energy and social services and ensure support is better tailored to the needs of vulnerable groups. Additionally, a gender action plan is being developed to address the interconnection between gender, energy poverty, and energy communities. It defines site-specific actions to integrate gender aspects across all project areas, including team composition, decision-making, communication, and energy-related topics such as behaviour and literacy.

4. First insights into practice: Challenges and implications

Early challenges observed during implementation at SHH emphasize the importance of incorporating infrastructural, behavioural, and educational aspects into inclusive energy transition strategies. From a technical perspective, a key barrier is the existing gas-based heating system, which is tied to a long-term supply contract and thus limits flexibility in pursuing decarbonization strategies. Also, the structural complexity of the SHH main building with its fragmented layout, functional zones, and varied construction materials further complicates the planning and implementation of energy efficiency and retrofit measures. It becomes evident that thorough technical and legal assessments early in the planning process are necessary to develop site-specific strategies for renewable energy integration in institutional contexts.

Beyond physical conditions, the everyday energy practices observed at SHH present another challenge. Electrical devices such as televisions, kitchen appliances, and chargers are used frequently and inefficiently. Reported behaviours include prolonged use of electronic devices, unnecessary lighting, heating with open windows, and limited attention to resource conservation. These practices reflect not only a general lack of awareness but also structural knowledge gaps regarding energy use and its broader implications. At the same time, it demonstrates that social workers and care staff also require targeted training to integrate energy-related concerns into their work. To be effective, such capacity-building efforts should also consider gender-related aspects of energy use and caregiving responsibilities to ensure that energy advice is responsive to the diverse realities of vulnerable groups. These efforts must also balance competing priorities in patient's daily lives, where energy concerns are often secondary to more immediate needs. Encouragingly, early engagement shows that when energy topics are woven into everyday therapeutic routines, even small interventions can lead to meaningful shifts in awareness and behaviour. Overall, this case highlights the central role of capacity building in socially inclusive transition processes, with energy literacy among both users and professionals proving essential for tackling energy poverty in institutional settings.

5.0 Outlook

The case study illustrates how social institutions can serve as important intermediaries to reach and support people affected by energy poverty. In this context, EWV as a socially committed real estate owner and SHH as a therapy facility jointly demonstrate how integrative energy transition strategies can be embedded in existing social infrastructures. Initial findings from the early implementation phase show that addressing energy poverty in institutional facilities requires more than just technical solutions. While technical frameworks can be complex and require tailored planning, sustainable outcomes also depend on behavioural change and the active inclusion of vulnerable groups. Embedding gender-sensitive approaches across all project dimensions, from planning and communication to therapeutic routines, helps ensure that transition processes address the specific needs and circumstances of all individuals. By integrating energy-related measures into everyday therapeutic practice and strengthening the competencies of care and support staff, the case demonstrates the potential of social institutions to make a meaningful contribution to a just and socially inclusive energy transition. Ultimately,



it can offer relevant insights for other institutional settings that engage with groups affected by energy poverty.

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Changing policy-makers' behaviours to bring about transport (r)evolution

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Extended Abstract

Scope and Objective

The harms from our social dependence on private cars for health [1], environment [2] - NEED SOURCE] and even economy [3 NEED SOURCE] have been widely documented and many cities - and their policy-makers have been engaging with car-reduction policies [4]. However, the progress is slow and even in cities that offer a wide range of non-car modes such as Ghent, car-dependence is still a problem [5]. This paper investigates the barriers to policy-makers' engagement with sustainable mobility policies and identifies possible strategies, to be employed by the civil society, or other policy-makers, to influence change.

Problem

As Walker and Brömmelstroet observed in their recent paper [6], the external, what they call the exo system, facilitates or hinders mobility behaviours. It can be argued that this environment is created by policy-makers and their decisions: to build cycling infrastructure, fund public transport and drastically reduce parking available, or, to the contrary, build ever more roads for cars and ignore other modes of transport. Politicians need to have a vision, clear strategy and be determined to propose, vote and implement policies that re-define the mobility environment and reduce the space given to cars [7]. These could be defined to form part of the motivation to engage in the behaviours, defined as proposing, voting and implementing sustainable mobility policies. Motivation to engage in those behaviours is influenced by a range of factors, which this paper investigates. Policy-makers who have successfully supported sustainable mobility policies in their cities from across Europe: Spain, Switzerland, UK, France and more, have been asked to provide their views. The paper provides ideas for civil society and other policy-makers on influencing the status quo and speeding up the transport (r)evolution.

Methodology

Semi-structured interviews with policy-makers across Europe - politicians and transport department officials - were performed to identify motivation-related barriers and enablers to sustainable mobility policies implementation among policy-makers, as well as ideas on strategies to support their behaviour change. The results were analysed using a thematic analysis approach.

Overview of the main results

Political beliefs and political identity were found to be key barriers and enablers, depending on the view of the subject, to engage with sustainable mobility policies. Policy-makers have difficulty to imagine different futures, not having experienced alternative ways of moving about the city, showing status quo bias. Oftentimes, they exhibit different behaviours and beliefs in



private vs those in public, showing a certain hesitance to engage with radical change. This may be due to the pluralistic ignorance, the belief that only a small minority of people want change. They also fear backlash and not being re-elected. However, when politicians have a strong sense of public duty, a clear vision and an idea of a strategy before being elected, once in office, they deliver strong change.

Among the strategies to motivate change identified, using the window of opportunity to implement change [8] was key - elections as well as the COVID pandemic appeared to spur change in the cities investigated. Understanding how the political system works helps implement changes within a short time frame of the local election cycle. The framing of the car dependence problem as one of health, quality of life and economic prosperity issues is also key. Multiplying touchpoints that get the message across - in the right frame for the given policy-maker - is important. We also need to pay attention to the messengers. A rightwing politician will be more susceptible to what business leaders say about the impact of congestion on the quality of life of their employees, whereas a leftwing one will be more likely to listen to activists pushing for cleaner air and social justice. Presenting the need for change as something that a lot of voters want can help burst the normative belief that it is only a wish of the minority. Finally, offering opportunities for first-hand, experiential learning of different a way of moving around is crucial for helping policy-makers to change their minds. And once policy-makers propose changes, it is important to support them through emails, letters, petitions and physical presence at public consultation events - to ease the burden of the backlash they undoubtedly receive.

Main conclusions/ recommendations

Policies that reduce our society's dependence on cars are crucial for environmental sustainability and well-being of our communities. However, there are multiple barriers for policy-makers to engage with those policies: status quo bias, difficulties in imagining different ways of moving around and pluralistic ignorance. We recommend that civil society, transport professionals and politicians use insights from behavioural science to support a mind shift among politicians regarding the implementation of car-reducing policies. In particular, framing, multiplying touch points from right messengers and experiential learning

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An Analysis of factors influencing the application for bio-based insulation support programs in Germany

3a) Acceptability and ownership of public policies by stakeholders and the public (e.g. energy laws, taxes, subsidies, infrastructure changes, system changes, ...)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: bio-based insulation, support program, acceptance

Extended abstract: The construction sector plays an important role in achieving Germany's goal of becoming climate-neutral by 2045 [1]. In Germany alone, 40% of CO₂ emissions are generated by construction, use, renovation, and refurbishment of residential and non-residential buildings [2,3]. Bio-based insulation, such as cellulose, cork, hemp, and wood fiber, can be a step in the right direction due to their lower carbon footprint compared to fossil-based insulation materials [4]. Despite their advantages (e.g., fewer chemical additives), bio-based insulation materials only represent 9% of market sales in Germany [5]. To boost the adoption of these materials, public support programs exist in Germany. These are offered nationwide by banks, for example, but also at the local level, and provide financial support for insulation, depending on the material. However, the effectiveness of the support programs is controversial, as previous studies in Germany have shown that private homeowners in particular often act for non-economic reasons and that most of the renovations would have been carried out without the support program [6,7]. This raises the question which factors influence the application of public support programs in the insulation market in Germany.

To answer this question, a nationwide, standardized online survey was carried out in Germany in May 2024. The survey was subject to the university's strict data protection guidelines, designed with Sawtooth Software's Lighthouse Studio 9.15.0, and data was collected by a research institute.

The target group for the survey was adult private homeowners who live in a detached or terraced house or who plan to live in one in the future. This house must either have been built and insulated within the last 5 years, renovated and insulated within the last 10 years, or currently be undergoing renovation and insulation. In the case of a current refurbishment, the planning phase has to be completed. Individuals who met these criteria but had acquired the property after installation of the insulation were excluded.

As part of the data cleansing process, cases with a response pattern (“straightliners”) were excluded. In addition, participants who answered questions twice as fast as the median of



participants with a similar number of questions were removed. Furthermore, suspicious cases were re-examined and excluded in case of doubt. In addition, all participants who have not installed or are not planning to install any bio-based insulation materials were excluded from this study. A total of 418 participants remained after the adjustments and were part of the study.

Of the participants, 121 used exclusively bio-based insulation materials, while 297 used bio-based insulation materials in combination with conventional materials. Altogether, a total of 125 of the 418 respondents applied for public funding for bio-based insulation materials.

The binary question of whether public funding had been applied for bio-based insulation activities was selected as the dependent variable. It was irrelevant whether this funding was on a national or local level. The independent variables were divided into three categories: “psychographic”, “socio-demographic”, and “home-related” variables. The independent socio-demographic variables were “income (INC)”, “region (REG)”, and “education (EDU)”. The “house-related” variables consisted of “building material of the house (BM)”, the number of components insulated with bio-based insulation materials, the (hereafter referred to as “Insulation Behavior (IB)”), and whether it was a “refurbishment or new build (R/N)”. The “awareness (AW)”, where participants indicated whether they were aware of a support program in their municipality or city, was the first “psychographic” variable. The other psychographic variables were measured using items measured on a 5-point Likert scale. Since the items for the “availability of the material, information about bio-based insulation, and the craftsmen (AV)” variable were developed by the authors themselves, Cronbach's alpha was tested to check the internal consistency and the reliability of the scale. “Environmental Concern (EC)” was measured according to Paul et al. [8], Garay et al. [9], and Lavuri et al. [10], while “Perceived Effectiveness of the support programs (PESP)” was measured by three items adapted from Wan et al. [11] and Sun et al. [12]. The items of “innovativeness (IN)” were adapted to the topic of “bio-based insulation materials” following the example of Parasuraman [13]. According to Davis [14], four five-level semantic differentials were used to test the “attitude (ATT)” towards the use of bio-based insulation.

In order to check whether the nominal independent variables were associated with the dependent variable, chi-square tests were conducted. Based on the non-significant results (Table 1), the variables INC, REG, and R/N were excluded from further investigation.

Table 16 Results of the Chi-square test (n=385*)

Dependent Variable	Independent Variable	Chi-square test (asymptotic significance)
Application for bio-based insulation support programs	BM	<0.001
	EDU	0.001
	INC	0.969
	REG	0.143
	R/N	0.856
	AW	<0.001

*“Don’t know” responses were excluded from the analysis.

To compare the metric variables between the persons who have applied for a support program and those who have not, a Mann-Whitney-U-Test was conducted. Significant differences were found between the groups for all variables (Table 2).

Table 17 Results of the Whitney-U-Test (n=418)

Dependent Variable	Independent Variable	Whitney-U-Test (asymptotic significance)
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Application for bio-based insulation support programs	IN	<0.001
	AV	0.029
	PESP	<0.001
	EC	<0.001
	ATT (towards bio-based insulation)	0.049
	IB	<0.001

In the final binary logistic regression, 415 participants were included (291 participants did not apply for funding, 124 participants applied for funding). Individuals who were unable to provide information about their education were excluded. A significant influence of AW, IN, ATT, EC, and AV (Table 3) on the dependent variable application was found. In the case of BM, only concrete had a significant influence. In contrast, the EDU, the PESP, or the IB had no significant influence.

Table 18 Results of the binary logistic regression: Significant influences on the application for bio-based insulation support programs (n=415)

Variables	Category	Coefficient B	p	Exp (B)
Metric variables				
EC		0.656	0.019	1.928
ATT		-0.652	0.014	0.521
AV		-0.447	0.015	0.640
IN		0.620	0.026	1.860
PESP		-0.003	0.988	0.997
IB		0.177	0.179	1.194
Categorical variables				
AW	Knowledge of support programs.¹	3.095	<0.001	22.077
EDU	Lower secondary school ²		0.357	
	Secondary school	1.418	0.220	4.129
	University of applied sciences qualification	0.779	0.511	2.180
	High school: University qualification	1.131	0.315	3.099
	Other qualification	2.220	0.103	9.209
BM	(mainly) Wood ²		0.129	
	(mainly) Concrete	0.939	0.047	2.558
	(mainly) Brick	0.305	0.526	1.356
	Other materials	0.619	0.381	1.857

$\chi^2(14) = 194,193$; $p < .001$; Cox & Snell R^2 : 0.374; Nagelkerkes R^2 : 0.530

¹Reference category = No knowledge of support programs.

²Reference category

The results confirm the importance of AW in the application for support programs, similar to findings from a literature review on green finance for sustainable buildings [15]. Furthermore, IN and EC also have a positive influence on the application. The results indicate a significant negative impact of AV on the application for bio-based insulation support programs. Additionally, ATT towards the use of bio-based insulation has another significant negative impact on the application for the corresponding funding programs. The influence of EDU cannot be confirmed, which differs from previous findings on drivers for green finance in the built environment [15]. In addition, the influence of PESP, which can be proven for the intention to recycle, cannot be transferred to the application for support programs [11]. Regarding BM, only concrete has a significant influence. Wood, bricks, or other materials have no significant influence on the application of corresponding subsidy programs. The assumed influences of INC, IB, REG, and R/N do not materialize.



These findings suggest that to draw attention to funding programs in the future and increase the number of applications, providers should conduct information campaigns on support programs or policies. The focus should be on the environmental friendliness and novelty of bio-based insulation to address the AW, EC, and IN of building owners.

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Heating Practices and energy-related Behaviour in Heritage Townhouses

Theme 5 Social practices of sufficiency, sub-topic a)

“Academic contribution”

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Keywords: Sufficiency, Heritage buildings, IEQ, Case study approach

Extended abstract

1. INTRODUCTION

Achieving a climate-neutral European Union by 2050 represents a significant challenge. Alongside issues concerning energy supply, transport, food systems, and other sectors, reducing the environmental impact of the residential building stock is a crucial component. Currently, the residential sector accounts for approximately 26% of Europe’s total final energy consumption [1].

The European residential building stock is relatively old, with 42% of the dwellings today in North and West Europe predating 1960 [2]. As a considerable proportion of 85% of the current building stock is estimated to still be in use by 2050 [3], substantial renovations of the existing building stock will be necessary to mitigate its environmental footprint. In certain countries, a large part of the dwellings even predates 1918 (12% in Italy, 12% in Czech Republic, 13% in Ireland) [4]. These older buildings may be considered inherently sustainable in a broader sense, by virtue of their longevity. Preparing these historic structures for a fossil-free future poses a particular challenge. In alignment with the principles of the New European Bauhaus, it is imperative that these culturally and historically significant assets are not lost or stripped of their heritage value, but rather transformed respectfully into resilient icons for the future.

Generic renovation strategies cannot be uniformly applied in this context. The prevailing modern approach of maximising thermal insulation to reduce energy demand is not always appropriate for historic buildings and may have aesthetic implications for these heritage buildings and our historic cities [5]. Alternative strategies will therefore be required, including intelligent heating solutions, behavioural change, and a re-evaluation of modern thermal comfort standards.

2. SCOPE

This research focuses on historical buildings in Belgium, more specifically heritage masonry terraced townhouses built between 1800 and 1918. This type of building is prevalent in almost every historic city in Belgium, with an estimate share between 3.8% and 9.8% of the Belgian building stock [6]. Additionally, these buildings can also be found in other regions in Europe,



like for example the North of France, The Netherlands and in cities like Paris and Vienna. The scope of this extended abstract is characterising these type of buildings, and more specific the energy related user patterns of the habitants. Research by Delghust et al. [7] showed that in buildings with a high energy use (which is often the case for historic buildings), the gap between the real energy use and the calculated energy use (for energy performance certification (EPC)) is high. Previous research on these historical buildings showed that the real energy use can be 7 times lower than the calculated [8]. This is to a large extend the consequence of the occupant behaviour, which is difficult to take into account. This paper aims to investigate and document this (energy conscious) behaviour to eventually be able to leverage this for future renovation strategies.

3. METHODOLOGY

To gain insights into energy-related behaviour in historic townhouses, both long-term indoor environmental quality (IEQ) monitoring and interviews with occupants have been undertaken in several case studies in Ghent, Belgium. In five heritage townhouses, indoor and outdoor measurements of temperature, relative humidity, and carbon dioxide were conducted with high spatial resolution (aiming for one sensor per room) over a period from March 2024 to April 2025. In four of the dwellings, in-depth interviews with the occupants were conducted. These interviews explored perceived thermal comfort, the use of different spaces within the home, heating patterns, and the occupants' considerations regarding the building's energy use.

4. RESULTS

In a first step, a general analysis of the indoor temperatures is made. By calculating the average volume-weighted temperatures of the cases, a comparison with the Belgian EPC framework is possible for the winter (December-January-February) and summer (June-July-August) period. For the EPC calculations an homogeneous indoor temperature of 18°C is assumed in winter and 23°C in summer [9]. As illustrated in Figure 1, the actual volume-weighted indoor temperatures are well below the 23°C mark in summer, although no active cooling elements are present. During summer, the volume weighted temperature is also below the 18°C mark, certainly Occ_E. Some habitants indicate that the temperature setpoint of the central thermostat (located in the living room) is lower than the design temperature for the living room (bron): for Occ_A (with no winter measurements) it is 19°C, for Occ_C 17°C during the day, and for Occ_E 19.5°C.

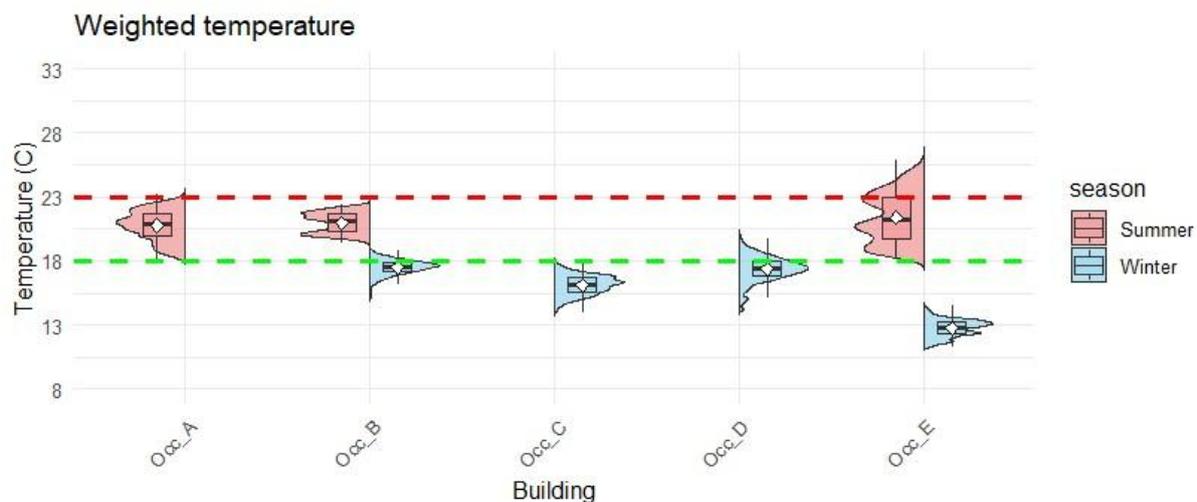


Figure.1: Distribution and boxplots of the building average volume-weighted temperature for summer and winter for the five cases.

For all cases, the habitants indicate that they are conscious about their heating behaviour and the rooms and times they heat. In general, rooms like the hallways, toilets, cellar, attic and empty rooms are not heated and in the rest of the building an intermittent heating pattern is applied, which is common. However, the bedrooms in all the investigated cases are not heated as well, which can also be observed in Figure 2. The temperature is around 15°C, indicating that no heating is used. The habitant added that the windows of the bedroom are opened (almost) every day of the year. In Occ_A and Occ_D, the bathroom is not heated as well.

In general, the habitants have the habit of only heating the rooms that are used a lot to actual live in to a relatively comfortable level, and the other rooms only when needed (by opening the radiator valves). For Occ_C, this is even more extreme, like the habitant indicate:

“We don’t care about heat. Especially the living room and the kitchen are the spaces that are heated a lot and are used a lot. In all the other rooms, the heating is of secondary importance and is been done more ad hoc”.

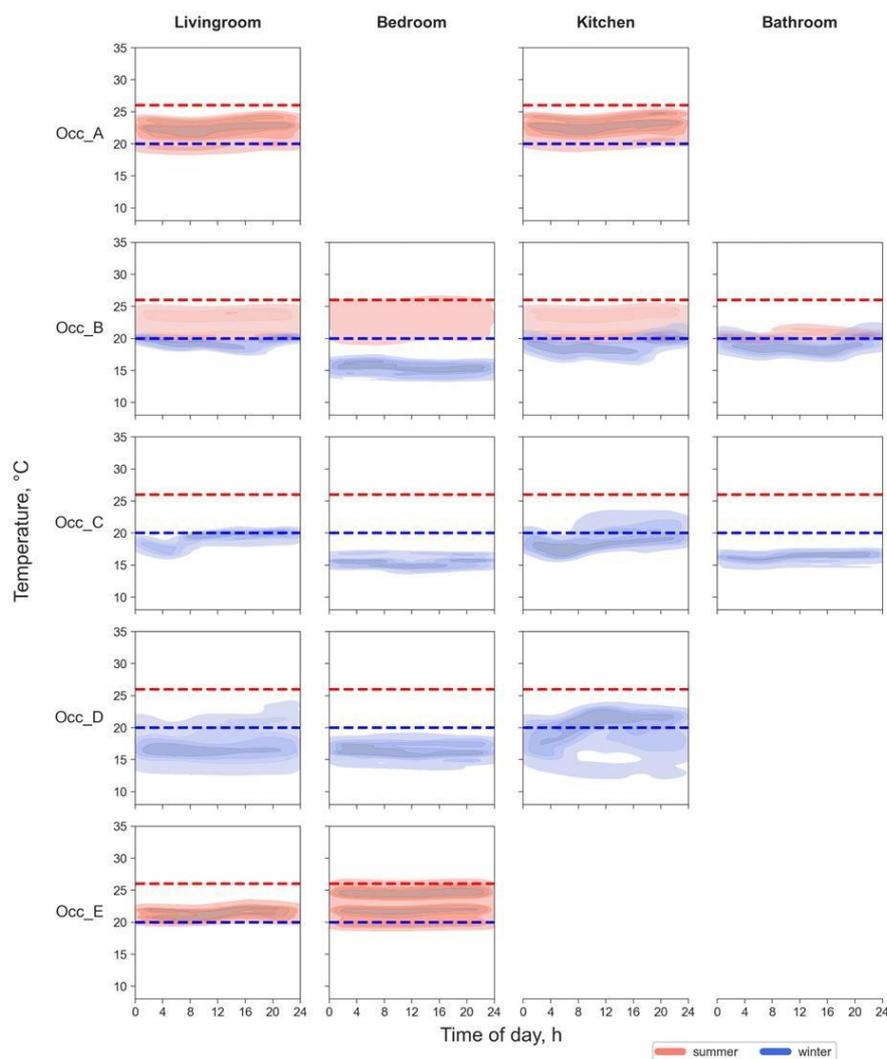


Figure 2: Indoor temperature distribution (density plot for approximately the 2.5th-97.5th percentile) as a function of the time of day for summer and winter. Empty slots mean no relevant data was available. The blue and red dotted reference lines are the minimum operative temperature for heating (20°C) and the maximum operative temperature for cooling (26°C), respectively for IEQ class II according to EN 16798 [10]

The habitant of Occ_C also mentioned that saving on the heating costs was the most important reason for their energy conscious behaviour and retrofit measures, as heating the whole

building would be too expensive. This is clearly the *prebound effect*, where the comfort demand is lower because of a high(er) comfort cost [11]. Also in the other cases, the economic incentive was present, but the habitants indicate that the ecological incentive and the protection of the heritage aspects is sometimes as important.

5. CONCLUSION

The occupants of these heritage townhouses have adopted their behaviour to the context of their homes. They tend to have lower setpoint temperatures for their thermostat than can be assumed in newly built homes, and maybe more important, they tend to only heat the spaces they need at the time they need them to be heated. The living rooms are heated to a comfortable level during the day, while the bedroom (and in some cases the bathrooms) are not heated at all. The habitants indicate that there is no problem regarding thermal comfort, while the temperature levels are lower than what is assumed in European standards. This behaviour is mainly driven by economic, ecological and heritage incentives and can be leveraged in renovation strategies.

6. ACKNOWLEDGEMENTS

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What would engage people in taking the next steps in their heat pump journey?

Theme 3, sub-topic 3b)

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Keywords: Heat decarbonisation, Ground source heat pumps, Consumer attitudes, Retrofit

Extended Abstract

As part of global efforts to tackle climate change, the UK has adopted a carbon reduction target of net zero emissions by 2050, compared to 1990 levels¹. A crucial component of the UK government's net-zero strategy, given that approximately 86% of UK households rely on gas boilers, is the decarbonisation of domestic heating and hot water². Since the majority of these homes are privately owned, the government has introduced incentives to encourage homeowners to transition to electric heating solutions, such as air and ground source heat pumps.

In 2020, the UK Government set out a policy aim of installing 600,000 heat pumps per year by 2028³. Although heat pump sales are increasing, uptake remains low, and there is scepticism about the government's ability to meet this ambitious target⁴. While there is a broad consensus on the positive role of heat pumps in decarbonising space and water heating, non-technological barriers hinder their widespread adoption⁵. These barriers include financial⁶⁻¹¹ and motivational¹² aspects of researching, procuring, installing, running, and maintaining heat pumps in homes. There can also be physical barriers^{5,11,15} to each dwelling having its own heat pump, such as not having adequate space, which would necessitate a communal approach, like a shared-loop system. A shared-loop system comprises a network of boreholes located in communal areas, such as the street, that serve multiple heat pumps, one of which is installed in each home. This indicates that while the technology to decarbonise domestic heating and hot water systems is available, understanding consumer perceptions and attitudes towards heat pumps is crucial. Aside from financial barriers, people are generally supportive of decarbonisation policies and switching to a heat pump¹³, with many individuals willing to make the change¹⁴. However, very few are actually making this transition.

Previous research has primarily concentrated on attitudes towards heat pumps and the obstacles to their adoption. Yet, there has been relatively little exploration of what might *motivate*



individuals to take action. Our study aims to understand the attitudes of UK homeowners and how they might be engaged to take the next steps in their heat pump journey, either air source, ground source, or shared-loop systems.

Our 35 participants took part in semi-structured interviews (n=15) or one of four focus groups (20 participants) that explored attitudes towards air source, ground source, and shared-loop heat pumps, perceived barriers to using them, and the information and support that would facilitate a switch from their gas boiler. Discussions were informed by the Theory of Planned Behaviour¹⁶. Interviews and focus groups were transcribed and analysed thematically¹⁷ using the research question ‘What would engage people in taking the next steps in their heat pump journey?’

We identified four themes in the data. *Frame the finance* is about how heat pumps should be framed as an investment in your home, rather than an energy-saving measure that should pay back installation costs within a reasonable time. Instead, it should be framed as a new technology that adds value to the home. Ideally, the cost – with incentives – should be broadly similar to replacing a gas boiler or offering interest-free payments. *Trust the technology* describes how most people lack knowledge and experience of heat pumps, so there needs to be readily available, easy-to-understand information from a trusted source. People want to see a heat pump in action to understand what it looks and sounds like, how well it works, and how reliable it is. They would like to talk to someone who has had one installed, rather than rely on information from salespeople. They also want to find an installer with a good reputation and feel confident that they are getting quality equipment and service. *Make it expected* describes how people would be motivated by a proactive invitation to join a local heat pump scheme for all three types of heat pumps, particularly when the invitation is from a trusted source. For shared-loop systems, they would be motivated by their neighbours expecting them to join. Finally, *Minimise disruption* describes how people would be more likely to take action if installation was quick and easy and they did not have to go without heating and hot water for several days, and for shared-loop systems, if their garden did not need digging up.

Our findings have implications for practical and communication-based strategies to increase the uptake of heat pumps.

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Understanding financial decision making in apartment buildings: Insights from Flemish apartment owners

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy renovations, financial decision-making, apartment owners

Extended abstract

OBJECTIVE

The building sector contributes significantly to global greenhouse gas emissions, making energy renovations essential to achieving climate targets [1], [2]. To accelerate renovations, the EU has introduced initiatives such as the Renovation Wave Strategy and the Energy Performance of Buildings Directive [3], [4]. However, investments in building renovation remain suboptimal, with the current annual energy renovation rate of buildings in Europe at just 1% [5], [6]. Apartment buildings are the most common building type across the EU [7], and therefore have substantial renovation potential. Although several studies have examined the factors influencing homeowners’ renovation decisions, little research has focused on the specific factors shaping financial decision-making in apartment buildings. These buildings face unique hurdles, particularly related to the collective decision-making process, where multiple co-owners must agree on energy renovations and their financing [8], [9], [10], [11]. By identifying the key factors, motivations, and concerns influencing apartment owners’ financial decisions, this study aims to fill an important knowledge gap and support the design of financing and policy instruments that are better suited to the complex dynamics of apartment co-ownership. Therefore, the objective of this study is to gain an in-depth understanding of how apartment owners make financial decisions regarding collective energy renovations in apartment buildings.

METHOD

This study employed a qualitative vignette-based interview design to gain insight into the financial decision-making processes of apartment owners, particularly in the context of energy renovations. Vignettes were used as structured prompts to ground participants’ responses in specific, relatable situations [12], [13]. Vignette-based in-depth interviews were chosen over typical semi-structured interviews, as the latter often do not allow sufficient time to uncover the reasoning behind complex decisions. The use of vignettes provided structured yet realistic



scenarios, enabling more focused questioning and a deeper exploration of how owners reason through the different stages of the decision-making process in apartment buildings [14].

The first vignette described the initiation of a collective energy renovation within a homeowner association, followed by a situation in which the participant could not personally afford the renovation costs. The subsequent three vignettes introduced possible financing solutions to this problem. These included: (1) a collective loan taken out by the homeowner association, linked to the apartment rather than the individual, and transferable to the next owner upon sale; (2) a deferred payment model in which an external organization pre-finances the renovation costs, to be repaid by the owner at the time of sale, including a small share of the value increase due to the energy renovation; and (3) a sell-and-stay arrangement where the apartment is sold to an external party who pays for the renovation, while the original owner continues living there as a tenant. The vignettes were selected based on expert interviews with professionals in the energy renovation field.

A total of 21 interviews were conducted with Flemish apartment owners ($n = 21$), including 11 owner-occupiers and 10 landlords (of whom one was also an owner-occupier). Twelve of the 21 interviews were conducted face-to-face, either in participants' houses or at the principal investigator's office, while the other nine interviews were conducted online. The interviews were carried out between March and June 2024.

RESULTS

The analysis of our interviews with apartment owners revealed three distinct themes: the importance of ownership; the role of perceived return on investment; and the need for clarity and transparency. Together, these themes offer insight into the dimensions that shape apartment owners' financial decision-making in the context of energy renovations.

1) The importance of ownership

Participants highly valued retaining ownership and control over their homes during energy renovation decisions. They strongly rejected scenarios forcing them to become tenants or rely on unfamiliar external financing, fearing loss of autonomy, security, and fairness. Familiar loans felt more acceptable, while flexibility and the freedom to compare financing options were seen as essential to protect their financial independence.

2) The role of perceived return on investment

Participants viewed homeownership as a key long-term investment, often preferred over renting or stock market investments. They rejected scenarios involving a shift to renting, fearing financial loss and missed opportunities to build equity. Energy renovations were only seen as worthwhile if they protected or enhanced property value. However, many doubted the renovation would significantly increase value, especially when competing with new-build properties. Reduced energy costs were not a major motivator - owners were skeptical about savings, and landlords wouldn't benefit directly. Financing options that linked debt to the property (not the owner) raised concerns about resale value. Participants preferred flexible financing with early repayment options or value-based repayment upon sale, as long as they expected property prices to rise.

3) The need for clarity and transparency

Apartment owners stressed the importance of clear, transparent financial information before committing to energy renovations. They wanted a full cost overview from the property manager, covering all long-term interventions to reach EPC label A, and not just separate measures. They also expected information on subsidies, multiple contractor quotes, and a clear renovation timeline.



Many preferred fixed repayment terms if financing was needed, rather than vague repayment upon sale. Profit-sharing models were viewed negatively due to uncertainty about future profits and unclear percentages. Overall, transparent contracts with clear terms - regardless of whether a financing organization was for-profit or non-profit - were considered essential for owners to feel secure.

CONCLUSION

The results of this study underscore that apartment owners' financial decision-making regarding energy renovations is complex and multifaceted, extending far beyond purely economic considerations. Central to their concerns is the deep-seated importance of ownership and the control it entails. Financing solutions that undermine the sense of ownership or the owner's autonomy can face significant resistance. Apartment owners primarily view their property as a secure long-term investment, which explains their reluctance to accept financing models that could impact the value or marketability of their real estate, or threaten to strip them of their ownership.

Crucial for the uptake of energy renovations and their associated financing is the need for complete clarity and transparency. Owners demand detailed, upfront information about total costs, potential savings, and the precise terms of any financing arrangement. Uncertainty about the financial implications, particularly with unfamiliar concepts or variable repayment models, leads to distrust and rejection.

In summary, these findings suggest that policymakers and property managers aiming to stimulate energy renovations in apartment buildings must look beyond just the technical and financial aspects. Successful implementation requires a profound understanding of the psychological and emotional attachment to ownership, the perception of investment returns, and a proactive approach to providing full financial clarity and transparency.

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Do Behavioural Biases Influence Household Investment in Energy Efficiency? Insights from a Four-Stage Discrete Choice Analysis

Theme 1, sub-topic 1a)

- “Academic contribution”
 “Policy/practice contribution”

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Keywords: Energy-efficiency investments, Behavioural biases, Discrete choice experiment, Decision-making, Tailored interventions

Extended abstract

Household investment decisions in energy-efficient technologies and retrofits are shaped by a complex interplay of economic preferences, behavioural biases, and socio-demographic factors. This study employs a discrete choice experiment (DCE) with a representative sample of 2,200 Dutch households to explore how behavioural biases—such as risk aversion, loss aversion, status quo bias, and present bias, influence energy efficiency choices. Our findings reveal that risk-averse individuals are more sensitive to costs, while loss-averse individuals strongly prefer shorter payback periods. Present bias exacerbates aversion to upfront costs, and status quo bias is mitigated by policy support. These insights enable the design of tailored policy interventions that address specific behavioural barriers, accelerating the transition to sustainable household investments in the Netherlands.

Background and Motivation

The residential sector plays a pivotal role in reducing CO₂ emissions. Despite ambitious



national targets and substantial financial incentives, the uptake of energy-efficient technologies in Dutch homes remains limited. Behavioural barriers—such as status quo bias, present bias, loss aversion, and risk aversion—are frequently cited as underlying causes of this inertia. This study aims to quantify the impact of these biases on investment decisions and identify which household segments are most affected.

Methodology

We conducted a DCE with six key attributes: upfront cost, payback time, policy support, CO₂ savings, comfort, and disruptiveness. The experimental design was informed by focus group interviews with stakeholders in the Dutch energy transition, including municipal officers and energy advisors. Participants faced six choice sets each, with two retrofit options and a status quo alternative.

Behavioural traits were elicited using incentivised survey tasks measuring present bias, risk aversion, loss aversion, and status quo bias. The choice data were analysed using a sequence of models: a Mixed Logit model (MXL) in preference space, an MXL in willingness-to-pay (WTP) space, a logistic regression on investment likelihood, and an extended MXL with interaction terms to capture behavioural influences.

Key Results

The results highlight strong heterogeneity in household preferences. In the WTP model, respondents were willing to pay €4,800 for comfort improvements and €2,640 for CO₂ savings, but demanded high compensation to accept long payback periods (€7,510) or disruptive installation processes (€1,130).

The logistic regression confirmed that age, gender, education, and financial literacy significantly affect the probability of choosing investment options. Behavioural biases—particularly present bias—were also found to reduce investment likelihood.

The behavioural model revealed statistically significant interactions between specific biases and decision attributes:

- Risk-averse individuals were more sensitive to higher costs.
- Present-biased respondents placed greater emphasis on immediate costs.
- Loss-averse individuals strongly disliked long payback periods.
- Status quo-biased participants were more responsive to the presence of policy support.

These findings suggest that even when households are financially able and technically informed, behavioural constraints can inhibit sustainable investment decisions.

Contributions

This study contributes to the growing literature on behavioural economics in energy policy by:

- Quantifying the impact of specific behavioural biases in a nationally representative setting.
- Providing monetary valuations of retrofit attributes in both general and bias-specific contexts.
- Demonstrating how tailoring interventions (e.g. framing payback periods, enhancing policy visibility) can address behavioural barriers effectively.



Policy Implications

The insights are actionable for policymakers and housing authorities. For instance, targeting present-biased individuals with short-term financial incentives, or addressing status quo bias through default policy options and advisor support, may significantly boost investment rates. Financial instruments alone may not suffice; psychological nudges and personalised engagement are crucial to close the energy efficiency gap.

Conclusion

Behavioural biases significantly shape household investment decisions in energy efficiency. By embedding behavioural indicators into a robust choice modelling framework, this study provides empirical evidence for more nuanced and effective policy design. Accelerating the residential energy transition requires not only economic support but also interventions that address how people actually decide.



Longitudinal Study of Energy Behaviours at Home

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Behaviour change, Longitudinal research, Energy saving behaviour

Extended abstract

Recent energy crisis of 2022 demonstrated the need for fast energy transition to renewable resources, as well as reduction in overall energy consumption. The bills for energy were and still are putting a big financial strain on individuals. The energy crisis is undeniably affecting the environment as well. There has been a lot of messaging coming from the government about saving energy in order to reduce the burden of paying the high electricity bills, along with messages of benefits of it for the environment. Research has been done to understand the effective ways for people to save energy at home, and there are several considerations to take into account. We know that financial motivations tend to work short-term usually until the incentive is removed while motivations to protect the environment tend to work more long term¹. Moreover, when we talk about energy saving behaviours and energy consumption in social sciences, we mainly rely on self-report measures taken at a single moment in time², which might not provide an accurate picture of the actual behaviours. In technical sciences, however, the reliance is on objective measures, such as actual units of energy consumed without taking into account social and psychological factors that can underly fluctuations in energy consumption. Study of energy saving behaviours and ultimately the behaviour of the grid would benefit from integrating psychological factors and fluctuations over time into the functioning of energy system.

This study is aimed to address several problems within the domain of energy use at home. The first problem is the lack of studies that look at energy saving measures in long-term perspective, which could provide understanding of dynamic processes underlying variability in energy consumption. That is why we propose a longitudinal study to see how the behaviours may change over time. Moreover, there is little known about possible interactions between everyday fluctuations in energy consumption within households and psychological factors that can affect it. This leads to the second aspect of the study, where we propose to pilot a novel approach to measure everyday fluctuations in energy consumption using ecological momentary assessment (EMA) principles³, where the potential changes within energy behaviours and psychological factors are measured throughout the day for a prolonged period of time.



Third problem concerns a more practical application of testing the minimum effective intervention to reduce energy use at home. The longitudinal design is supporting the testing of an intervention message for possible short- and long-term effects.

Finally, since the project under which this study is implemented (TeSoPs) is interdisciplinary in its nature, we aimed to collect longitudinal data to reflect the changes in energy behaviours to see if it can assist in predicting the behaviour of energy system. Our colleagues from the faculty of engineering are able to build models of energy grid and include the dynamic psychological individual factors to see whether there is an effect on the grid functioning and possibilities for optimisation. This has not been done before and ultimately can provide insights into how the individual behaviour can be used in optimising the functioning of the energy system, which can lead to the more efficient use of energy.

The main research questions are around the change of behaviour after the introduction of an intervention message. We are investigating whether the energy saving behaviours increase after the implementation of the intervention and the actual usage of energy decreases. We are also interested in the roles that psychological factors, such as values, norms and habits, might play in the process. Through the use of the daily measures (EMA) we wanted to explore whether the everyday behaviour fluctuations would vary in separate individuals before and after intervention, whether there is a connection between mood and temperature settings, and whether the overall pattern of energy use changed between first and second measurements.

We received 261 responses from Dutch participants whose data we can use at all time points.

The study consisted of three phases. Baseline phase consisted of a questionnaire and EMA measurements. First questionnaire was sent to participants in January 2025 and included questions about personal values; temperature preferences at home; social norms, habits, and curtailment behaviours around energy saving behaviours at home; kWh and cubic meters of gas from the latest monthly energy bill; characteristics of the house they live in and socio-demographic information. After the first questionnaire a week of EMA measures was introduced. Participants received two SMS messages per day with links to a short questionnaire, asking about the temperature their thermostat is set on, actual temperature at home, level of comfort, and mood. After that a short intervention message was introduced with participants randomised to one of three conditions: environmental message, financial message, and a control condition. Second phase was introduced a month later with a similar questionnaire to the first one and another week of EMA measures. Third phase included a questionnaire similar to first and second ones.

The results are being discussed in the context of behaviour change before and after intervention and the role of psychological factors. Recommendations are given on minimal effective interventions for policy makers and energy companies.

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Segmenting Households, Industry, and Communities to Tailor Sector Coupling Business Models

Theme 1, sub-topic 1c); Theme 4, sub-topic 4c)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Business models, User profiling, Sector Coupling, Tailoring

- INTRODUCTION

Achieving Europe’s climate neutrality by 2050 will require coordinated decarbonization across all sectors of society [1]. This requires ramping up renewable electricity generation and fostering sector coupling: the integration of energy uses in transport, buildings, and industry- to leverage technologies like EVs, PV, heat pumps, and battery storage in a unified system [1], [2]. Sector coupling entails linking renewable power with other energy sectors to create an efficient, interconnected system [3], and electrification of end uses is widely seen as a cost-effective decarbonization route across sectors[2] .

Despite the need for an integrated transition, public policies are often designed as “one-size-fits-all,” failing to account for the heterogeneous motivations and constraints of different actors. Citizens, businesses, and community energy initiatives exhibit diverse readiness levels and behavioral drivers, meaning uniform policies risk misalignment with on-the-ground realities. Recent research underlines that the effectiveness of energy interventions “depends on the diversity of the target audience,” and that simplistic segmentations (e.g. by income or usage) are insufficient to capture the complex technological and behavioral context of the energy transition [4] . To address this, a survey was designed, distributed, and responses were analyzed by applying a latent class analysis, a statistical method to identify hidden subgroups based on response patterns, across three domains: energy communities, industrial firms, and households, in Belgium. The aim is to uncover distinct archetypes in each domain, providing early insights into how different groups respond to energy transition policies and business model incentives. By identifying these archetypes, policymakers and business developers can tailor interventions (financial incentives, communication strategies, co-created programs) to better support sector coupling services and technology adoption within each group.

It should be noted that the findings presented here are preliminary. They form part of an ongoing mixed- method study in Belgium, wherein we triangulate quantitative LCA results with qualitative data (stakeholder interviews and literature) to refine our understanding of each segment. The full results, including integration of interview insights and detailed, co-designed business model archetypes for each segment, will be published in a forthcoming journal article. This extended abstract thus focuses on the initial class structures that emerged from the survey analysis, which will later be enriched by the interview layer and validated against real-world business model logic.



- METHODOLOGY

One survey per domain was developed and distributed. We collected survey data from three groups in Belgium (25 energy community members, 10 industry stakeholders, 10 households) and applied LCA to each dataset to identify latent classes. Three archetypes per domain were identified. The surveys covered factors such as investment readiness, perceived barriers, technology preferences, and trust. Given the small samples and complex behaviours, these quantitative results will later be triangulated with qualitative insights (interviews) to validate and enrich the profiles [4].

- PRELIMINARY RESULTS

Three distinct segments emerged for energy communities: EC1 large, mature initiatives with structured governance (frustrated by regulatory complexity and engaging via formal channels). EC2 small experimental pioneers (pursuing peer-to-peer microgrids and novel models, often wary of incumbent utilities). Finally EC3 grassroots cooperatives (socially motivated, deploying diverse tech, pragmatic with policy and high in community trust).

Three segments were identified among industrial firms; IND1's support gradual decarbonization via mechanisms like CfDs/PPAs). IND2s integrate sector coupling and long-term carbon neutrality into strategy, ready to invest in electrification and green hydrogen given stable rules. IND3 are smaller niche players open to pilot projects and regulatory sandboxes, more ambivalent toward rigid regulation).

The latent classes for households were: HH1 represent empowered homeowners installing PV, EVs, efficient heat pumps, driven by green values and cost savings. HH2 have low trust in providers and policy, unmotivated by incentives, little adoption of new tech. and HH3 values sustainability but hindered by external barriers like renting, policy confusion, or upfront costs.

- IMPLICATIONS FOR BUSINESS MODELS AND SECTOR COUPLING

These preliminary segments highlight how behavioural segmentation allows tailoring business models to each group's context. For instance, energy communities can be differentiated by formality and innovation-readiness: regulators might streamline rules and provide technical assistance for those belonging to EC1, offer sandbox environments and innovation grants to those identifying to EC2, and provide capacity-building support to grassroots groups, such as EC3.

Each type of community contributes to sector coupling differently, so support should be segmented accordingly.

In the industrial sector, business models can distinguish companies that need predictable long-term frameworks such as IND2. This is opposed to those that respond to targeted incentives IND1, and those that require flexibility for innovation, like archetype IND3.

For example, stable carbon pricing and infrastructure planning will enable IND2 to invest in electrifying processes and deploying green hydrogen, while IND3 might benefit from pilot programs and partnerships to test new models.

For household-level, segmentation suggests that programs be tailored to different levels of agency and trust. HH1 can be tapped as early adopters. For example, incentivized to participate in demand response or vehicle-to-grid programs that enhance grid flexibility. HH2 require rebuilding trust and lowering complexity: business models and policies should provide simpler incentives and use trusted local outreach to demonstrate the benefits of technologies like heat pumps or EVs. The HH3 points to the need for systemic solutions (e.g. landlord-tenant incentives, community solar, shared resources) to enable their participation despite structural hurdles.



Tailoring residential programs in this way can accelerate the uptake of distributed assets (EVs, PV, batteries, heat pumps) across all segments.

Another cross-cutting insight is the role of trust, perceived control, and stakeholder engagement. These “softer” factors vary considerably between the found groups. This underscores that successful incentive design is not only about the economic value proposition, but also about communication and design. Engaging stakeholders in the design of policy measures and new business models can improve receptivity. For example, co-designed interventions tend to achieve greater buy-in and effectiveness than top-down measures [5]. Our ongoing interviews with participants from each segment aim to delve deeper into these attitudinal dimensions, ensuring that the final intervention strategies and tailored business models are grounded in the lived experiences of the stakeholders themselves. Early evidence shows that bringing diverse perspectives can broaden business model innovation with system-level thinking [5]. Tools such as a recent energy community business model typology enable stakeholders to configure tailor-made models for their context [6]. Building on such insights, our next phase will develop segment-specific business model for each of the found archetypes.

- CONCLUSION

Latent class analysis has provided a data-driven map of hidden archetypes within three stakeholder groups. These preliminary segments reveal that different actors will embrace the sector coupling innovations in different ways. A nuanced understanding of these classes allows for more precise and inclusive business model design and development: rather than treating all actors as monolithic, business developers can craft segmented incentives, communication, and support programs that resonate with each group’s motivations and constraints. This approach can increase the uptake of critical technologies (from EVs and heat pumps in homes to multi-vector integration in industry) by aligning policy tools with stakeholders, thereby accelerating progress toward decarbonization.

These findings are preliminary; future work will integrate qualitative insights and co-designed business models. However, even at this early stage the segmentation provides immediate value for business model design and stakeholder engagement. By acknowledging heterogeneity and targeting business models accordingly, public authorities and energy providers can foster a more inclusive and effective energy transition.

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Risk perceptions of direct air capture: experimental findings on moral hazard from the United States and Germany

Theme 3, sub-topic 3b)

- “Academic contribution”
- “Policy/practice contribution”

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Keywords: direct air capture, moral hazard, tampering with nature, public acceptance

Extended abstract

Motivation

Technologies to remove carbon dioxide from the atmosphere are increasingly seen as essential for reaching current targets to limit global warming [1]. Different options exist to remove carbon dioxide, with varying benefits and drawbacks, such as removal potential and environmental impacts [2],[3]. Direct air capture (DAC) is one prominent option with a theoretically large removal potential, as it relies on a chemical process to capture carbon dioxide directly from the ambient air through large filters. The captured carbon can then be permanently stored in underground sites, which creates negative emissions. For a rapid upscaling of carbon dioxide removal technologies such as DAC, public support is crucial. However, facilitating public acceptance requires an understanding of the risk perceptions related to the use of these technologies [4].

Past research has examined a potential moral hazard as one central concern related to the public acceptance of DAC, whereby the availability of carbon dioxide removal technologies might be perceived as an insurance against the failure of other mitigation options [5],[6]. Thereby, the use of these technologies might bear the risk of decreasing commitments to reduce carbon dioxide emissions through other means. If the public perceives such a hazard, this might lead to decreased public acceptance of their use. However, empirical studies on moral hazard have yielded conflicting results regarding the consequences for mitigation efforts and acceptance of carbon dioxide removal technologies due to this risk [7],[8],[9],[10]. We present two experimental studies to investigate how the framing of DAC as a moral hazard influences public support of the technology. The two studies build on each other by first examining how different framings of moral hazard affect public acceptance, and then taking a broader perspective by comparing a moral hazard frame to a



different frame that highlights tampering with nature as an alternative risk of using DAC.

Study 1

Study 1 explores a novel way of manipulating moral hazard in terms of the necessity and temporality of carbon removal [11]. Necessity communicates DAC as either essential or as dependent on current mitigation efforts, and we expected that an essential frame would increase public support whereas a dependent frame would decrease support. Temporality emphasizes the removal of either past emissions or future emissions as they are released from burning fossil fuels. We expected that highlighting the removal of past emissions should increase public support (as these emissions cannot be mitigated anymore), and vice versa, relative to a control group.

The study used a 3 (necessity frame: essential, dependent, control condition) x 3 (temporality frame: past emissions, future emissions, control condition) factorial between-subjects experimental design to analyse the effects of four frames related to moral hazard. Two frames—namely DAC being dependent on other mitigation efforts and removing future emissions—present a moral hazard, whereas the other two frames do not constitute a moral hazard. We analysed the effects of these frames on the general support for DAC use on a large scale in the United States. Participants were recruited using Google Survey to generate a representative sample of the internet-using population in the United States. 2,891 participants completed the survey (women: 41%, median age group: 45-54 years). The responses were weighted using inferred sample weights to reflect the general population of the United States.

Weighted linear regression modelling showed that the different frames only had weak effects on public support. In line with predictions, highlighting DAC removing future emissions lowered support, but highlighting DAC being dependent on current mitigation efforts had no significant negative effect on support. Moreover, describing DAC as essential or emphasizing the removal of past emissions did not increase support, suggesting that public support is relatively stable across different moral hazard frames.

Study 2

Study 2 builds on the first study by again highlighting that the use of DAC could pose a moral hazard. We then compare the effects of this frame with an alternative frame that has been examined in previous research, namely the risk of tampering with nature [12]. Tampering with nature refers to the risk that the use of DAC, in particular when combined with subsequent permanent storage of carbon dioxide underground could have negative impacts on the nature and the local environment. We expected that both a moral hazard frame and a tampering with nature frame should decrease public acceptance of DAC relative to a control group. Study 2 also provided more insights into potential mechanisms and boundary conditions of these framing effects, by studying perceptions of a moral hazard and tampering with nature as mediators, and biospheric and egoistic values as moderators.

The study used a between-subjects design with three experimental groups: a moral hazard condition that emphasized the concern that the possibility of using DAC will lead to reduced efforts in emission reduction strategies, a tampering with nature condition that emphasized the concern that the use of DAC can have a negative impact on nature, and a control condition that described DAC in neutral terms. We examined the effects of these frames on the general support for DAC use in Germany. This study used a convenience sample



generated via social media and snowball sampling. A total of 179 participants completed the study (women: 42%, median age group: 18-24 years). DAC support, perceptions of moral hazard, tampering with nature, and biospheric and egoistic values were measured as multi-item scales.

Results showed a slight decrease in public support for DAC when a risk of tampering with nature was presented, though this effect was not statistically significant. Highlighting a moral hazard did not affect support. However, biospheric and egoistic values moderated the way in which the frames affected perceptions of moral hazard and tampering with nature, which were in turn related to DAC support. This suggests that different frames of DAC use may indirectly affect public support among some groups of the population, conditional on their personal values.

Conclusion

We experimentally test different framings of moral hazard related to the public acceptance of direct air capture. Across two studies in the United States and Germany, we find very limited effects of moral hazard frames on public support. While highlighting this risk may modestly influence support among subgroups (based on personal values), our findings suggest that public support is largely insensitive to simple moral hazard frames. While this might indicate an optimistic outlook for future policies to upscale DAC, future research could examine if longer or more intensive exposures to moral hazard frames have different effects on public support.

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A personalized app for sustainability-focused behavior change

Theme 1, sub-topic 1a) and 1b)

- “Academic contribution”
- “Policy/practice contribution”

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Keywords: behavior change, smartphone app, personalization, personal values, sustainable behavior, energy savings

Extended abstract

Capgemini Engineering is developing a mobile application which helps users adopt environmentally friendly habits in their daily lives by offering support that is tailored to them.

In navigating the current climate and environmental crisis and its dramatic consequences, understanding human behaviors is a key element¹. We believe that understanding how to encourage pro-environmental behaviors is of major importance for a more sustainable future².

Among the broad category of pro-environmental behaviors^{3,4}, energy saving is of particular interest: electricity and heat account for 32.2% of greenhouse gas emissions worldwide in 2021⁵ and have strong environmental impacts through mining, waste disposal, large infrastructure, etc.⁶ In addition, households are directly responsible for a large part of energy consumption (28% in France⁷) and are therefore a relevant target for interventions aiming to curb energy use.

Interventions targeting individuals have had promising results⁸, but also face barriers such as low retention rates or inadequacy with the target population^{9–11}. Smartphone apps are a promising avenue for such interventions^{12–14}: they allow to target specific populations with minimal infrastructure; they can help users navigate real-life situations and provide relevant feedback. Studies have also found that personalized experience can make interventions more successful^{13,15}, and smartphone apps are a powerful tool for this. Personalisation encompasses a broad range of practices: what is being personalised and along which individual characteristics can vary greatly^{15–18}. Despite a rich literature on personalised apps for behavior change, research on personalized apps for sustainability has been scarce, mostly focusing on transportation^{19,20}.

Following these insights, we are currently developing an app which relies on users' values and past behaviors to offer them personalised guidance in reducing their energy consumption, as well as encouraging other sustainable behaviors. Indeed, past behaviors are often the best predictors of future behaviors, and values also play a strong role in sustainable behaviors²¹.



The general experience of users in the mobile app is designed to maximize user engagement and retention, in order to maximize its impact on users' environmental footprint. Users pledge to adopt a daily habit for a few weeks ("challenge"), and they confirm daily that they have performed the habit. They can also see a tally of the amount of CO₂ they have saved through challenges. Specific commitment can help shift behavior²², as can introducing reminder cues and feedback²³.

We then surveyed 142 employees of Capgemini in France about their sustainable habits along 5 categories (transportation, buying, water use, energy use, waste) and about their values (hedonism, environment, social prestige, etc.). We identified 3 clusters, and a set of 6 questions allowing to reliably sort participants into these clusters.

Building on this basis, we offer users an experience that is personalized along two axes: the difficulty of challenges is tailored to past behavior (declared in the onboarding quiz, then based on past challenges), and the content of the challenge is tailored to personal values.

Our first use case are energy-saving behaviors, which are both environmentally and financially motivating. Moreover, widespread deployment of Linky smart meters in France allows users to share detailed energy consumption data, enabling accurate, real-time evaluation of app impact.

This project offers a concrete example of how behavioral science, personalization, and digital technology can be combined to promote sustainable practices at scale. It will provide an opportunity to assess the real-world effectiveness of tailored behavioral interventions, while delivering an adaptable tool to foster sustainability in organizational settings and beyond.

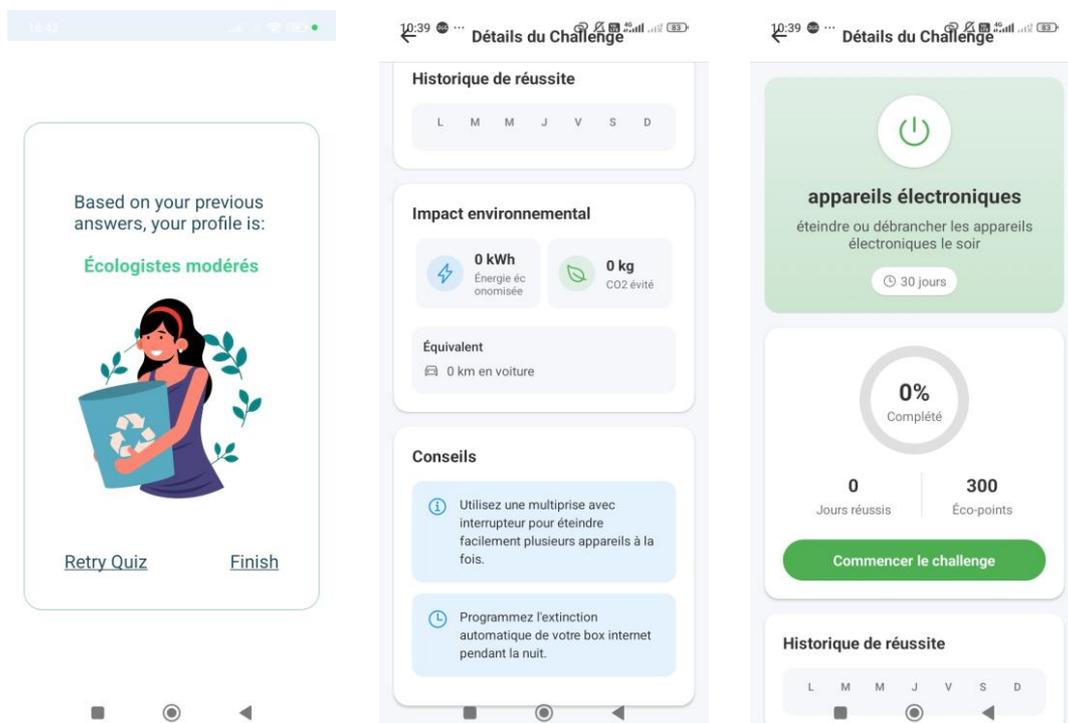


Figure 45: Visuals from the app. From left to right: personalization quiz result, home page, challenge page

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TRENDS IN BEHAVIORAL ENERGY EFFICIENCY PROGRAMS IN THE UNITED STATES AND CANADA

Theme 1, sub-topic 1a)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy efficiency, Behavior, Utility, Program, United States, Canada

Extended abstract

INTRODUCTION

Leveraging behavioral science insights to boost energy savings and other benefits from energy efficiency efforts is a tactic that is gaining momentum in the utility industry. Information sharing of utility program details and learnings is key to further fueling this growth. For the past 15 years, the Consortium for Energy Efficiency (CEE) has inventoried and documented behavioral efforts that members are running across the United States and Canada to provide them with the opportunity to improve their programs by learning what their peers are working on. The 2024 Behavior Program Summary documents 52 programs spanning a variety of program types (Home Energy Reports¹, Strategic Energy Management, Demand Response, Community Based/Social Marketing) and sectors (residential, commercial, and industrial). The database provides valuable details on program design, evaluation, and overarching lessons learned with a focus on targeted behaviors and social science techniques used. We propose a presentation sharing findings from the 2024 Behavior Program Summary, touching on key successes regarding connected and two-way feedback technology, adjusting evaluation methods by increasing frequency or changing procedures, and proposed solutions to challenges around program design and engagement. This presentation will serve the purpose of informing and enhancing the efficacy of future behavioral-based programs.

BACKGROUND ON THE CONSORTIUM FOR ENERGY EFFICIENCY

CEE is an award-winning consortium of investor-owned or municipal utilities, state or provincial energy offices, government agencies, and nonutility program administrators across the U.S. and Canada. Members work to unify program approaches across jurisdictions to increase the success of efficiency in markets. A subset of CEE members funds the Center for Equity and Energy Behavior—a project launched in 2022 to support energy utilities as they strive to ensure that customers benefit more equitably from present and future demand side management programs. The Center is where program administrators align on common equity and behavior objectives, touching on a host of elements central to integrated demand side management (IDSM), including affordability, energy savings, and equity.

CEE BEHAVIOR PROGRAM SUMMARY OVERVIEW

²⁶ A Home Energy Report (HER) documents home energy use and costs in a standardized format in order to compare these metrics across households and motivate customers to use less energy. It also provides solutions to improve energy efficiency in the home [3].



Purpose

The Behavior Program Summary is an inventory of behavior-based programs offered by CEE members that serves to provide a high-level overview of members' recent work to leverage behavioral science techniques and facilitate information sharing among utilities. The database highlights specifics of program design, implementation, evaluation, and lessons learned, with an emphasis on program goals and behavioral strategies to achieve them. The primary goal of this publication is to increase both the quantity and quality of behavioral-based utility programs available to ratepayers in the United States and Canada.

Methods and Related Caveats

The information collected in the program summary was gathered through direct communication between CEE staff and member organizations via an online survey and follow ups to glean additional program details. The survey process for the Behavior Program Summary typically begins in late January and runs through the spring or summer. In 2023, the survey was sent to 51 CEE members. After the survey is fielded, CEE staff typically follow up with member organizations throughout a two-month period in July and August. While no CEE member organization is required to respond, the survey is sent to all member organizations who have indicated their interest or expertise in behavior work to CEE. Participating organizations can enter details for up to five programs.

Data Collected

The 2024 Behavior Program Summary documents 52 programs from 23 member organisations across 17 U.S. states and two Canadian provinces. There are 22 Home Energy Reports (HERs), 5 community-based / social marketing efforts, 5 Strategic Energy Management (SEM programs), 4 demand response / load flexibility efforts, 1 educational effort, 2 peak time savings and 13 additional unspecified efforts included in the inventory.

For each of these efforts, the Behavior Program Summary documents specific details regarding program design, evaluation, goals and takeaways, with an overarching focus on the use of social science insights. Information on program design includes a brief program description, program type, duration, and sector categorization (residential, commercial, or industrial). The summary also captures program goals, strategies used to achieve these, as well as overall targeted behaviors leveraged and social science techniques used. Further behavior-specific data includes behavioral techniques used in load management, as well as customer engagement technologies or platforms utilized (e.g. connected and two-way feedback technology). Evaluation data on evaluation design, metrics used to measure success (e.g. energy savings, customer satisfaction, percent of participants reached, or adoption level of efficient practices), methods of determining persistence, and duration of persistence information is also included. The summary highlights challenges, outcomes and lessons learned as well.

CONCLUSIONS

A number of key takeaways emerged from the 2024 Behavior Program Summary. Of the 52 programs shared in the summary, over half were residential. Behavioral efforts have historically skewed residential, and the authors note that there is significant potential to leverage behavior and tap into additional savings in the commercial and industrial sectors—this finding has sparked work at CEE on strategies to implement social science in the income-qualified multifamily space. Next, HER programs continue to be a common model, making up 41% of all efforts included in the program summary. However, driving customer engagement and education continues to be a challenge, particularly in programs like HERs where the average consumer's understanding of (and interest in) energy efficiency is often overestimated.



Updating messaging content and aesthetics and investing in relationship-building early on were two strategies that were helpful in engaging customers and addressing these misunderstandings. Further, several programs reported success switching to online and virtual programs in allowing for larger-scale dissemination, as well as leveraging two-way feedback and connected technology to encourage reduced energy consumption. Regarding program evaluation, programs also experienced improvements in customer satisfaction and energy savings when they adjusted their methods of evaluation, either by increasing their frequency or changing specific procedures. They also discussed program design in general as a challenge, particularly when an existing program needed to be adapted in response to changing demographics, regulations, or goals.

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Empowering Local Governments for Carbon Neutrality: A Decision Support Tool for Strategic Planning

Theme 6, sub-topic 6b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Decision Support Tool, Local Government, Smart Meter Data, Decarbonisation Scenarios

Extended abstract

1. BACKGROUND AND OBJECTIVES

Japan has set a national goal of achieving carbon neutrality (CN) by 2050 [1]. However, initiatives in the residential and commercial sectors are largely left to individual voluntary actions, resulting in limited effectiveness. While national-level strategies exist, the implementation of practical measures often depends on the ability of local governments to understand regional conditions, plan appropriate responses, and engage local stakeholders effectively.

Local governments, which are closer to end-users and communities, are in a unique position to drive behavioural change and implement region-specific solutions [2][3]. Despite this potential, many municipalities face institutional, technical, and informational barriers to initiating robust decarbonization strategies. In particular, the lack of access to structured data



and decisionmaking tools has hindered their ability to formulate and communicate climate action plans. To address these challenges, our research team has developed a prototype decision support tool as part of the Local Energy Platform (LEPF) initiative. The tool aims to enable municipalities to systematically understand their current energy and carbon profiles, explore and evaluate multiple decarbonization scenarios, and improve communication with policymakers, citizens, and other stakeholders.

TOOL CONCEPT AND STRUCTURE

The tool is structured to support the initial “Plan” stage of the PDCA (Plan-Do-Check-Act) cycle and is designed for simplicity, transparency, and flexibility. It is composed of two core modules:

- A Static Slide Generator that automatically produces a sequence of slides showing the energy consumption status, scenario assumptions, and emissions projections for a selected municipality. This module compiles various data sources into visual narratives to support internal planning and public communication.
- A Dynamic GUI Tool that allows users to modify parameters such as household electrification rates, PV adoption levels, energy efficiency improvements, and behavioural factors. The tool immediately reflects changes in energy demand and emissions outcomes, enabling interactive scenario exploration.

Figure 1 illustrates the system architecture and information flow of the tool. The web-based interface enhances accessibility, allowing municipal staff to select their region and download presentation-ready documents without specialized training.

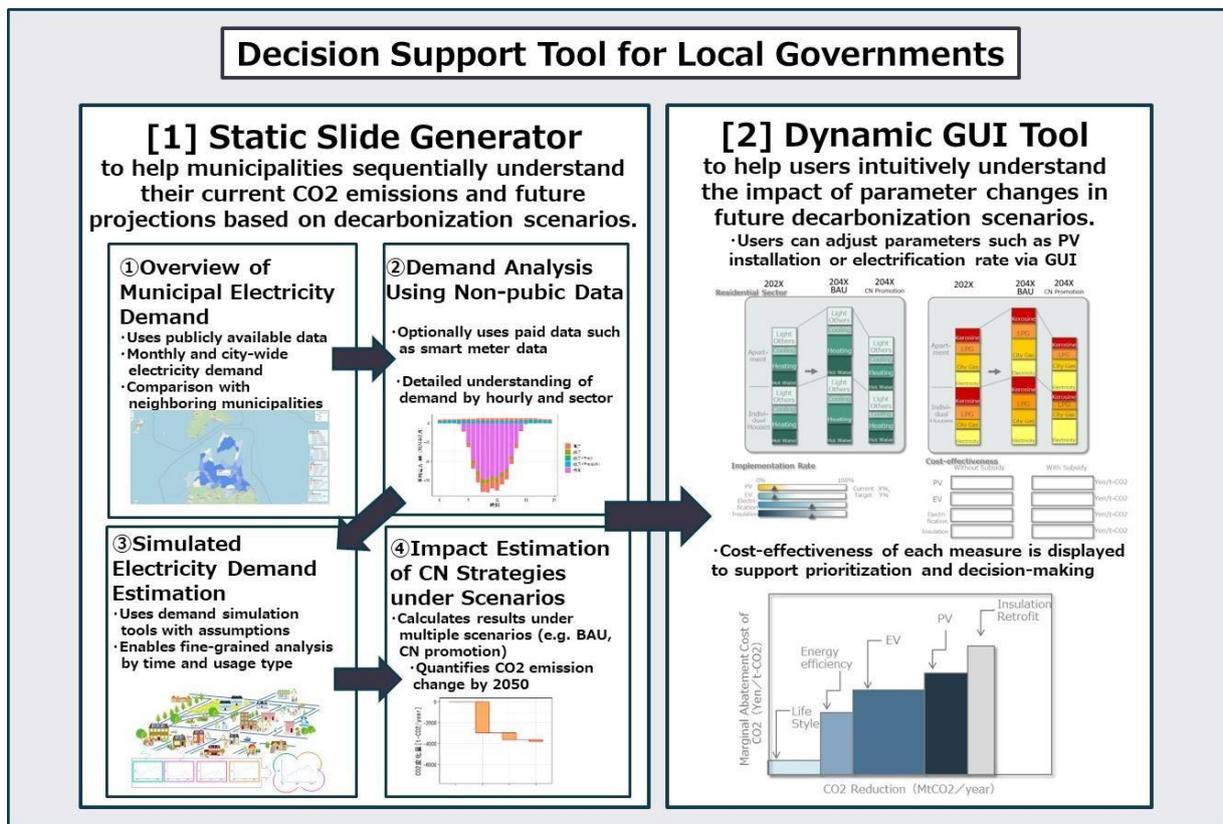


Figure 1 Overview of the decision support tool architecture and workflow

METHODOLOGY AND DATA SOURCES

The static module integrates multiple layers of data to support evidence-based scenario development:

- Electricity Statistics published by Japan’s Agency for Natural Resources and Energy, providing monthly electricity demand by voltage class and consumer type at the municipal level [4].
- Census Data from the Statistics Bureau of Japan, including household counts, population structure, and building characteristics [5].
- Smart Meter Data (where available) providing 30-minute interval electricity demand and enabling detailed analysis of load curves and peak demand characteristics [6].
- GIS and Demographic Forecasts, allowing for the estimation of demand density and population trends at the neighbourhood level.

As a pilot application, the tool was applied to Sosa City, Chiba Prefecture. Figure 2 presents the monthly electricity demand trends using public data sources. Figure 3 compares Sosa with neighbouring municipalities on consumption per square kilometre. Figure 4 shows disaggregated hourly demand profiles using smart meter data, highlighting differences between residential and non-residential usage patterns. Sosa City has already experienced widespread deployment of PV systems, resulting in a significant amount of reverse power flow in daytime.

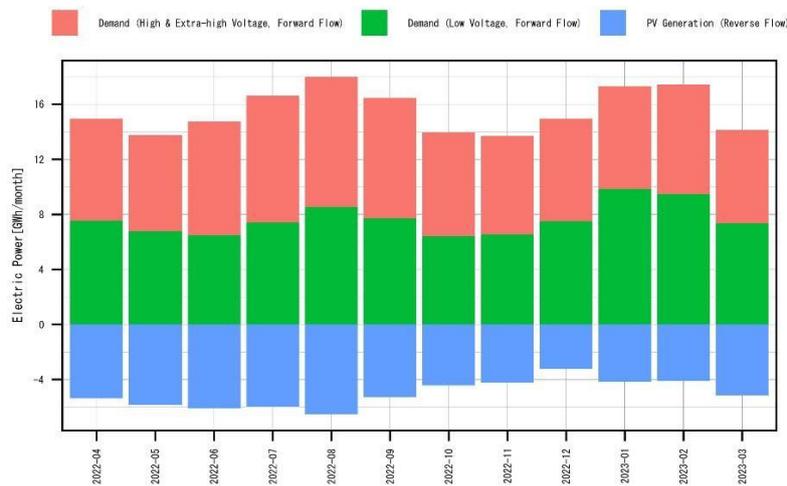


Figure 2 Monthly electricity demand trends in Sosa City based on public statistics (2020)

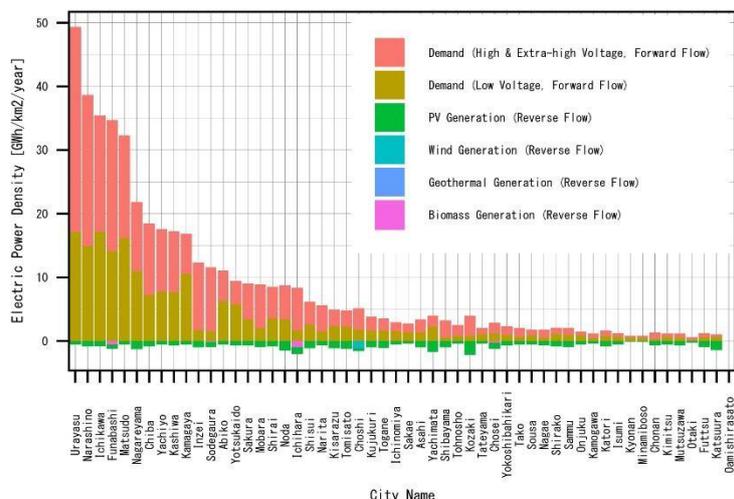


Figure 3 Comparison of electricity consumption per square kilometre across municipalities

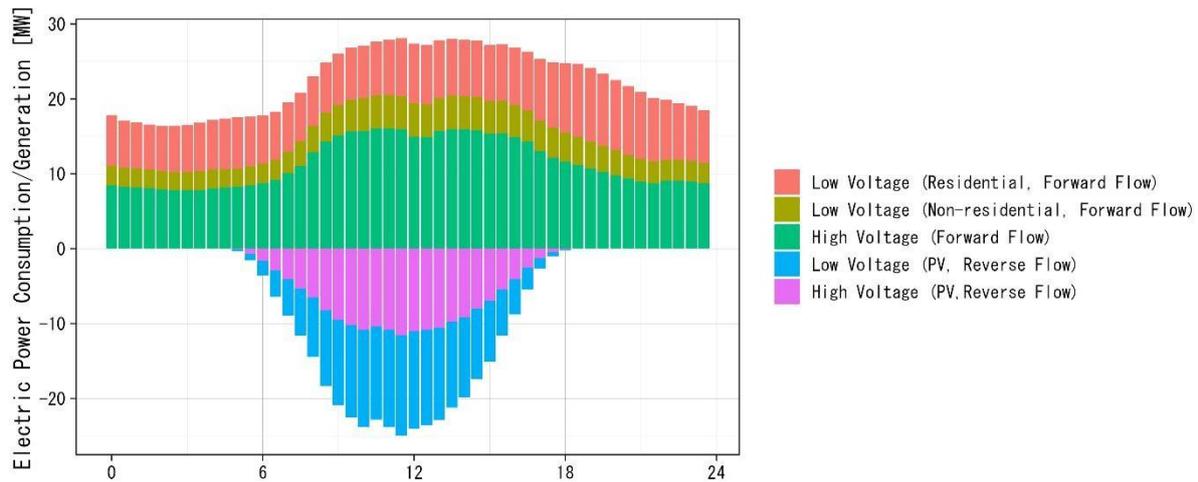


Figure 4 Hourly electricity load curves at August, 2022 in Sosa City using smart meter data

SPATIAL VISUALIZATION OF BASELINE ENERGY DEMAND

To enhance planning capabilities, the tool integrates spatial analysis features. Figure 5 maps estimated electricity demand density by neighbourhood within Sosa City using simulation models [7][8]. These spatial insights can guide municipalities in prioritizing regions for targeted retrofitting programs, energy efficiency campaigns, or infrastructure upgrades.

Additionally, spatial visualization supports participatory processes by providing intuitive and location-specific information for public workshops and community meetings. This functionality has proven especially valuable for municipalities seeking to localize climate strategies in a way that resonates with their communities.

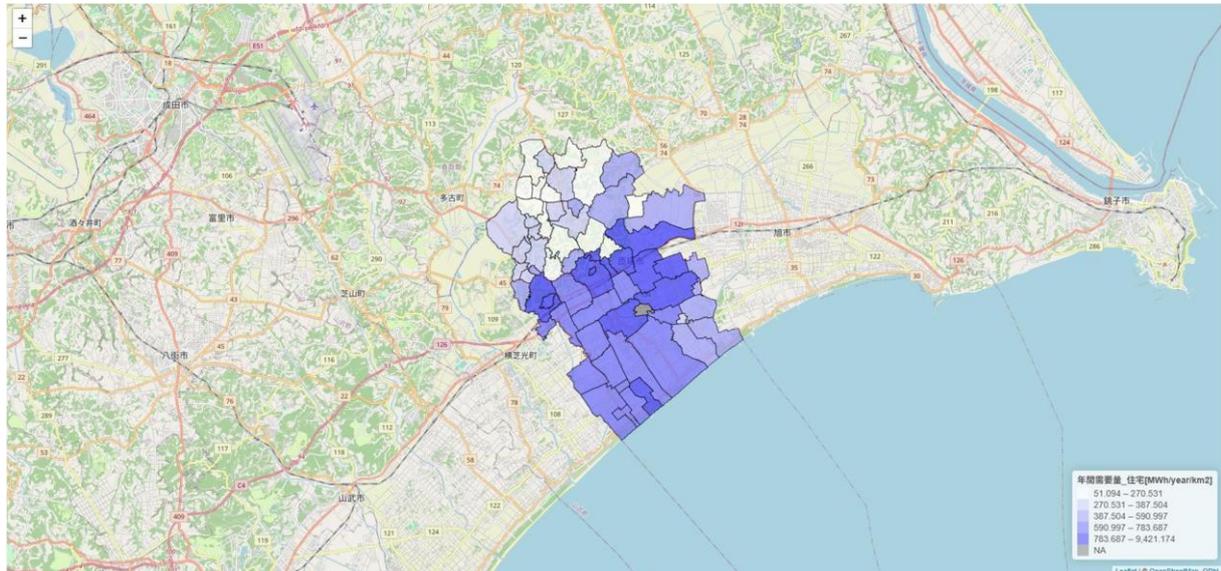


Figure 5 Simulated electricity demand density for residential buildings by neighbourhood in Sosa City (2020)

SCENARIO ANALYSIS AND KEY RESULTS

We designed two decarbonization scenarios for the residential sector with the goal of evaluating achievable CO₂ reductions under different intervention combinations. These scenarios are:

- Business-as-Usual (BAU): Assumes current trends continue without significant new interventions.

- CN Promotion: Reflects accelerated action in electrification, insulation, energy efficiency of appliances, and behavioural change.

The following measures were analysed:

- Full electrification of space heating, hot water supply, and cooking equipment.
- Improvement of thermal insulation in existing residential buildings through retrofitting.
- Adoption of high-efficiency appliances, especially for air conditioning.
- Behavioural changes, such as temperature setting adjustments.

Using the simulation engine embedded in the tool, we modelled energy demand and CO₂ emissions from 2020 to 2050. Inputs included future population and household projections [9], PV installation rates, CO₂ intensity of electricity, and technology efficiency gains.

Figure 6 presents the comparative results of CO₂ emissions under the BAU and CN Promotion scenarios. This projection accounts for population decline driven by low birthrates and demographic aging society, with the number of households in 2050 expected to fall 68% of the 2020 level. Notably, under the CN Promotion scenario, CO₂ emissions from the residential sector can be reduced to approximately 55% of BAU levels by 2050. Figure 7 breaks down the contribution of each measure (e.g., PV installation, electrification, insulation, behavioural change) to overall CO₂ reductions.

While technological interventions showed significant potential, the scenarios also confirmed that behavioural change and citizen engagement are essential to realizing meaningful decarbonization. This highlights the importance of providing transparent and understandable materials to facilitate local decision-making.

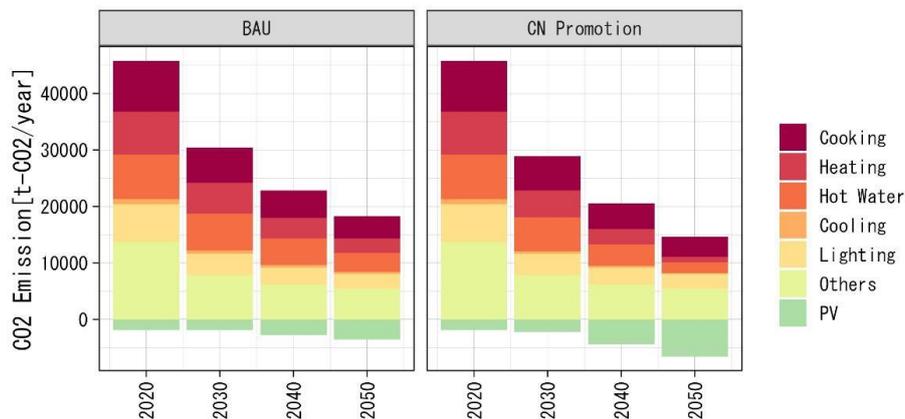


Figure 6 Projected CO₂ emissions under Business-as-Usual and Ambitious scenarios (2020–2050)



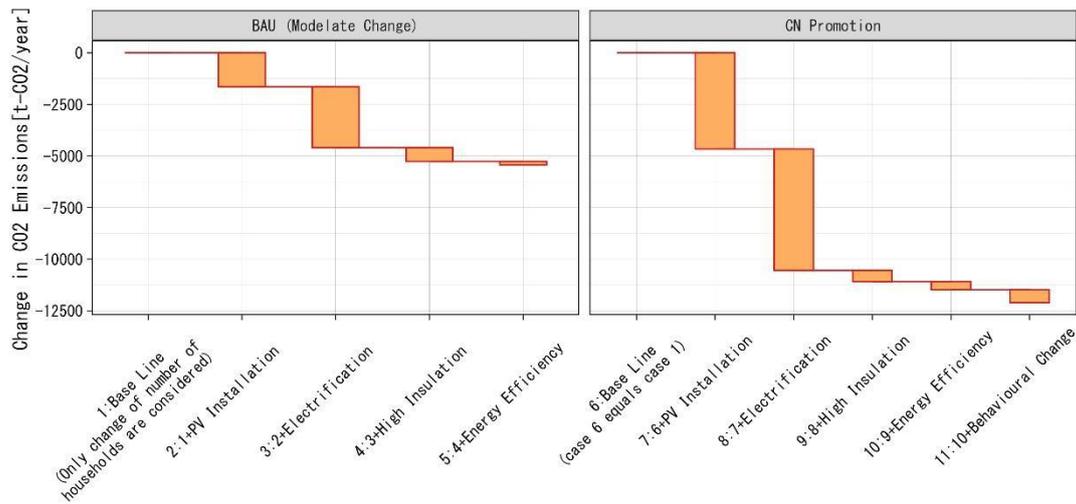


Figure 7 Contribution of individual measures to CO₂ emissions reduction by 2050

STAKEHOLDER FEEDBACK AND POLICY IMPLICATIONS

Through interviews with multiple municipalities, we collected feedback on the tool (particularly the static slide modules) and its expected policy utility. The following key points were highlighted:

- **Data Privacy and Accessibility:** Smart meter data are useful but often limited due to privacy regulations and data availability; hence, simulation-based modelling is essential for broader applicability.
- **Expectation of Practical Use:** Local governments emphasized the importance of preparing proposals that include monetary indicators, in order to support residents in making autonomous and optimal decisions. The ability of the tool to present cost-effective scenarios was seen as particularly valuable for awareness-raising and subsidy design.
- **Need for Periodic Updates:** Municipalities pointed out the value of incorporating updated datasets annually, enabling them to monitor changes and track progress in climate policy. These findings suggest that a user-friendly, transparent, and evidence-based planning tool can bridge the gap between high-level climate targets and on-the-ground actions.

CONCLUSIONS AND FUTURE WORK

The proposed decision support tool offers a scalable and adaptable platform for municipalities to plan, simulate, and communicate decarbonization strategies. By combining national datasets, local simulations, and intuitive visual outputs, the tool empowers municipalities to take proactive steps toward climate neutrality.

Future development will focus on:

- Expanding coverage to commercial and transportation sectors
- Incorporating detailed financial and cost-benefit analyses

Moreover, we see strong potential for the tool to serve not only as a planning platform but also as a communication and educational resource. By translating complex data and policy scenarios into visual formats, the tool can support informed dialogue with citizens and enhance the capacity of local government staff and related stakeholders.

We believe this approach contributes meaningfully to aligning local actions with national and global carbon neutrality goals and offers a replicable model for community-driven climate governance.



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Energy and Transport Poverty in Finnish Rural Areas

Theme 2, sub-topic 2b)

“Academic contribution”

“Policy/practice contribution”

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Keywords: Energy poverty, Transport poverty, Rural areas, Finland

Extended abstract

1. INTRODUCTION

Energy and transport poverty have significant impacts on individuals and society. During the recent years, the rising cost of energy, fuel and other living costs have increased economic challenges of households. The characteristics of rural areas even intensify the difficulties. In rural areas, the risk of energy poverty is increased by factors related to regional development, such population losses, deteriorating living standards, falling housing prices, and accumulating societal disadvantage [1]. Rural areas are also more vulnerable to long-term energy poverty than urban areas, as dropping value of houses reduces opportunities for energy investments and access to credit [1].

Rural areas face challenges organizing mobility services due to long distances, sparse population and narrow flows of people [2]. Thus, mobility in rural areas relies mostly on personal cars. Rising cost of fuel affects the mobility of rural residents remarkably, as distances are long. In addition, demographic changes, especially the growing number of elderly people, will further complicate matters as fewer elderly have driver’s licences and they need more transport services.

This paper is based on a study co-funded by The Ministry of Agriculture and Forestry of Finland. The study aimed to identify how energy and transport poverty are manifested in rural areas and define actions on various levels to reduce them. Energy poverty refers to a situation in which households are unable to access essential energy services, such as adequate warmth through heating, cooling, lighting, and energy to power appliances [3]. Transport poverty refers to individuals’ and households’ inability or difficulty to meet the costs transport, or their lack of or limited access to reach essential services [3, 4].



This paper focuses on the survey and interview results of rural residents identifying how energy and transport poverty are manifested in Finnish rural households.

2. METHODOLOGY

In late 2023 and early 2024, a nationwide online survey was conducted to collect research data from adults living in rural areas of Finland. There were 742 survey respondents. They could volunteer for interviews, and multiple criteria was used to select the interviewees, such as geographical coverage, used heating type, and car-ownership. Ten interviews were conducted by phone in spring 2024.

3. RESULTS

Two-thirds (67%) of the respondents lived in sparsely populated areas, about a quarter (23%) in rural villages, and one-tenth in urban-like areas. The respondents were mostly (78%) working-age adults (18-64 years). One-person households accounted for one-fifth of the respondents and a majority (64%) represented two-person households. One-third of the respondent households had minors, mostly one or two. More than half (55%) of the respondents were employed, 14% were self-employed and a quarter (24%) were retired. Respondents were quite evenly distributed across different income levels.

3.1. Energy poverty

The majority of survey respondents (89%) had owner-occupied homes. The respondents lived in big houses; only 9% had less than three rooms in the house, and nearly half (45%) had 5 or more rooms. The most common heating modes were wood (71%), direct electricity (44%) and heating air-conditioner (26%) (it was possible to choose maximum two options). Over a fourth (27%) stated that a member of the household has reduced functional capacity affecting heating work (e.g. making and carrying firewood).

Regarding household electricity, nearly one-third (29%) reported no challenges and continued life as usual despite increased electricity prices. The majority (44%) reduced electricity consumption and managed to pay their bills. However, over a quarter faced real problems: 23% reduced consumption but still struggled to pay bills, and 4% experienced financial difficulties due to electricity bills.

Regarding households' energy challenges (Figure 1), 13% had accumulated payment arrears in the past 12 months, meaning they could not pay household utility bills (e.g., heating, electricity, water) on time. One-fifth could not afford to keep their home warm enough, and 18% had insufficient heating systems. Nearly one-third (32%) felt their home was not adequately insulated against the cold. Less than one-fifth (18%) had structural issues such as leaking roofs, damp walls or floors, or rotting window frames or floors.



Your household's energy challenges

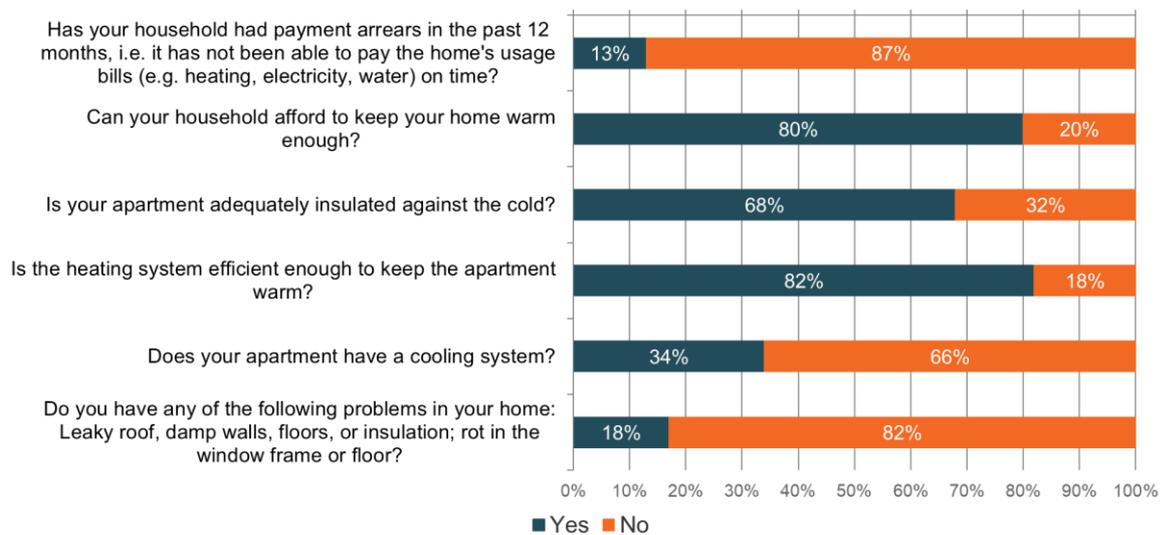


Figure 1. Rural households' energy challenges.

The most common ways to reduce energy consumption were increasing wood use (70%), reducing overall electricity use (53%), and carefully planning electricity usage moments (44%). Nearly one-third (29%) cut other spending due to electricity bills. One-fifth invested in energy efficiency (e.g., heating, insulation). Less than 10% did not reduce energy consumption.

3.2. Transport poverty

In the context of households' mobility, only 3% of the respondents did not have a commissioned vehicle. The most common (47%) was to have two commissioned vehicles in the household. The main transport poverty related challenges were lack of public transport (54%) and high mobility costs. Over half of the respondent (53%) stated that there is no alternative to car use, which is not affordable as before. Majority (59%) considered that mobility to daily needs is not possible at a reasonable cost. Due to the car ownership, 11% had difficulties with other living expenses (e.g. rent, energy bill, food). Lack of sufficiently safe travel options was reported by 32%. In addition, the poor condition of infrastructure and challenges in maintaining private roads were raised.

Households solved their mobility challenges mostly by planning trips more carefully (44%), using online services or meeting virtually (36%), omitting trips regularly (25%) and by ridesharing (10%). Those who omitted mobility due to financial reason or difficulty, skipped mostly travels to hobbies (38%) and shopping or other services (34%), but also e.g. visits to health care (12%) (Figure 2).



If you have had to omit transportation due to high price or difficulty, what trips?
(You can choose one or more options)

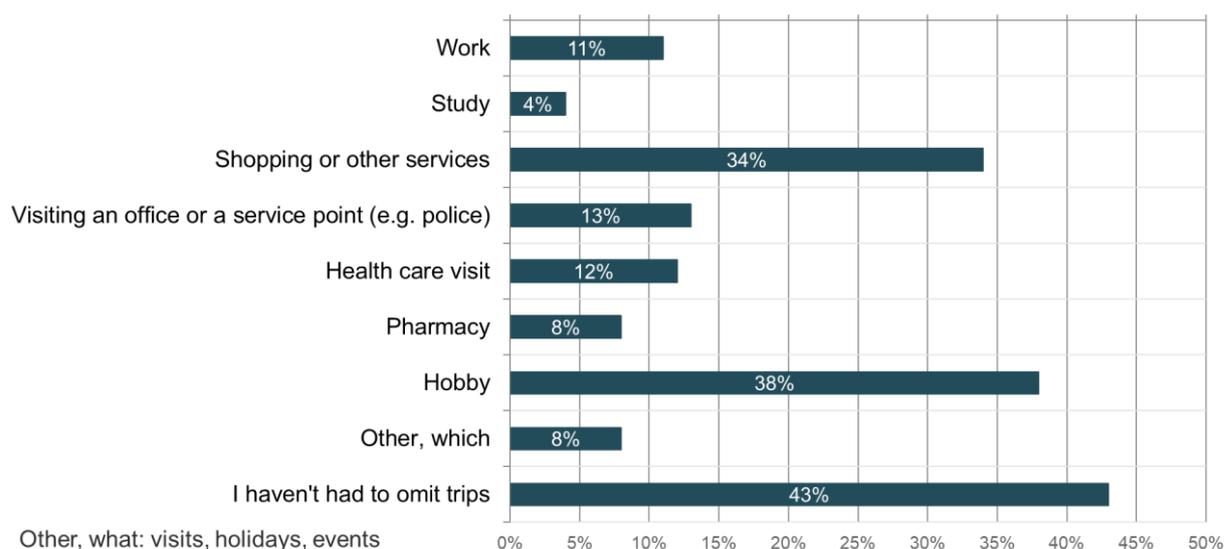


Figure 2. Skipped trips due to difficulty or cost of mobility.

4. DISCUSSION AND CONCLUSIONS

Based on the survey results and statistics on energy poverty indicators (Table 1), the energy poverty situation in rural areas is far more severe than the situation on average in Finland. The sample of rural households was self-selected as respondents actively chose to participate in the survey, which may affect the results. However, another Finnish study has also found that energy poverty is experienced widely in rural areas (North Karelia), but the impact of season in energy poverty is significant. In January, 29.5% of the population in the study region experienced energy poverty, while the corresponding figure in July was only 0.3% [1]. The meaning of insulation in wintertime is important, and 32% reported having a poor insulation in the rural household survey.

Table 1. National statistics and rural survey results on energy poverty indicators.

Indicator	Finland 2023 (statistics)	Rural households (survey)
Inability to keep home adequately warm	2.6% [5]	20%
Arrears on utility bills	7.4% [6]	13%
Living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor	5.3% [7]	18%

Based on the results, transport poverty affects the access to essential services but also to social life of rural residents. In addition to high cost of rural mobility due to lack of mobility services and long driving distances, private roads' maintenance is an extra burden for rural households. Mobility is especially challenging in rural areas for those not having a personal car or a driver's licence.

Energy, mobility and other (e.g. digital) challenges may occur in the same households. This is why the problems, especially of vulnerable groups and people with disabilities, should be solved in cooperation across administrative sectors.

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Sustainable Behaviours and Policy Support Across Energy, Transport and Food Sectors: Findings from 9 OECD Countries

Theme 3, sub-topic 3a; Theme 1, sub-topic 1a

“Academic contribution”

“Policy/practice contribution”

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Extended abstract

Energy, transport, and food sectors are among the largest contributors to climate change and amongst those where consumer behaviour change can have the greatest impact. [1]. Successful implementation of environmental policies directly or indirectly targeting consumer behaviour in these sectors is therefore an important policy opportunity for delivering long-term, population-wide sustainable outcomes [1]. However, designing effective policies is challenging due to population heterogeneity and the need for public acceptability—an essential factor for policy adoption and compliance in many countries. Public responses to policies can be difficult to predict, particularly when interventions are introduced in new contexts. To develop effective policies, policymakers must account for differences in public acceptance and behavioural response across population groups and understand the factors driving these variations [2–5].

Segmentation approaches can help by identifying different behavioural patterns within populations and in informing targeted policy design, public engagement, and communication strategies [2, 6, 7]. One such approach is Multi-Level Latent Class Analysis (MLCA). MLCA can group populations based on patterns in their behaviours, attitudes, and beliefs, and accounts for the nested structure of participant data in specific contexts, allowing researchers to examine behavioural patterns within and across regions and countries. Using self-reported household behaviours in three sectors (energy, transport, and food), data from the 2022 OECD Environmental Policy and Household Behaviour (EPIC) survey of over 17,000 individuals across nine countries: the United States, Canada, the United Kingdom, Sweden, Switzerland, the Netherlands, France, Belgium, and Israel, we applied MLCA to



identify population segments with different behavioural patterns in energy, transport, and food.

We found distinct population segments with varying levels of sustainable behaviours (Figure 1). Cross-sector analyses found correlations in behaviours across sectors, where individuals in sustainable segments of one sector were more likely to behave sustainably in others. Across all sectors, the majority of respondents self-reported less sustainable behaviours, with only a minority consistently reporting the most sustainable practices (Table 1). Unlike previous studies [8,9], socio-demographic characteristics of respondents did not consistently predict population segments as characterised by behavioural patterns. The relationship between socio-demographics and sustainable behaviours also varied across sectors. This finding aligns with results from a literature review on sustainable food consumption, which suggests that socio-demographic characteristics alone may not be sufficient to explain differences in sustainable behaviour across population segments [10].

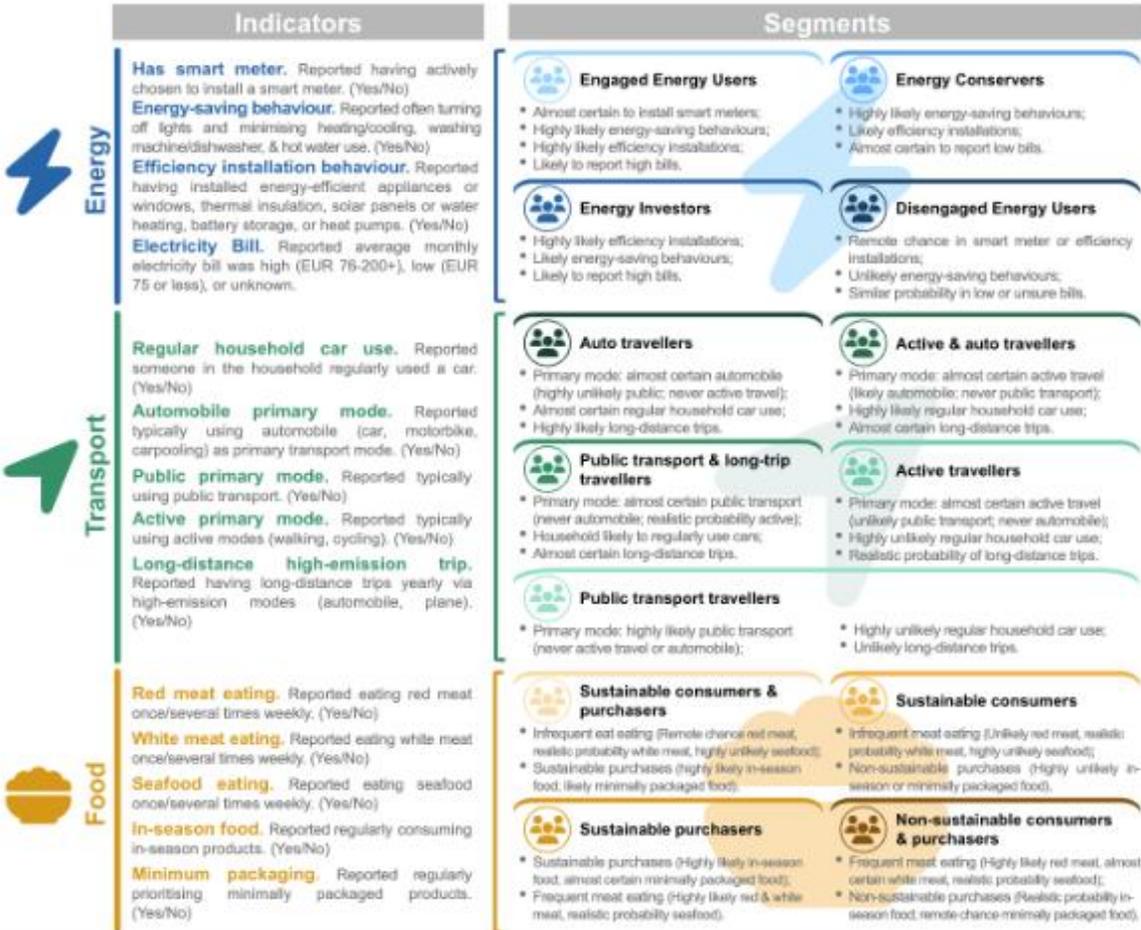


Fig. 1 Description of indicators and definitions of the resulting individual-level population segments. The “Indicator” column (left) defines the indicators used in the MLCAs in the energy, transport and food sector (from top to bottom). The “Segments” column (right) describes the distinct features of the resulting segments in each sector. The electricity bill was originally measured in equivalent value ranges in local currencies and were converted to and presented in the EUR scale in the OECD survey.

Sector	Segment	Percentage
Energy	Energy investors Efficiency installations, likely energy-saving behaviours, likely high bills	66%
	Disengaged energy users No smart meter/efficiency installations, no energy-saving behaviours	12%
	Energy conservers Energy-saving behaviours, likely efficiency installations, low bills	11%
	Engaged energy users Smart meters, energy-saving behaviours, efficiency installations, likely high bills	11%
Transport	Auto travellers Primary mode: automobile, regular household car use, long-distance trips	61%
	Active & auto travellers Primary mode: active, regular household car use, long-distance trips	17%
	Public transport & long-trip travellers Primary mode: public transport, likely household car use, long-distance trips	8%
	Active travellers Primary mode: active, × regular household car use, likely long-distance trips	8%
	Public transport travellers Primary mode: public transport, × regular household car use, × long-distance trips	7%
Food	Non-sustainable consumers & purchasers Frequent meat eating, non-sustainable purchase	51%
	Sustainable purchasers Sustainable purchases, frequent meat eating	24%
	Sustainable consumers Infrequent meat eating, non-sustainable purchases	13%
	Sustainable consumers & purchasers Infrequent meat eating, sustainable purchases	12%

Table 1. Individual-level population segments and their distribution. The MLCA identified four segments for energy; five segments for transport; and four segments solution for food. For food, eating less red and white meat was considered more sustainable than buying seasonal or minimally packaged products. For transport, not regularly using a household car or not using a car as primary mode of transport was weighted as most sustainable.

Linear regressions predicting policy support by segment indicated that segments with more sustainable behaviours generally showed stronger support for environmental policies within their respective sectors than those with a low likelihood of sustainable behaviours. Regarding cross-sector policy support, individuals in more sustainable segments in one sector also tended to express greater support for environmental policies in other sectors, though the differences remained small. This was particularly evident in food segments, where individuals in more sustainable segments showed stronger support for energy and



transport policies (Figure 2). Our findings contribute to growing evidence that suggests sustainable behaviours and environmental policy support share common causes [11]. Evidence from longitudinal research also indicates that support for sustainable policies can in turn influence individuals' likelihood of engaging in sustainable behaviours over time, both within and across sectors [12].

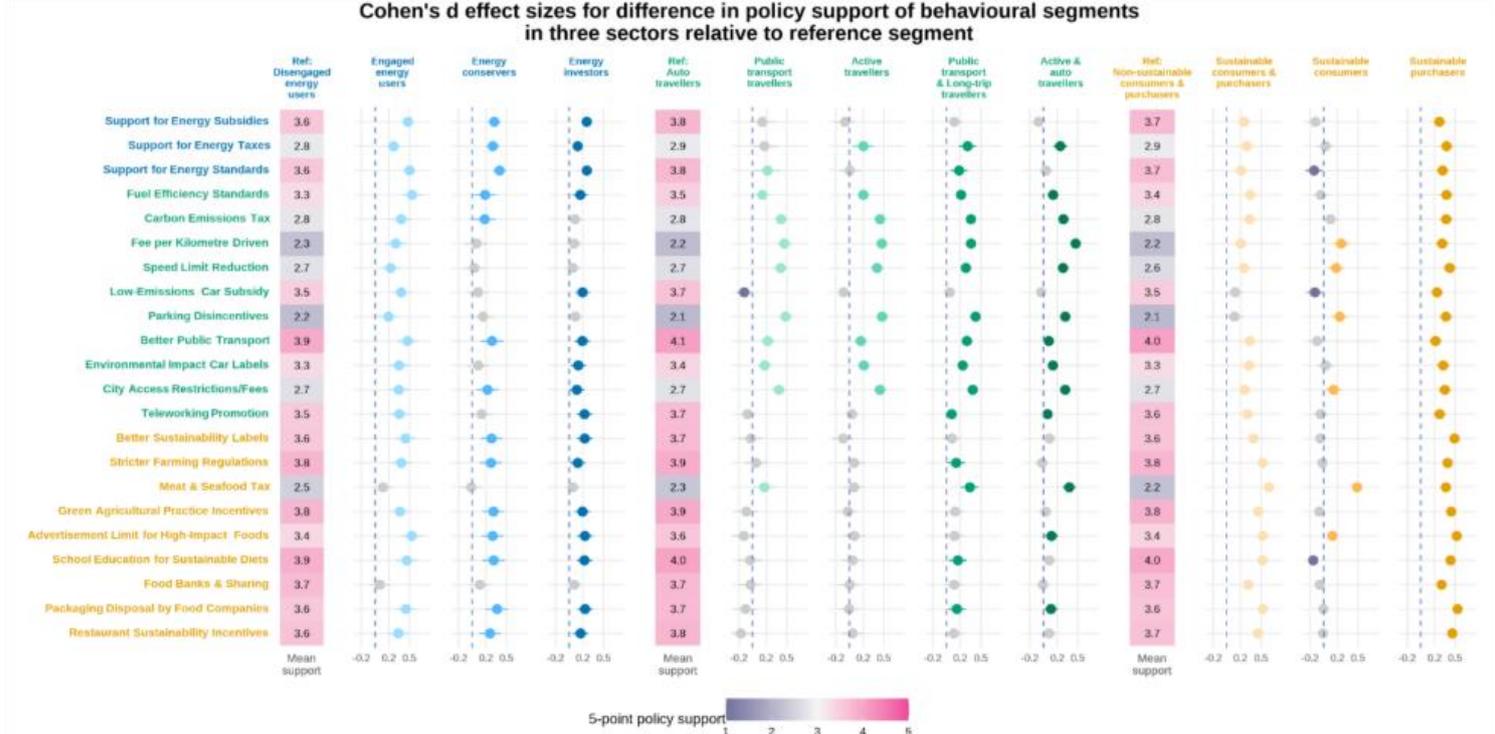


Fig. 2 Policy support across individual latent class segments and sectors. Forest plots display Cohen's d effect sizes with 95% confidence intervals (from linear regressions predicting policy support by segment membership), showing differences in support between each population segment and the reference segment with least sustainable behaviours in each sector. Tile plots present mean policy support ratings on a 5-point Likert scale for each reference segment.

Regional analysis was conducted on the second level of the MLCA. The nine countries were divided into 61 regions. Across all sectors, regions typically (but not always) clustered into the countries to which they belong. (Figure 3 and Table 2). Our regional results aligned with behavioural theories and prior research highlighting the strong influence of material factors (e.g., infrastructure) and social contexts (e.g., norms and policy environments) on sustainable behaviours. The observed within- and between-country differences and similarities align with documented variations in environmental policy and infrastructure. For example, European countries (France, the Netherlands, and the UK) had the highest proportion of individuals likely to have a smart meter, likely reflecting the EU's regulatory push for large-scale rollouts. Whereas in North America, the USA and Canada shared the same regional classifications across all sectors, with low proportions of individuals engaging in the most sustainable energy, transport, or food behaviours. These patterns underscore the need for top-down policies and regulatory measures to shape behavioural choices in these contexts.

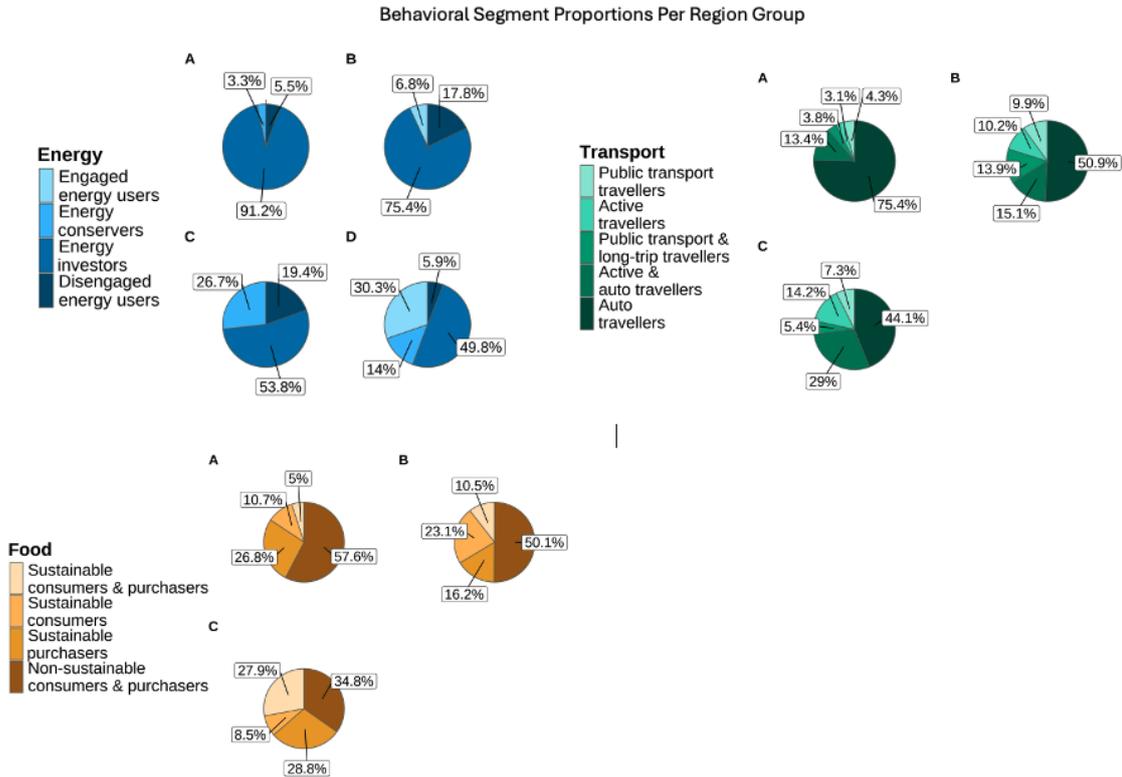


Fig. 3 This plot displays the regional-level classes for each sector. These classes group regions based on similarities in the distribution of individual-level behavioural classes. The proportions of individual-level behavioural classes within each regional class for Energy (top left), Transport (top right), and Food (bottom left) are visualised via pie charts.

Country	Region	Energy	Transport	Food
Canada	Newfoundland and Labrador, Prince Edward Island, Nova Scotia, Quebec, Ontario, Manitoba, Saskatchewan, Alberta	A	B	A
	British Columbia	D	B	A
Belgium	Brussels	C	B	C
	Flanders	A	C	A
	Wallonia	A	B	C
France	Centre - Val de Loire, Bourgogne -Franche-Comté, Normandie, Pays de la Loire, Bretagne, Nouvelle-Aquitaine, Occitanie, Provence-Alpes-Côte d'Azur	D	A	C
	Île-de-France	C	B	C
	Hauts-de-France, Grand Est	D	A	A
	Auvergne-Rhône-Alpes	D	B	A
Israel	Central	D	B	A
	Haifa, Jerusalem	D	A	B
	Northern, Tel Aviv	D	A	A



	Southern	D	B	B
Netherlands	North Netherlands	D	C	A
	East Netherlands, West Netherlands, South Netherlands	D	C	B
Sweden	Stockholm, Smaaland med Oearna, Oestra Mellansverige, Sydsverige, Vaestsverige	C	B	B
	Norra Mellansverige, Mellersta Norrland, Ovre Norrland	C	C	C
Switzerland	Région lémanique, Espace Mittelland, Nordwestschweiz, Zürich, Ostschweiz, Zentralschweiz, Ticino	C	B	C
United States	New England	A	A	A
	Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific	B	A	A
United Kingdom	North East, North West, Yorkshire and Humberside, West Midlands, South West, South East, Greater London, Scotland	D	B	A
	East Midlands	D	B	B
	East Anglia	D	B	C
	Wales ⁺	D	A	A
	Northern Ireland ⁺	A	A	B

Table 2. Region groupings per sector (as detailed in Figure 3) of each region in each country.

This study is among the first to apply MLCA to cross-sectoral and cross-regional behavioural patterns, highlighting the importance of tailored policy strategies and harmonised sectoral approaches. There were two notable limitations to the study. First, the population segments were identified based on self-report measures, which a previous meta-analysis shows do not always accurately reflect actual sustainable behaviours [13]. Second, the data was cross-sectional, meaning that it was not able to capture potential changes in behavioural patterns over time. Our segmentation approach shows where and among whom behavioural differences exist, helping policymakers pinpoint where policy reform and infrastructural improvements are needed, and how they can tailor and target behavioural change efforts. Regional public and stakeholder engagement can help these efforts by identifying how factors such as implementation strategies or public attitudes contribute to higher policy acceptance and adoption of sustainable behaviour. With the majority of individuals across all nine countries falling into segments featuring least sustainable behavioural patterns, urgent implementation of more ambitious, targeted policy and behavioural interventions is critical to accelerate progress against climate change.



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