Conference proceedings

BEHAVE 2020-2021

the 6th European Conference on Behaviour Change for Energy Efficiency

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A voluntary network of European energy agencies

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BEHAVE 2020-2021

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BEHAVE 2020-2021 – the 6th European Conference on Behaviour Change for Energy Efficiency

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Preface

The world community is increasingly recognizing the severe impacts of climate change and raising its levels of ambition in mitigating it. Countries, cities and businesses are announcing targets to reach net-zero emissions by the middle of the century or earlier and devising policies and technological innovations to achieve them.

The COVID-19 crisis has highlighted further the significance of sustainable development and the important role of behavioural change in addressing global problems. Behavioural insights and interventions have an important role in reducing global energy demand and ecological footprints and enabling the transition to carbon neutrality and sustainable energy. Through nudging, such interventions can be achieved at low or even zero cost, while significantly increasing the effectiveness of policies and measures relating to energy efficiency, renewable energy and environmental protection.

For the first time the BEHAVE 2020-2021 Conference was moved online due to travel restrictions amid the COVID-19 pandemic. The Conference organizers of this edition are the EnR Network, the custodian of this event, and the Copenhagen Center on Energy Efficiency, the supporting organization for this year's edition.

The BEHAVE 2020-2021 Conference continues to attract a high number of abstracts. This publication of the Proceedings aims to create institutional memory of the knowledge shared at the event. The Conference organizers have also negotiated a special issue of the journal Energy Policy, to which several authors have chosen to submit their full papers. This special issue is being produced under the title 'Behavioral insights for sustainable energy use: theories, evidence and policy implications', and it is expected to be published by December 2021.

This edition of the BEHAVE conference covers a diverse set of topics, from behavioural insights and interventions for buildings, transport and businesses to applications in developing countries and the use of digital solutions, among many other themes, as well as covering a large range of energy efficiency policies.

Behavioural economics and sciences are an emerging and interdisciplinary area of research. So far, most studies within it focus on developed countries. The organizers hope these findings and their methodologies will inspire more analysis and applications in further geographies, sectors and activities, as well as help motivate green and sustainable behaviour, thereby contributing to achieving low carbon and climate-friendly development.

EnR - The European Energy Network

The Copenhagen Centre on Energy Efficiency, UNEP DTU Partnership

April 2021

SECTION 1

FULL PAPERS

1.1 The Influence of Energy Policy Instruments upon the Promotion of Solar Thermal Technology in Greece

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energy policy in Greece, solar thermal technology, energy efficiency

ABSTRACT

Renewable Energy Directive (EU) 2018/2001 sets a binding EU target to have at least 32 percent renewable energy in the Union's gross final energy consumption by 2030. National policy strategies are expected to play a key role in achieving this target.

Greece's national energy policy aims at ensuring the EU's energy goals are achieved by 2030. The achievement of such goals requires a significant energy transition and the adoption of higher objectives for reducing greenhouse gas emissions, increased penetration of Renewable Energy Sources (RES) in gross final energy consumption, improved energy efficiency to make greater energy savings, and lignite phase-out in power generation. The national policy for the development of policy instruments and innovative technologies for both RES and energy efficiency is still an ambitious objective and a key parameter for securing the required funding and enhancing the energy market.

The objective of this study is to elaborate on the influence of energy policy instruments on the promotion of solar thermal (ST) technology in Greece. To achieve this objective, the existing ST market in Greece is analysed, and the prospects for fostering ST technology through the implementation of effective policy instruments are discussed. Moreover, the existing Greek policy instruments for ST market deployment are elaborated, and successful policy instruments in other EU countries are studied.

Policy instruments in Greece are limited and mostly addressed to RES technologies and not directly to ST systems. They include a proper regulatory framework, incentives and funding opportunities aimed at improving energy efficiency and meeting the targets set by the EU, thus promoting sustainable energy behaviour.

The analysis in the present study has shown that, although there are certain policy instruments in Greece related to ST technological development, further actions should occur to exploit the potential of the ST sector. This study therefore provides a set of guidelines in order to reinforce the implementation of ST technology in Greece.

1. Introduction

According to Renewable Energy Directive (EU) 2018/2001 on the "Promotion of the use of energy from Renewable Sources", the EU's member states are expected to develop proper support mechanisms to promote solar thermal (ST) energy, alongside other renewable energy sources (RES).

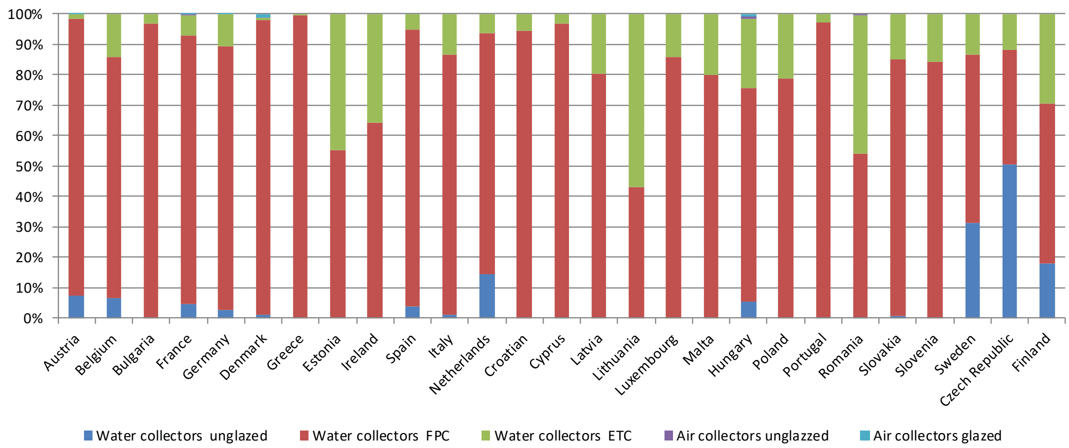
The objective of this study is to examine the existing ST market in Greece and to identify the potential for promoting ST technology through the introduction of appropriate policy instruments. In order to achieve these objectives, the existing policy frameworks in Greece and other EU countries are described. The result of this elaboration is a set of guidelines for policy instruments that suitable for Greece and are expected to change citizens' behaviour in the direction of the use of ST technology.

The main categories of ST systems are the non-concentrating system for low and medium fluid production temperatures and the concentrating system for medium and high fluid production temperatures.

In Greece, ST technology for low and medium temperatures has great potential in terms of energy savings and cost effectiveness. The total ST installed capacity in operation in 2017 for low and medium temperature applications was 3.2 GWth, corresponding to 4,618,000 m^2 of solar collective area[1]. This category includes the technologies of water unglazed and glazed flat-plate collectors (FPC), evacuated tube collectors (ETC) and air collectors. The distribution by technology of the total installed collector area in operation by the end of 2017 in the EU 27 is presented in Figure 1[1,2]. As shown in this figure, the main solar thermal collector technology in Greece is FPC, which uses water as a heat-transfer fluid, corresponding to 99.5% of the total market.

Figure 1.

Distribution by technology of total installed collector area in operation in 2017



More than 95% of the low and medium temperature solar systems in Greece are thermosiphon systems. However, forced-circulation systems have been included in the recent years in national funding mechanisms (e.g., in "Energy Saving I and Energy Saving II" programmes) and their total numbers are expected to increase in the coming years. The main solar thermal applications in Greece are hot-water production for the domestic and hotel sector, solar heat industrial processes, solar "combi" systems for heating support and solar air conditioning.

Regarding the concentrating solar thermal (CST) systems, also known as concentrated solar power (CSP) or solar thermal electricity (STE) systems, currently there are some pilot CSP installations in Greece, installed within the framework of funded national or European projects. Commercially there is no facility in operation. However, although currently CSP does not contribute to electricity production, this is expected to change in the coming years, as the national target for 2030 is 260 GWh of electricity production from CSP[3].

2. Background

The Greek government's strategic goal is to contribute significantly to the required proportion of energy produced from RES in the most sustainable way for the purposes of the national economy, and to achieve a significant reduction in greenhouse gas emissions through a robust and coordinated set of policies and measures. This transition will be coupled with establishing a proper regulatory framework to ensure the sustainable development of the national economy by making optimal use of national and European financing mechanisms and adopting appropriate market instruments and mechanisms in line with EU legislation.

Another important objective is the preservation and management of energy sources so as to ensure the smooth, uninterrupted and reliable coverage of domestic energy needs, as well as access for all consumers to affordable and safe energy.

In order to comply with the European Directives, Greece needs to maintain low energy demand, or even reduce it, while trying to achieve economic growth. To implement energy policy measures and achieve the relevant energy and environmental targets, specific instruments must be introduced to promote energy efficiency and the penetration of RES.

The existing Greek policy instruments for ST market deployment are limited and are mostly addressed to RES technologies, not directly to ST systems. They include a proper regulatory framework, incentives and funding opportunities aimed at improving energy efficiency and meeting the targets set by the EU, thus promoting sustainable energy behaviour.

The current Greek regulatory framework, which directly or indirectly promotes ST technology and also provides incentives and funding opportunities, is analysed in the "Findings" section of this study. It includes, among other things, *"Law 4342/2015"*, which creates incentives for ST market deployment, *"Law 3855/2010"* for the mandatory installation of central ST systems in existing and new central government buildings, *"Law 3468/2006"*, *"Law 3851/2010"* providing for production of electricity form RES and *"Greek Development Law 4399/2016"*.

Regarding the incentives and the funding opportunities for ST systems in Greece, most of them stem from the implementation of existing policy strategies as formulated by European policy strategies and their implementation in Greece. The main such strategies are the "Research & Innovation Strategies for Smart Specializations (RIS3)" for Greece, the "Strategies Energy Technologies (SET-PLAN) Implementation" in Greece, the "National Energy Efficiency Action Plans (NEEAP) for Greece" and the Greek "National Energy and Climate Plan (NECP)". Existing funding programmes of this sort that we have identified are discussed the in "Findings" section of this study.

3. Methodology

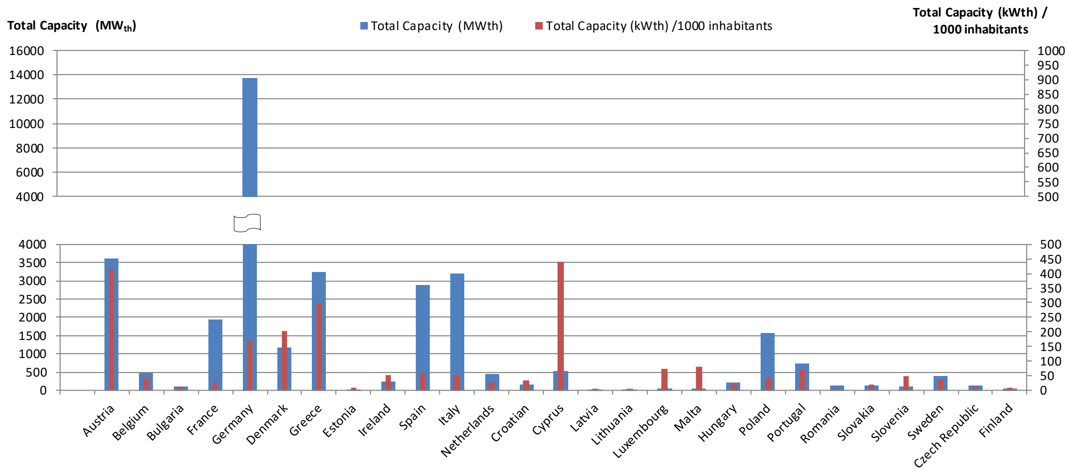
The aim of this study is to provide specific policy recommendations on how to promote ST energy in Greece. In order to achieve this objective, past and ongoing policy strategies were identified and their successes were assessed. The outcome of this work is included in the "Findings" section of this paper. This study has also examined the barriers that prevent the dissemination of ST systems and provides recommendations for overcoming them.

Furthermore, best practices currently applied in other EU countries were thoroughly examined, and the most suitable ones selected for application in Greece. In order to choose those EU countries with high penetrations of ST systems, total installed capacity in operation and total installed capacity in operation per thousand inhabitants by the end of 2017 for the EU27 were elaborated and are presented in Figure 2. The data for 2017 are elaborated according to the methodology as presented by Oikonomou Th.[2].

As shown in Figure 2, Greece ranks third in EU27 in respect of both total ST capacity in operation in 2017 and total capacity per capita, reflecting its well-established ST market. However, the vast majority of installed systems in Greece are of the simplest yet very efficient type of the technology, namely the thermosiphon system for domestic hot-water production. The effective expansion of ST technology use in more complex systems for heating and cooling, as well as for other applications such as solar heat industrial processes (SHIP) and electricity production requires the effective implementation of proper national policy instruments.

Figure 2.

Total ST capacity in operation in 2017 and total capacity per capita in EU27



The behavioural, policy and other interventions to promote ST systems in other EU countries with high rates of ST penetration that are ranked high in Figure 2 – such as Germany, Austria and Cyprus – were examined for the purposes of this study[4,5,6,7].

This work has resulted in a number of suggestions for interventions suitable for Greece, as provided in the "Discussion" section of this study.

4. Findings

Greece's existing policy framework is aimed at the creation of a competitive energy market, a contribution towards a low-carbon economy and the efficient use of energy. The energy sector is one of the most important pillars in terms of policy development, and the legislative framework and associated incentives have the objective of contributing to maintaining low energy demand and achieving economic growth.

Regarding the current Greek policy framework for ST technology, with a few exceptions it is not distinct from that for RES in general. The existing policy framework cover the legislative and regulatory framework, incentives and funding opportunities. In Greece there is no specific regulatory framework for ST technology, as exists, for example, for photovoltaics and wind-power applications. However, there are certain national laws within which ST technologies could be incorporated.

One such regulatory framework has been developed by Greece's *"Law 4342/2015, Part B Integration of the European Energy Efficiency Directive 2012/27/EU"*, a significant instrument for enhancing energy efficiency in Greece. It includes several articles for creating the regulatory framework and providing incentives for the deployment of the ST market.

According to Article 7 of *"Law 4342/2015"* the "Heads of Regions and Mayors" are responsible for developing an energy efficiency plan for the buildings within their authorities and for setting specific energy-savings and energy-efficiency targets and measures every two years. This plan may include the implementation of ST systems.

Article 9 of *"Law 4342/2015"* provides for the enforcement of "Energy efficiency obligation schemes", created under Article 7 of the *"Energy Efficiency Directive 2012/27/EU"*. Under this provision, each EU member state must set up an energy-efficiency obligation scheme to ensure that the energy distributors and/or retail energy sales companies, which are designated as obligated parties, operating in each member state's territory achieve a cumulative end-use energy savings target. ST system implementation is included in the given list of indicative measures for achieving the required energy-saving targets.

Article 10 of the *"Law 4342/2015"* and in the *"Circular ΔΕΠΕΑ/Γ/οικ.181906/5.10.2017, Clarifications on the energy audits of Law 4342/2015"* include an indirect incentive for ST market deployment that consists of the implementation of energy audits in all large enterprises. According to this legislation, all large enterprises are obliged to carry out an energy audit in an independent and cost-effective manner. These energy audits must meet the minimum criteria set out in *"Law 4342/2015"* (Government Gazette, Series I, No 143, 9.11.2015) and must be carried out on the basis of the EN 16247 series of European Standards on energy audits.

Article 20 of *"Other measures promoting energy efficiency"* of *"Law 4342/2015"* sets out the governments' willingness to establish financial measures, incentives and funding mechanisms to promote energy efficiency.

Another legislative framework related to ST technology is *"Law 3851/2010: Accelerating the development of Renewable Energy to address climate change and other provisions on jurisdiction of the Ministry of Environment, Energy and Climate Change"*. Article 10 of this Law imposes the mandatory installation of ST systems in new residential buildings to cover some of the demand for hot-water production. The same also applies to buildings in the tertiary sector [*"M.D. D6/B/oik.5825/09.04.2010"*, Article 8]. The minimum percentage of the solar share on an annual basis is set at 60%.

Regarding electricity production by RES, *"Law 3468/2006, Electricity production by RES and high-efficiency cogeneration and other provisions"* and *"Law 3851/2010, Accelerating the development of RES to address climate change and other provisions relating to issues with the competence of the Ministry of Environment, Energy and Climate Change"* lay down the necessary procedures for installing concentrating ST plants in Greece.

The Greek Government also supports a more market-oriented financial support scheme. One important such financial instrument for RES (including ST technology) is the *"Greek Development Law 4399/2016, Institutional framework for establishing Private Investment Aid schemes for the country's regional and economic development - Establishing the Development Council and other provisions"* (Government Gazette, Series I, No 117/22.06.2016). The objective of this law is to encourage investments mainly in the field of manufacturing and energy by covering up to 55% of the eligible costs.

Another market-oriented policy instrument is the establishment of an *"Infrastructure Fund" ("Government Gazette B 4159 / 29.11.2017")*. This action aims at offering favourable financing conditions to the private and public sectors for the implementation of small and medium-sized projects with an emphasis on energy, the environment and urban development. This is a financial support scheme that aims to ensure the maximum possible use of different financial instruments to cover the financial gap, including in the fields of energy savings and the promotion of RES. The total resources of the *"Infrastructure Fund"* amount to 450 million Euros, while the funds for the *"Operational Program Competitiveness, Entrepreneurship, Innovation"* (OP-CEI) programme in the energy sector total 128.7 million Euros. In the energy sector the projects that will be financed by the Infrastructure Fund will include the energy up-grading of public buildings, as well as the production and distribution of energy from RES (energy-efficient space cooling & heating systems, and domestic hot-water production).

There are also direct funding programmes for which ST systems are applicable, such as the "Saving – Autonomy", "Improving the Energy Efficiency of SMS Enterprises", and "Modern Processing" programmes.

5. Results and Discussions

This study describes the energy-policy instruments affecting the exploitation of ST technology in Greece as part of the country's efforts to promote sustainable energy behaviour and achieve energy efficiency. It also focuses on tracking down and gathering the existing Greek policy instruments in the energy sector, which are specifically applicable to ST technology.

Greece already has certain policy instruments related to ST technology that are expected to contribute to the promotion of sustainable energy behaviour. These instruments will promote innovation in key areas of added value by exploiting Greece's competitive advantages and investing in its highly qualified human resources. However, further actions should take place to ensure the potential of the ST sector can be exploited.

The Greek ST market for low and medium temperature applications is well-established across the EU 27. This is the result of policy instruments being introduced to develop the national ST market, which was established in the early 1980s, including successful marketing campaigns and fiscal incentives, such as low-interest loans and tax credits (VAT exemptions).

Where complex ST systems such as SHIP are concerned, the banking sector in Greece is cautious in approving private funding for energy-efficiency investments. The main reason for this is the lack of personal knowledge, resulting in considering such systems risky investments. This leads to high interest rates being charged on business loans. To overcome this, personal knowledge should be enhanced and interest rates subsidized.

To promote ST systems in Greece, the following guidelines are suggested:

- The national energy targets, set out in Greece's National Energy and Climate Plans, should be realized by implementing specific policy measures, including ST systems. This should include implementation of competitive tendering programs aimed at facilitating the take-up of energy-efficient technologies, such as ST systems.
- Best ST practices in other countries should be studied and adopted in Greece. The effectiveness of ST applications should be disseminated, using proper tools such as leaflets, workshops and seminars.
- More financial support programs, addressed directly to ST systems for heating and cooling purposes, as well as to SHIP and ST electricity production, should be introduced.
- Implementation of market-oriented financial support schemes, including subsidy measures (tax credits and exemptions, preferential interest rates, etc.) to prospective investors who prove their energy-saving potential, to be achieved by ST installations.
- Deployment of the Greek legislative framework to ensure the carrying out of energy audits and mandatory energy-efficiency interventions, including ST systems, not only in large enterprises but in all enterprises.
- Investigate and establish policy instruments, and tackle energy poverty in Greece in order to achieve economic and social cohesion. The relevant policy instruments will include measures for the deployment of the ST sector.
- Support to pilot actions under a specific marketing strategy capable of predicting and anticipating the replication of ST interventions.

6. Conclusions and Policy Implications

The potential for fostering the solar thermal sector in Greece through the adoption of suitable policy instruments is revealed by this study. The current policy framework in Greece does not explicitly address solar thermal technologies, but it does provide for interventions in this field through the policy framework for renewable energy sources in general. It is important to identify and disseminate these policy instruments, which are applicable to solar thermal interventions, in order to change citizens' behaviour in the direction of the use of sustainable energy and energy efficiency. This study not only identifies the current policy instruments that are applicable to the solar thermal sector in Greece, it also examines best practices in other EU countries and provides a set of guidelines for reinforcing implementation of ST technology in Greece.

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1.2 Determinants of Citizens' Participation and Investment in Energy Community Initiatives

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KEYWORDS

energy community, participation, investment, benefits, barriers, motives

ABSTRACT

Collective action will be necessary to reshape societies into models of sustainable production and consumption. Initiatives to create energy communities can help achieve this goal, but their successful diffusion requires acceptance, support and participation by citizens. The present paper is part of a project investigating the introduction of energy communities in Greece. More specifically, the project examines citizens' awareness levels and willingness to participate and invest in energy communities while also addressing related subjects such as structures, benefits, barriers and motives. This paper introduces the results of the review and assessment of the themes just mentioned. The findings of this work will be further used to ask relevant research questions concerning Greek Energy Communities by means of quantitative and qualitative analysis.

1. Introduction

Reshaping societies as models of sustainable production and consumption is crucial in the current century[1]. Apart from changing behaviour at the individual level, changes at the systemic level through collective action are needed to address existing energy system challenges, as collective action has previously been successful in leadingto social transformation[2].

Energy communities transform energy production from a centrally coordinated fossil fuel-powered system to a decentralized low-carbon system[3]. They create new roles for citizens and local communities, placing them at the heart of energy systems[4]. Citizens' acceptance, support and participation will be essential if these ongoing energy transformations are to be managed successfully[5].

Three main approaches to the analysis of energy communities can be identified: micro-level processes, social acceptance and institutional conditions[6]. Regarding the micro-level examination, the relevant work focuses on the factors that can determine the creation and development of energy communities[7] and that can lead citizens to participate[5] and o invest[8] in such initiatives. Despite the efforts made to describe these initiatives, these processes have not been thoroughly examined. Only a small number of studies exist presenting empirical data on citizens' intentions to participate and invest in such initiatives, or on citizens' motives and other determinants of decisions (e.g.[5,8,9,10]).

The present paper is part of a project focused on examining the creation of energy communities in Greece, its aim being to innovate in research by examining new research questions regarding energy communities at the micro-level. More specifically, this project investigates citizens' views and behaviour regarding awareness, participation and investment in energy communities and addresses relevant issues (benefits, barriers, structures, motives) that have not been explored in the past. In this context, the present work presents the results of a literature review that focused on identifying, organizing and assessing the available findings relevant to the themes mentioned above.

Section 3 presents the methodology used to conduct the literature review. Its findings relate respectively to the structure of energy communities (Section 3.1), relevant policies (Section 3.2), potential benefits (Section 3.3), identified barriers hindering the establishment and development of energy communities (Section 3.4), and the motives and other determinants affecting citizens' willingness to participate and invest in such initiatives (Section 3.5). The discussion and conclusions on these findings are presented in Section 4.

2. Methodology

A search was performed on Scopus and Google Scholar platforms (February 2020) as the first step in the literature review. The search targeted materials (papers, reviews, conference proceedings) combining the term 'Energy Community / Cooperative' with one of the following words: awareness, participation, investment, benefits, motives, barriers, policy and participants. Approximately 270 items were identified; after the next round of material evaluation, sixty items were selected as most relevant to the current work. This material was used to describe the issues under investigation and to identify existing gaps in the relevant literature.

3. Findings

3.1 Structure

Depending on different national policies, energy market conditions and the level of collective organization[10], energy communities may assume different organizational forms, such as cooperatives, local social enterprises, or locally-owned energy service companies[11,12]. In this respect, an energy community may embrace several different types of stakeholder, such as residents, local governments, local bodies, NGOs, professionals, development companies, energy companies, (cooperative) banks and financiers[13,14,15,16].

Regardless of the organizational form, all these initiatives share the International Co-operative Alliance's cooperative principles[17]. Additional characteristics common to all energy communities include 1) their close connection with renewable energy sources (RES) and their use[18,19,20], 2) democratic decision-making procedures[19,20], 3) community participation in ownership[21,22] and 4) an emphasis on geographical distribution[18,21]. Hence, as Brummer[23] has argued, energy communities are energy systems that are more sustainable in terms of their technical aspects and that allow greater higher participation and democratic control.

Energy communities' main objectives can be categorized into five groups: economic, environmental, social, political and infrastructural[12,24]. They are therefore involved in numerous activities, such as electricity and thermal power generation, power grid and heating network management, energy purchasing, distribution and sale, consultation activities and energy-saving actions[16].

3.2 Policies

The role of policies in establishing and facilitating the development of energy communities is essential[25], whether talking about legislative, regulatory and standardization frameworks, financial support tools, or awareness-raising activities. However, it is challenging to devise policies that can foster all conceivable forms of energy community. Hence, specific policies will be more suitable for specific types of energy community in relation to others[25].

In this context, financial incentives are an integral component of the policy toolbox, as this type of organization typically relies on limited financial resources, such as members' funds and external financing. Most representative financial incentives consist of subsidies and grants, income-tax deductions, long-term low-interest loans and loan guarantees[15,25,26,27].

3.3 Benefits

The benefits of the establishment and development of energy communities can be grouped into the economic, the environmental and the social. Economic benefits have mainly a local effect, including in many cases the reinvestment of generated profits in the rural- community and increased revenues for the local and regional authorities[15]. Also, they can help reduce energy prices[28] and energy poverty overall[11]. An additional impact is the creation of local employment[29] and the development of a local 'circular' economy with energy communities' revenues to supporting other community targets[30]. It should be noted that the economic benefits are those most frequently mentioned in the relevant literature[23].

In respect of the environmental benefits, it is clear that energy communities, through the production of RES and the enhancement of energy savings, support climate, energy and environmental goals. As Coenen et al.[31] note, the contribution to energy savings is achieved through increased awareness, improved interpersonal trust and the foundation of social norms.

Identified social benefits include the increased acceptance and diffusion of RES on a local level[20,32], the enhancement of energy autonomy and security, the reinforcement of community values and the promotion of democratic values and self-governance[4,33,34,35]. Additionally, they can assist community building and self-realization[23], as well as social capital creation[36], thus enhancing social cohesion[11].

3.4 Barriers

In general, barriers can be grouped into four categories: economic, technical, social and institutional. Economic barriers include high investment costs[37], long payback periods[7], a lack of profitability and high levels of risk aversion[38]. Technical barriers include a lack of equipment, know-how and expertise[33,39].

Social challenges include a lack of community involvement[11], which could be expressed through low participation or difficulties in filling managerial positions[23]. Local opposition could also arise due to a lack of procedural and distributional justice[11] and collaboration[40]. Moreover, insufficient awareness (e.g., legislative framework, benefits) and previous negative experiences with the cooperative structure could hinder the development of energy communities[27].

With reference to the institutional barriers, it should be noted that the main obstacles to establishing and promoting energy communities are the centralized management and regulation of current energy markets. In this context, issues such as inefficient regulatory interventions, bureaucratic constraints and unstable short-term policies should be mentioned[7,24].

3.5 Motives and other determinants

The present section considers the motives and other factors that can affect citizens' involvement in energy communities, as expressed through volunteering, investing in, or contributing through a managerial position. First there are possible egoistic and ethical motives affecting these kinds of decisions, especially investment-related ones. Egoistic motives are concerned with returns on investments[8,41], affected in their turn by factors such as potential subsidies and tax incentives[42,43], and operating and maintenance costs[44].

On the other side, individuals are also moved by social and ethical norms, which can be distinguished between interpersonal trust, social recognition and environmental concerns[5]. Interpersonal trust is identified as the trust that must be cultivated among all the internal and external stakeholders involved in an energy community[36,40,45,46]. Social recognition refers to individuals' desire to be part of a group and be accepted by their local community[41,45]. Environmental concerns also positively affect participation in energy communities[5,40,41,45]. These concerns can be expressed through ownership of a RES microgeneration system, a willingness to reduce CO_2 emissions, environmental awareness, or environmentally friendly behaviour generally[2,5,7,8].

All the egoistic and ethical motives mentioned above may be affected by various factors, including the institutional framework[5,8,9], spatial factors (distinguishing communities of place and interest)[47] and the adoption of a perceived innovation[48].

Additionally, energy-related motives have been identified as affecting individuals' decision-making regarding energy communities. Based on previous research, these motives have been demonstrated as RES acceptance, energy autonomy, contribution to the energy transition and influence on local energy policies[7,40,41,49,50].

Demographic and socioeconomic characteristics should also be taken into consideration, such as age, gender, marital status, education, type of education, occupation, income, home-ownership and area of residence[2,5,44,50,51,52,53].

4. Discussion and Conclusions

The present study has presented a literature review performed in the context of a project focusing on the participation and investment determinants of citizens' participation in Greek energy communities. The review presents and discusses the structure, benefits, barriers, motives and overall factors that have been found to affect citizens' participation and investment in such communities.

First of all, it should be noted that energy communities may take the form of numerous organizational structures, depending on legislative, market and institutional conditions. Moreover, various stakeholders, activities, policies and benefits may be relevant to the different types of energy community. In any case, all these initiatives should operate based on the sharing of cooperative principles, emphasizing the promotion of sustainable solutions, community participation and democratic procedures.

In this regard, the significance of targeted policies on the establishment and promotion of energy communities should be highlighted, including the legislative and regulative frameworks, financial tools and awareness-raising activities. However, not all policies are appropriate for all different types of initiative. Thus, the particular conditions should be taken into account in each case with the aim of devising suitable policies, as inappropriate policies may hinder the diffusion of energy communities.

Furthermore, individuals' willingness to participate and invest in energy communities should be noted as a necessary condition for their successful development. Citizens' low interest in such community-based institutions may result in them failing. Numerous factors have been found to act as motives and determinants of citizens' participation and investment: 1) egoistic motives, mainly in the form of an interest in financial returns; 2) social and ethical norms, including interpersonal trust, social recognition and environmental concerns; 3) institutional and spatial conditions; 4) innovation adoption; 5) energy-related motives; and 6) demographic and socioeconomic characteristics.

The findings of this work will be utilized to develop a theoretical model and, in combination with the current status of the Greek market, to draw up specific research questions. These questions will focus on awareness, participation, investment, structure, activities, benefits, barriers and policies, all in the context of Greek energy communities. These issues will be examined in depth through future qualitative and quantitative analysis.

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SECTION 2

BEHAVIOURAL INSIGHTS AND INTERVENTIONS FOR BUILDINGS

2.1 Designing Tailored Interventions: a Pragmatic Segmentation Approach to Change Energy Behaviour in Residential Buildings

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energy consumption behaviour, tailored interventions, framework, segmentation

1. Introduction

Despite important political goals to reduce individual energy consumption, overall household energy consumption has shown stagnation or, at best, only a marginal reduction (Statista, 2017). Thus, the efficacy of current instrument designs to reduce energy consumption need to be reviewed and improved.

There is a growing consensus that, with regard to interventions, one size does not fit all when it comes to the energy consumption behaviour (ECB) of households (Klöckner, 2015; He et al., 2010). We can identify at least five rationales for tailoring interventions rather than applying "one size fits all" approaches. First, *people are heterogeneous*, i.e. there is no "average" consumer. Instead, interventions should be directed and tailored to different consumer (or social) segments. Second, people show *different types of energy-related behaviour*. Behavioural change therefore needs to be triggered in accordance with the diversity of existing forms of behaviour. Third, people *respond differently to behavioural factors*, i.e. sets of norms, a diversity of values, attitudes and socio-economic factors related to various contexts and circumstances (e.g. different places, dwellings, financial situations, knowledge and access to technology, etc). Assuming that these factors or combinations of them are trigger points for changing individual behaviour, it is reasonable to assume that they can be stimulated through tailored interventions. Fourth, people *do not change their behaviour continuously or linearly*: instead, behavioural change can be divided into different, not necessarily consecutive phases. Therefore, phase-based interventions have a greater effect on behavioural change than temporally cross-cutting ones. Finally, people *respond differently to different types and combinations of intervention*, e.g. rational information, price-based instruments or normative appeals. In addition, single interventions are less effective than consistent policy mixes.

Without claiming that tailored interventions are the key to establishing a pathway with substantial reductions in energy consumption, we nevertheless identify tailoring interventions as an important aspect of this change. The aim of this paper is to develop an approach to systematically setting up tailored intervention strategies. In doing so we ask the following research question: How can different types and packages of instruments be tailored to different groups of people, different types of ECB, different trigger points and different behavioural phases?

To answer these questions, we are developing a framework to include these features of tailored interventions in a recommendation engine as part of the Horizon 2020 Project UtilitEE (https://www.utilitee.eu/). We are therefore not only contributing to the scientific debate on tailoring interventions to change ECB, but also addressing different governance actors, especially utilities, to set up pragmatic intervention strategies.

2. State of the Art and Methodology

A small but rapidly growing body of literature on ECB (e.g., Klöckner, 2015; Poortinga and Darnton, 2016; Sütterlin et al., 2011) has taken up the task of identifying consumer segments and types of behaviour that are responsive to specific tailored instruments. Mostly, this is investigated through personalized feedback instruments (e.g. Abrahamse et al., 2007; Coleman et al., 2013). Others investigate how instruments can be tailored to different behavioural phases or trigger points (e.g. Bamberg, 2013). However, there is little evidence on how to tailor different designs or mixes of instruments to different social groups with various types of behaviour, trigger points and behavioural phases in real-world contexts.

To this end we have conducted a systematic literature review on tailored interventions to change ECB and their designs. Based on this, we used the method of argumentative reasoning to develop our framework, which builds on two existing frameworks, described in Burger et al. (2015) and Bornemann et al. (2018) respectively. The two frameworks are further spelled out and adapted in line with the real-world contexts of residential and commercial buildings and according to business models of utilities in five European countries. This leads to our pragmatic framework and a recommendation engine for tailored ECB interventions.

3. Results and Findings

Important elements of our framework are:

1. Tailoring to suit different consumer segments. For group-specificity, we integrate a segmentation approach along the core values (egoistic, hedonistic, altruistic, biospheric), finally distilled into three groups: "self-focused", "environmentally concerned" and "socially concerned".
2. Tailoring to types of behaviour. To be type-specific, our framework refers to energy services and focuses mainly on habitual behaviour in the fields of electricity and heating as the main consumption domains.
3. Tailoring to different trigger points. We integrate the different trigger points or factors (multi-factorial) that will be influenced by the interventions or ICT tool applied by utilities or other governance actors. These include, for example, knowledge, values, social norms etc.
4. Tailoring to behavioural phases and dynamics. Interventions are tailored to three phases of behavioural change (unfreeze, change and refreeze habits), allowing for a dynamic approach to influencing ECB.
5. Tailoring different types and combinations of instruments. Interventions are directed to different groups of people (recommendations and feedback), types of behaviour and trigger points (recommendations, information, feedback and nudging). Different tailored interventions are therefore combined in a dynamic approach.

The framework is currently being tested with a recommendation engine. In order to implement the behavioural change framework in real-world settings, we have spelled out the different elements in the recommendation engine that were then implemented by utilities through a configuration of technical appliances.

4. Discussion and Conclusions

The framework was successfully translated into a tailored recommendation engine for changing ECB. Most importantly, the scientific aim of not following a one-size-fits-all approach and tailoring interventions has been translated into a design that is applicable in real-world settings. The design targets different types and packages of intervention by differentiating consumer groups, types of behaviour, trigger points and behavioural phases. Specifically, recommendations are specified for three consumer groups identified by a segmentation questionnaire. Preliminary results show that engaging people via the different interventions already decreases energy consumption.

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2.2 Human-driven Energy Efficiency in Historic Buildings

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1. Introduction

In Europe, historic buildings constitute about 14% of the total building stock; however, in several historic cities this percentage could grow dramatically, up over 50%[1]. In Italy, for example, about 30% of buildings (around 12.5 million) date from before 1945[2]. These data, coupled with the current replacement rate of existing buildings by new-builds, which is under 3%, highlights the importance of finding individual, suitable solutions for the energy retrofit of historic buildings[3]. Despite this necessity, until today the majority of energy-related standards in Europe exempted this category of buildings from respecting the energy performance regulations[4]. This is because the European culture of preserving historical evidence preservation conceives of the protection of cultural heritage in terms of its 'material' conservation, which theoretically requires leaving the object (in this case the building) as history left it[5].

For this reason, implementation of the most common energy-retrofit measures, such as envelope insulation or replacement windows, on historic buildings is not always possible, nor even allowed. There is thus the necessity to experiment with individual energy retrofit solutions that could balance the necessity to preserve such buildings as material evidence, while also reducing their environmental footprint and adapting them to present-day standards of liveability, well-being and comfort. In fact, their persistence is strictly related to their usability, accessibility and suitability for human activities.

Based on these considerations, one possible solution is to explore the potential of human-driven energy efficiency. In fact, a building's energy usage is strictly related to how humans run it. Moreover, intervening in building operations does not require any 'material' intervention, thus avoiding any damage to the historical evidence and, in some cases, contributing to the conservation of historical materials and decorations. This paper introduces a methodology called BIOSFERA (Building Intelligent Operational Strategies For Energy Retrofit Aims), which investigates the potential for enhancing energy savings and indoor environmental conditions by acting only on how the building is run by the building's administrators and occupants. Moreover, the results obtained in a first pilot study will be critically analysed, given the potential impact that the adoption of this methodology in a broader scale could have in economic, environmental and social terms.

2. Methodology

The methodology for this project follows a pre-test post-test design and is articulated in three subsequent phases: Diagnosis, Intervention and Control. The Diagnosis phase has the objective of hypothesizing the potential for energy savings and indoor environmental enhancement by characterizing building operators' energy-related management, quantifying the building's energy consumptions and related costs, assessing the building's indoor environmental conditions and acquiring energy-relevant information about behaviour and comfort from its occupants. The second phase, Intervention, is addressed by devising actions to ameliorate the building's operations by building administrators and occupants through the pursuit of three objectives: lower the building's energy consumption, enhancing the perception of comfort and the behaviour of the occupants, and ameliorating or solving the indoor environment-critical situations related to the conservation of artwork. The third and final phase, Control, defines the potential, previously hypothesized, so it is dedicated to determining the Intervention impact on the building's energy consumption, occupants' perceptions of comfort and behaviour, and the indoor environmental conditions in relation to the conservation of artwork.

3. Results and Findings

The first pilot study in which the methodology was used showed promising results, in terms of both energy savings (all case studies saved between 10% and 30% seasonally) and behavioural change to reduce energy-wasting habits. The behavioural change was assessed both directly (by asking occupants about their perceptions of behavioural change towards specific energy-relevant building interfaces like thermostats or artificial lights) and indirectly (repeating some behaviour-related questions that were previously asked during Diagnosis). Moreover, the energy savings did not impact on or even ameliorate the occupants' thermal comfort. Also, in terms of engagement, the participants in the pilot study appreciated the means of communication that were adopted.

4. Discussion and Conclusions

This research demonstrates that human-driven energy retrofits have great potential from many points of view. First, based on the pilot study, the zero-cost (or almost zero-cost) strategies that were implemented can produce similar or even higher energy savings than those expected from other energy retrofit measures in historic buildings (e.g. substitution of heating and cooling systems).

Second, involving occupants and building operators at the same time allowed previously unexplained reasons for energy waste and chronical environmental discomfort to be detected. Third, the fact that a notable percentage of iconic historic buildings (like those taken into account in the pilot study) are owned or ruled by public administrations offers the possibility to involve citizens in the sustainable management of the cultural heritage in an active way, as strongly claimed by the Faro convention[6]. These results encourage broader reflections on the role that the energy sector, and particularly this kind of initiative, could play in helping to preserve the liveability and sustainability, both environmental and financial, of historic buildings. Moreover, the approach made possible by the BIOSFERA methodology could easily be adopted for other building typologies and be coupled with other 'material' energy retrofit measures, thus reducing the risk of rebound effects subsequent to these interventions[7]. In fact, unexpected increases in energy demand after energy retrofit interventions are quite frequent and could be efficiently addressed by combining improvements to buildings' energy performance with appropriate operating practices.

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2.3 Apartment-related Gaps in Energy Performance and Occupant Behaviour in Two Multi-apartment Buildings: What We Can Learn for Devices to Regulate Heating?

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KEYWORDS

energy performance gap, occupant behaviour, field study, multi-apartment buildings, social practice theory

1. Introduction

To decrease the demand for heating energy in residential buildings, it is not only necessary to increase the rate of building refurbishment[1], but also to make building technologies more robust with respect to changes in occupant behaviour. An ongoing problem with building refurbishments is the energy performance gap, that is, the percentage difference between the predicted heating demand and measured heating energy consumption of a building[2]. There are three potential reasons for energy performance gaps[3,4]: 1) deviations between real conditions and assumptions in energy performance calculations; 2) problems in realizing the technical and building design; and 3) occupant behaviour, which is often treated as a residual category in calculating energy performance. Our aim in this project is to understand in more detail how occupants and building technologies interact and therefore influence heating energy consumption in buildings. We focus on multi-apartment buildings, which are typically owned by institutional housing companies in Germany[5] and are therefore of particular interest as a target of efficiency policies. Multi-apartment buildings are special in that energy performance calculations are only available for the whole-building level, despite their containing different households with heterogeneous forms of behaviour. We thus calculated the apartment-related energy demand for 88 apartments in two multi-apartment buildings. We also conducted a survey in the same buildings to learn more about the energy-related heating and ventilation behaviour of the different households.

2. Data and Methods

We conducted a field study in two multi-apartment buildings, built in 1960 and since refurbished to an energy-performance rating of D, corresponding to a heating energy demand of 115 kWh/m² according to DIN 4108-6 / 4701-10/12 and EnEV 2014. The buildings have 40 and 48 apartments respectively, with apartment sizes ranging between one and four rooms. From the housing company and a preceding research project in these buildings, we obtained detailed data about the building's design, energy consumption and indoor temperatures.

During the winter months of 2019/2020 we also conducted a survey of 34 of the 76 flats (vacancy rate of 14%) using a standardized questionnaire to learn more about household composition, demographics and the heating and ventilation behaviour of the occupants. During the interviews, which we conducted face-to-face, we also took one-time indoor temperature measurements.

We used the building data to calculate figures for apartment-related heating demand comparable to the energy performance ratings of the buildings, but in this case on the household level. We then calculated the energy-performance gaps for each household-apartment. The answers from the survey tell us more about the heating energy consumption-related behaviour of the occupants.

3. Results and Findings

Usually energy performance ratings are only provided at the whole-building level. It can be shown that there is a huge variation in the energy performance between different buildings[6]. To gain a closer understanding of the interactions between occupant behaviour and building technology, we bring occupant behaviour and building physics in multi-apartment buildings closer together. Our results show that the following:

There is a huge variation between the energy performance gaps of different apartments, ranging from -87% to +253% (with an average EPG of 36%)

Indoor temperatures are not homogenous, as is usually assumed in energy performance calculations, within neither buildings or apartments. Temperature measurements, thermostat settings and ventilation behaviour show that occupants have different thermal comfort preferences for dif ferent rooms and activities.

While average apartment temperatures seem to be rather low (17.4 °C on average for the months between November to March), temperatures can differ wildly for single households, with a maximum of 28°C.

Heating practices differ widely. While housing companies usually advise their tenants to keep their thermostats continuously at a low setting and only turn them up or down when absolutely necessary or when ventilating for longer periods, the surveys show that tenants have very different modes of heating and ventilating.

Statements about reduced heating requirements due to the heating habits of neighbours and the apartment's location indicate the possibility that individual households with a lower sensitivity to moderate temperatures may free-ride on heating, generating potentially problematic internal heat transfers[7].

4. Discussion and Conclusions

The results show that, when it comes to occupant behaviour, we have to deal not only with varying thermal comfort preferences and practices, but also with negligence and a certain lack of interest in energy consumption and energy savings. This is supported by various pieces of evidence from energy research using social practice theory[8,9]. Policies building on information and education might therefore be largely inefficient[10]. Instead, we try to draw conclusions for the design and mode of operation of a smart heating regulation system, where the occupants regulate their temperatures through a tablet computer. This will be introduced to the same buildings as part of the ongoing research project in 2020/21. The system supports occupants not by providing information about energy consumption, but by including occupants' preferences in finding the optimal settings and thus reducing energy loss. The idea is therefore to relieve the household of the need to decide on the most energy-efficient behaviour, without, however, leaving them with the feeling of a loss of control, which has proved decisive for the occupant's thermal comfort[11].

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2.4 Reducing Energy Consumption in a Tertiary Building by Using Nudges

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KEYWORDS

energy consumption reduction, nudges, occupants' behaviour, dynamic thermal simulation

1. Introduction

In France, residential and tertiary buildings consumed 46% of total final energy in 2017 and were responsible for 30% of all energy-related carbon dioxide emissions in 2016[1]. This is then an important field where significant reductions in energy consumption can be achieved. However, this potential is not being exploited as much as it could be, and the building sector remains a silent consumer. With the development of the Internet of Things and the integration of Big Data and sensors in many fields of daily life, the idea of using technology to manage energy consumption in buildings is an interesting field for investigation. In fact, there is a significant need to develop intelligent approaches in order to develop sustainable environments in which less energy is consumed while responding to comfort needs. More and more importance is nowadays being given to the industrial and academic issue of using the potential of digital solutions to make buildings more energy-efficient. However, technology alone is not capable of bringing about change in the energy consumption of buildings. Indeed, excluding the human factor from the decision-making processes may lead to less comfort and more waste of energy[2]. By developing and using simulation tools, designers aim to predict the energy consumption and performance of buildings. However, the literature has shown that, because of different experiences, a considerable gap has emerged between predicted and real actual consumption of energy in buildings, and occupant behaviour is now fundamentally recognized as the main responsible factor for this disparity[3]. It is thus important to develop tools to understand and model the behaviour of building occupants more accurately in order to identify its impact on energy consumption. This will help in identifying appropriate energy-saving recommendations and turn occupants from consumers into active users of energy in buildings. For these reasons, an approach combining both behavioural insights and technology seems to be appropriate in improving the management of energy in buildings, taking all factors into consideration.

2. Background and Methodology

Buildings don't use energy, people do[4]. The relevant literature shows that the real energy consumption of a building can be five times higher than predicted[5,6] identified an energy gap of 34% between predictions and reality based on 62 case-studies of buildings. The interaction between users and buildings, the presence of occupants and the adaptive actions they may have to take to maintain their comfort are the reasons behind these disparities. Despite the integration of solutions of energy efficiency in order to make buildings consume less, consumption differs from what is predicted once the building has been occupied. In fact, the impact of occupant behaviour on this gap in prediction is estimated at between 10-80%[6]. Hence, occupant behaviour is an important factor that may cause higher energy consumption. For example[7], showed that some actions, like opening windows on hot days, can easily nullify the thermal benefits of a good insulation. That is the reason why changing occupants' behaviour to make it more virtuous can bring about significant energy reductions.

In this context, the aim of our work is to deploy both technological and behavioural solutions in order to increase energy efficiency in buildings. Our approach consists of simulations and experimental studies to show the impact of changing occupant behaviour on energy savings. For this, we use insights from behavioural economics, especially different types of nudges, and compare their multiple effects.

To reduce the gap between predictions and real energy consumption in buildings, the literature presents different stochastic behavioural models that can be integrated into simulation tools in order to make the results more accurate and simulate real occupant behaviour[8,4,9]. Another solution is to educate occupants by changing their behaviour without restricting their choice and simultaneously maintaining their comfort[3]. This is an interesting side to investigate by showing the impact of using nudges in reducing energy consumption in buildings by using simulation and experimental data. A "nudge" is an interesting way of transforming the incentives to take action by making individuals choose the desired decision by changing the environmental architecture[10]. Our ongoing methodology consists of using both simulation tools and field experiments to evaluate the impact of using nudges to reduce energy consumption in a tertiary building.

3. Results and Findings

The simulation part of this project is based on the co-simulation of a case-study building by using an energy simulation tool and models from the literature (presence, use of openings, shading, lighting, management of heating and cooling set points). The building concerned is an office building situated in Nice, France. The interest in studying such a tertiary building is that the occupants do not pay electricity bills and therefore do not have financial reasons to adopt virtuous attitudes towards energy use. The building is simulated by taking into account its envelope, architecture, location and HVAC (heating, ventilation and air-conditioning) systems in order to calculate its energy consumption. In parallel, a survey will be conducted in order to define occupants' profiles depending on their age, gender, job position, background, energy awareness and ability to use technology. This survey will also help confirm data that must be collected for the experimental study, as well as defining the behaviour that needs to be changed and on which we have to focus in order to avoid unnecessary energy consumption. On the other hand, since more and more smart meters and sensors are being installed in buildings, these developed tools can play an important role in studying the interaction between occupants and buildings, which is an important step towards behavioural change. They give access to a considerable amount of data concerning indoor and outdoor parameters, occupants' presence, use of openings and electrical equipment. Analysis of this data will enable the use of energy in the building to be understood and to define the factors behind excessive consumption. A change in the direction of virtuous behaviour can be made drawing on concepts from behavioural economics. In this regard, we will use sensors and collect data in the same simulated building for our experimental study. Data will be collected from different installed sensors on the physical parameters of the building, including temperature, humidity and luminosity, but also parameters representing occupant's activities such as the use of openings, shading, heating and cooling set points, and different energy consumption. The objective is to investigate the impact of using four types of nudges in the studied building by dividing the occupants into groups. The proposed nudges are: (1) peer to peer comparison, appealing to one's inclination to adopt the same behaviour as one's peers. This will take the form of benchmarking energy consumptions and the eco-friendly behaviour of other occupants; (2) feedback and tailored messaging, appealing to one's desire to build an eco-friendly self-image; (3) moral appeals to one's culpability for behaviour that leads to global warming; and (4) social reviews, which appeal to one's desire to be part of the majority adopting the right behaviour. The data collected from the field study will be exploited in order to highlight the impact of these nudges on changes in behaviour and thus on reducing energy consumption. Based on the previous results of modelling occupants' behaviour and the impact of certain activities on energy consumption, we can choose, develop and test the appropriate "nudge" to be implemented in the building concerned. To have more effective results, we may need to combine different type of nudges depending on the particular characteristics of the building and the estimated impact of the tested incentives had on reducing consumption[11].

4. Discussion and Conclusions

The main assumption underlying our work was the awareness that a multidisciplinary approach (technical and social) is required in order to understand energy use in buildings and achieve energy efficiency by changing occupants' behaviour[12,13]. By predicting occupants' activities and comfort needs, a more effective "nudging" to induce them to change energy use can be achieved. In future work, the objective will by automatization of the process of generating "nudges" for the building concerned based on our previous study of occupants' influence on energy consumption.

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2.5 Housing Choice Behavior and Location Efficiency in North America: A Case Study

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location efficiency, energy efficiency, housing location behaviour, housing choice

"…we just don't like the noise of having somebody there, noise, smells we could smell them cooking in the townhouse, we could smell their food."

1. Introduction/Background

By supporting location-efficient[1] (LE) housing developments, municipalities can help provide homes in areas that result in fewer vehicle miles travelled (VMT) while increasing the accessibility of employment, amenities and services, active transportation (walkability, velomobility) and transit options (Poticha and Haas, 2006; Burda, 2012; 2014). The potential benefits associated with choosing an efficient home location include reduced commuting time and costs, improved health and wellness, lifestyle effects (e.g. more leisure time) and lower greenhouse gas (GHG) emissions (Lyons and Chatterjee, 2008). A majority of North American homebuyers have still been shown to desire homes in suburban developments, and cities are still adding the majority of their growth in these types of development (Gordon, Hindrichs and Wilms, 2018; Saville-Smith and James, 2010). In order to reduce energy use by transportation, GHG emissions and the infrastructureal costs associated with new suburban developments, municipalities are attempting to promote the development of and the demand for homes that are situated closer to employment centres and along transit corridors (location-efficient development) (Hoehner, Barlow, Allen and Schootman, 2012; Litman, 2012; Natural Resources Canada [NRCAN], 2009; Rose, 2010).

Choice of home location has been studied by diverse disciplines, yet little is known about how location-efficiency is factored into such choices. A growing number of homebuyers are seeking easy access to amenities, services, employment and frequent destinations that are associated with location-efficient neighbourhoods (Becker, Bernstein, and Young, 2013; Borth and Summers, 2017; Burda, 2014; Litman, 2010; Lewis and Baldassare, 2010; Nelson, 2009; Rauterkus, Thrall and Hangen, 2010). These housing location preferences appear to be out of line with current

1 *Location-efficient neighbourhoods consist of compact mixed-use neighbourhoods with access to employment opportunities, shopping and essential services, and convenient access to public and active transportation options (trails, walkability, bike paths).*

development trends, as many homebuyers would rather live in a more location-efficient home, yet traditional suburban development still continues unabated in North America and other parts of the world. This research was undertaken to investigate the factors that influence choice of home location with regard to location efficiency and to consider participants' inclusion of location efficiency in their home location behaviour.

2. Methodology

Like many North American cities, Edmonton in Alberta, Canada, has identified urban densification, location-efficient infill (a goal of 25%) and TOD as principal components in changing the traditional development paradigm of new greenfield suburban single detached housing. Gordon, Hindrichs and Wilms (2018) study shows that of the 231,955 growth in population experienced in Edmonton from 2006-2016, 81% of it was classified as occurring in auto suburban developments (Calgary was the only city in Canada with a higher figure, at 83%). This study recruited recent homebuyers in Edmonton and used semi-structured interviews to look into choice of home location and location efficiency. Participants were recruited through multiple e-mail lists, message boards, social media, references through professional and personal contacts of the primary researcher, and local community groups. Snowball sampling was used to locate subsequent interview participants. Through this approach, 30 households were recruited with a total of 39 participants (21 solo participants and nine couples). The semi-structured interviews were audio-recorded, transcribed and analysed using thematic analysis as outlined by Braun and Clarke (2006; 2014).

3. Results and Findings

The qualitative findings of this research contribute to further understanding of the inconsistency between homebuyers expressing an interest in location-efficient homes and the continued, unrelenting growth of suburban areas. Results in four main thematic areas provide insights into how participants' past housing and commuting behaviour and experiences can have a sizeable influence on choice of home location, as well as participants' misperceptions and miscalculations of the associated long-term costs (health, finance, time) of choosing location inefficient homes. Local amenities (social, services, commercial) and neighbourhood design (walkability, velomobility etc.) were also shown to be contributing factors in participants' home location choice behaviour. This study provides recommendations for housing growth policy, housing development standards and behavioural interventions to help influence more efficient home location choices.

4. Discussion and Conclusions

These results provide evidence for improved LE prioritization in municipal outreach education and the real-estate sector (resources for municipalities etc). By making homebuyers more aware of the benefits of LE, municipalities, developers and planners can attempt to influence their home location decisions while mitigating issues like declining budgets due to increased municipal sprawl, traffic, GHG emissions and health issues related to long commutes and walkability. The areas of perceptions of transportation costs, past commuting and shared wall living experiences influencing home choices, as well as the existence of culs-de-sac as community hubs, offer some evidence that developers and municipalities could utilize to attract homebuyers to location-efficient areas they wish to prioritize. Location-efficient developers and home-builders could utilize these results to concentrate on acoustic upgrades and marketing. The snapshot provided by this research provides insights that can be built upon in future research directions to encourage location efficiency and home location choices.

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2.6 Can We Make Our Office Buildings More Responsive? Energy Efficiency and Behavior in the Post-Pandemic Office

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KEYWORDS

occupant comfort, occupant well-being, responsive buildings, smart office, energy efficiency, behaviour, occupant-centred automation

1. Introduction

The COVID-19 pandemic has accelerated the switch between traditional office-working and flexible working solutions. In 2017, the European Commission calculated that around 10% of people were working from home[1], while in June 2020 between 30% and 65% were doing so full-time[2]. The urgency of meeting climate targets by 2050 requires the energy consumption of buildings to be cut by 40%[3]. In the post-pandemic world, even if office-working returns to being more relevant, flexible hybrid solutions are likely to remain[4]. The design and operation of office buildings will then have to be adapted to new working habits while becoming more energy-efficient, given the stricter climate targets that the post-pandemic world is facing.

Automation plays a key role in creating flexible design and achieving energy efficiency while maintaining adequate levels of occupant comfort and well-being, which includes minimising the risk of contagion[5]. However, the disruptive advent of the pandemic and extreme climate events have combined to show that the design of office buildings is not responsive or automated enough. For instance, during the first wave of the pandemic, several buildings were still consuming large amounts of energy, despite the low levels of occupancy. In addition, office buildings will have to re-adapt over short time scales to even more variable occupancy rates than before the pandemic.

This paper presents data on occupant satisfaction with office environments with and without automated controls before and after the COVID-19 pandemic. Its aim is to provide evidence of the importance of occupant-centred building controls and indoor environmental quality in the post-pandemic office. Offices in the post-pandemic world will need to devise an optimal occupancy distribution both to control the infection risk from COVID-19 and energy consumption while maximising occupant satisfaction. Flexibility, responsive design and the use of occupant-centred automated building technologies will need to become a core design principle in order both to preserve occupant health and achieve carbon neutrality[6].

2. Methods

Data on occupants' perceptions of their working environments is compared at a distance of one year before and after the COVID-19 outbreak in two different office environments, one with automated controls of the building envelope, the other with manual controls. The offices are located in Central London, and both had automated environmental services for heating, lighting and ventilation.

Linear mixed models and repeated measures are used to analyse the data. Environmental data are collected by means of a novel internet of things (IoT) toolkit before, during and after the pandemic. The toolkit was designed to capture high-resolution data on the visual, thermal and acoustic environments and air quality. In addition, interfaces for gathering occupant responses in respect of occupant discomfort and environmental satisfaction were included. Occupancy and energy consumption are also monitored by the respective building management systems.

3. Results and Findings

Volunteers had on average statistically significant higher satisfaction with daylight, the thermal environment, the level of personal control and the acoustic environment when working from home than with their pre-pandemic working conditions. In addition, they also felt generally more productive than in the office environment. The volunteers considered the improved levels of personal control and flexibility to be a main factor in their higher levels of satisfaction with their workload, despite possibly working for longer hours than in pre-pandemic times.

Occupancy of the building already showed greater variation before the pandemic, highlighting the potential for better occupancy regulations to increase occupant satisfaction whilst while reducing the use of energy and space. After the first lockdown, occupancy levels were extremely low, but the energy consumption of the buildings was only 50% lower than in pre-pandemic times. Despite the abrupt reductions in occupancy, energy consumption fell gradually throughout the first month of the lockdown, showing an inertial response to the change in occupancy by the automated environmental services.

In the office with automated controls for the building envelope, occupants experienced two scenarios upon their return to the office space. In the first scenario, the building envelope was manually controlled, while in the second scenario a hybrid solution was adopted, the envelope being controlled by a combination of automated and manual methods. In the hybrid scenario, occupants were more satisfied upon their return to the office environment in comparison to the office with the manual controls since they felt there was better indoor environmental quality due to the improved levels of daylight and view.

4. Discussion and Conclusions

Automated occupant-centred control of occupancy regulations, building envelopes and artificial services can play a key role in redefining the office environment in the post-pandemic world. Office environments will have to offer spaces that can enhance occupant well-being and productivity, promote social interactions and minimise the risk of infections. The post-pandemic office presents an opportunity to accelerate the use of smart building technology, which will ensure that workplaces are designed in flexible and personalised ways, while minimising resource-consumption by increasing the level of responsive behaviour by buildings. This will be also important in supporting the optimization of space use, workspace allocation and physical distancing. Interfaces for better human–building interactions will also be crucial in empowering occupants, thereby increasing their levels of perceived personal control in a safe manner, for instance, through the use of touch-free interfaces. A shift from compliance to performance-based design will therefore be required to support responsive building design.

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SECTION 3

BEHAVIOURAL INSIGHTS AND INTERVENTIONS FOR BUSINESSES

3.1 Empowering Intermediaries to Train Agro-food Companies in Tracking the Organizational, Cultural and Behavioral Barriers to Energy Efficiency Measures

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KEYWORDS

organizational culture, behavioural change, energy efficiency, intermediaries

1. Introduction

For countries to reach their CO_2 emission reduction targets, the adoption of emission reduction measures in industry needs to accelerate rapidly[1]. Because of their substantial impact on countries' CO_2 emissions, decarbonization options for energy-intensive industries have received substantial attention in research and policy[1,2,3]. Smaller emitters, such as the agro-food industry, receive relatively little attention, although they face many challenges. Cost-effective energy-efficiency innovations for these companies are available, but often they are not adopted because middle managers lack the resources to identify innovation opportunities or to persuade higher management of their merits (or both).

The literature on the drivers of and barriers to the adoption of energy-efficiency measures tends to focus on the technical and economic barriers[5]. Similarly, most interventions (i.e., tools, methods, guidelines) to help companies improve their energy efficiency focus on removing these barriers by providing knowledge and insights on the technical and economic aspects[6]. While it is acknowledged that organizational, cultural and behavioural factors have an impact on the eventual implementation of energy-efficiency measures, it is apparently difficult to address drivers and barriers of this nature, whether in research or in practice.

Whether interventions have a lasting behavioural impact on companies strongly depends on the ability of intermediaries (i.e., training companies or energy managers in large firms). Intermediaries are typically very knowledgeable about the technical opportunities to make energy efficiencies and how to identify and implement them, but often lack the skills to make companies actually want to adopt these measures[7]. Expanding their knowledge to cover the non-technical drivers and barriers that affect the implementation of energy-efficiency measures may increase their impact on the company's energy efficiency. Thus, approaches aimed at improving current practice by incorporating insights on organizational, cultural and behavioural change also need to take the role of these intermediaries into account. Such interventions should preferably be developed in close cooperation with these intermediaries and should pay attention to transferring knowledge transfer to them.

Therefore, in this study, we ask the following research questions:

RQ1: What organizational, cultural and behavioural drivers and barriers stimulate or hamper the adoption of energy-efficiency measures in companies in the agro-food industry?

RQ2: How can training programs address the organizational, cultural and behavioural drivers and tackle barriers to adoption, in addition to the technical and economic drivers and barriers?

RQ3: How can intermediaries be empowered to use insights about their client's organization, culture and behaviour to help them realize technical improvements in energy efficiency?

2. Background and Methodology

The study described here was performed as part of a capacity-building project to boost energy efficiency in the European agro-food sector (INDUCE, 2018-2020). At the heart of this project was the development and implementation of a training program through co-creation involving fifteen pilot companies in four different countries (the Netherlands, Germany, Spain, and France), four training companies, four trade associations and a team of social scientists.

The training program was based on studies of the barriers to organizational energy efficiency[8,9], strategic decision-making[7,10], cognitive social psychology[11], group decision-making[12] and organizational culture[13].

After conducting a concise review of the drivers and barriers to organizational energy efficiency, we conducted three empirical studies for each of the fifteen pilot companies: (1) a structured interview with the energy manager about energy-efficiency measures already implemented and organizational routines; (2) semi-structured interviews with four or five employees about the drivers and barriers to implementing energy-efficiency measures; and (3) a survey of organizational culture. Based on the individual pilot outcomes, proposals for training programs were developed and discussed with each pilot company in co-creation sessions. Development of the training program followed the publicly available Human-Centered Design method[1]. This resulted in programs that took into account what companies considered useful and achievable at the specific time the trainings were to be conducted.

1 *https://www.designkit.org/human-centered-design*

The co-creation process provided an opportunity for the training companies to learn how to develop training programs focusing on the technical, financial, cultural, organizational and behavioural barriers to effective energy management. The training programs were delivered to the companies by the trainers, with the support of the behavioural scientists. A twenty-hour train-the-trainer course was developed and implemented in each of the four countries, training approximately sixty other trainers in the method. Training results were monitored and evaluated for their effects on the drivers and barriers. Trainers also filled in a questionnaire to report on their experiences with the training formats.

3. Results and Findings

In addition to identifying known barriers and drivers related to organizational structure and resources, this study extended insights on barriers and drivers related to organizational processes, communication, culture and individual behaviour on all organizational levels. In subsequent training proposals, however, it proved difficult to get companies to take up these training programs to address these barriers and drivers. To the extent that training addressing these "soft" aspects was implemented, the focus was the workplace, not middle management or the boardroom.

The organizational culture of the pilot companies generally focuses on cooperation rather than competition. This finding is interesting because many employee training programs contain competitive elements. The findings of the present study indicate that such elements may backfire in interventions targeting employees in agro-food companies. Monitoring and evaluation results of the trainings are being produced at time of writing this abstract and will be available by the end of June 2021.

4. Discussion and Conclusions

RQ1: Drivers and barriers stimulating or hampering the adoption of energy-efficiency measures in the agro-food industry are not only related to organizational structure and resources, but also to organizational communication, processes, culture and individual (exemplary) behaviour.

RQ2: Co-creation sessions appear to work well in generating ideas for training the workplace, but the setting was not suitable for making tempting offers to middle management. A stronger commitment on the part of the boardroom might have made a difference.

RQ3: The project marked the start of a learning process for training companies. However, since training companies, like every company, suffer from resource constraints, it is tempting for them to stick to business-as-usual training methods. Repetitive use and evaluation of the training formats developed in this project will be important in consolidating the learning effect.

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3.2 Industries and Energy Efficiency Awareness Campaigns: Assessment of Energy Saving from the Italian Experience

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KEYWORDS

awareness campaign evaluation; information programme assessment; energy saving assessment; Italy

1. Introduction

In the challenge to create a net-zero carbon economy, combined with the diffusion of renewable energy sources, energy efficiency has an essential role[1,2], being the 'first fuel' for the energy transition[3]. In order to achieve a decarbonised society, the European Union has launched the European Green Deal and the 'Clean Energy for all Europeans' package', that sets ambitious energy and climate targets for 2030, including at least a 32.5% reduction in energy use. It also introduces the principle of 'energy efficiency first', as saving energy is the most accessible way of saving money for consumers and reducing GHG emissions[4]. The moderation of energy demand should be achieved throughout the whole energy chain, involving both citizens and companies. In this context, information and training campaigns become valuable support tools to disseminate energy-efficient practices, helping fill the 'energy efficiency gap'[5] and reducing the issue of imperfect market information[6,8]. Once information campaigns have been implemented, the next crucial step is their evaluation in terms of their real impact on energy savings. Nevertheless, ascribing punctual assessments of the reduction of energy uses to information campaigns remains a big challenge[9]. While various studies have evaluated the impact of information campaigns targeted on citizens, there is a lack of investigations assessing the impact of such campaigns on non-residential sectors e.g.[10,11]. The research presented here, which aims to reduce this gap, describes the Italian approach to assessing energy savings resulting from the national information and training programme. Through a survey dedicated to those companies that are the targets of the programme, the paper presents the approach employed to quantify energy saved by companies as a result of institutional activities aimed at supporting the implementation of energy-efficient practices.

2. Background, History, Review of Literature and Methodology

The European Union framework on energy efficiency is set out in Directive 2012/27 (EED), according to which, as an alternative to energy-efficiency obligation schemes, member states may adopt other measures to achieve their goals. These include information and training programmes (Art. 7 EED). Italy, under National Decree 2004/2012, implemented an information and training programme targeted at households and companies between 2015 and 2019.

In the context of energy-efficient policies, in the non-residential sector there is a literature gap in evaluating if and to what extent information and training campaigns are effective in stimulating the implementation of measures to reduce energy consumption. The investigation presented here aims to address this gap by following a two-step procedure. The first step was to analyse companies' energy savings and calculate their annual energy savings achieved through energy-efficiency measures. The next step consists in administering a survey to companies with the goal of evaluating the percentage of energy savings that can be linked to the information and training campaign.

According to Article 7 of National Decree 2004/2012, companies subject to a mandatory energy audit should notify the additional energy savings achieved each year to the Italian Energy Efficiency Agency. Therefore, this specific group of companies was employed in the subsequent analysis. The companies' communications on their energy savings were adopted as a baseline to estimate energy savings during the years in which the information and training programme was being conducted. Next a questionnaire using a Likert scale 1 to 5 scale addressing this group of companies was carried out (Figure 1).

STEP 1 - Companies (%) that did not obtain saving from (1) measures implemented to comply with the legislation and to remedy design errors and (2) measures implemented through state incentives)

STEP 2 - Companies (%) that considered the information and training activities carried out by Public Authority as "very important" in the decision to carry out energy efficiency intervention

STEP 3 - Companies (%) that considered the increased awareness on energy efficiency as significant role in the decision to implemented energy reduction intervention

STEP 4 - Results multiplied by the communicated energy savings

STEP 5 - Results multiplied by the correction factor (0.2)

Figure 1.

Evaluation process of the energy savings arising from the information and training programme.

3. Results and Findings

The results of the survey show that 190 companies (63.33%) declared not having obtained any energy savings from measures implemented to comply with the legislation or to remedy design errors, nor through state incentives (STEP 1). STEP 2 identified the 36 companies (12%) that considered the information and training activities 'very important' in their decisions to carry out energy-efficiency interventions. Next, STEP 3 showed that 281 (93.67%) of respondents considered their increased awareness of energy efficiency to have played a significant role in the decision to implement an energy-reduction intervention. STEP 4 multiplied the additional savings communicated by companies by the percentages obtained in Steps 1-3 by a correction factor of 0.2 (STEP 5). Total savings from the information and training campaign were 196.13 ktoe (Table 1).

Table 1. *Companies' final energy savings in 2015-2019 associated with the information campaign carried out in Italy.*

ENERGY SAVINGS (KTOE)

Year	2015	2016	2017	2018	2019	Total savings
2015	14.89					14.89
2016	14.89	11.25				26.14
2017	14.89	11.25	21.10			47.24
2018	14.89	11.25	21.10	4.47		51.71
2019	14.89	11.25	21.10	4.47	4.44	56.15
					Cumulated savings	**196.13**

4. Discussion and Conclusions

The process presented in the paper has allowed the energy savings that can be attributed to the information and training campaign targeted at Italian companies to be quantified. The cumulated savings for the period 2015-2019 amount to 196.13 ktoe, corresponding to 1.44% of the energy savings communicated by companies that are subject to the obligation to notify additional energy savings to the relevant national authority. The approach described here and its associated results have significant implications for the national authority, as they demonstrate support for the decision-making process. In fact, they provide a way of evaluating the effects of public investment in spreading an energy-efficient culture to the most energy-intensive national companies. However, the process is not free of limitations, mainly due to the simplification that has been made to extract tangible results for energy savings and to the restricted scope of the survey. Future research would consider extending the scope of the survey to information campaigns targeted at citizens.

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3.3 Barriers and Enablers for Property Owners of Premises as Organizations

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KEYWORDS

photovoltaics, property owners, commercial buildings, barriers, enablers

1. Introduction

The electricity-system transition needs to speed up in Europe if we are to reach the European Union's (EU) goals for renewable energy and reduced greenhouse gas (GHG) emissions. Photovoltaics (PV) have a potential role to play in this transition. There is huge potential in the roofs of all buildings, many of which would be suitable for PV installation. The importance of using commercial and non-residential buildings for PV installation has been highlighted in earlier research[1]. The International Energy Agency (IEA) forecasts increased PV deployment over the next five years[2], which also applies to the Nordic countries[1].

In recent years, there has been a trend to increase the number of prosumers, or consumers producing their own electricity in their own homes. Barriers to and enablers of the adoption of PV in residential buildings and privately owned houses have been relatively well studied[3,7]. However, the barriers to and enablers of PV adoption by the owners of non-residential buildings have so far been little studied. The aim of this study is to fill this gap through a literature review and by means of an empirical study in Sweden using a survey and semi-structured interviews.

2. Methodology

A literature review was conducted focusing on the barriers to and enablers of the installation of PV on non-residential buildings. The studied literature covered peer-reviewed articles, non-academic papers and the grey literature. This systematic literature review was conducted in line with Sovacool et al.[8] and Efron and Ravid[9] (see Table 1). The literature search was conducted in two phases, in spring 2019 and spring 2020. The second phase was conducted to update the literature that had already been collected. For the literature search, four scientific (article) databases were used, yielding a total of 533 articles. The abstracts of these 533 publications were read, selecting those dealing with non-residential buildings and solar energy, and including a discussion of what enabled or hindered PV installation. Twenty-eight articles were identified in the second round.

Table 1.

The five steps of the systematic literature review.

NO.	DESCRIPTION OF STEPS	
1	**Explicit research questions**	
	What barriers to and enablers of the installation of PV in non-residential properties can be identified?	
2, 3	Systematically searching the available literature with explicit criteria for inclusion or exclusion	
	Type of literature	Peer-reviewed articles, book chapters, conference proceedings and grey literature.
	Keywords	Three groups of keywords were used and combined for a total of 267 keywords used in the search. *Group 1 – Building type:* non-residential building, commercial building sector, commercial real estate, non-domestic building, retail sector, office, institutional building, commercial property, non-residential *Group 2 – Solar energy:* PV, solar (energy), prosumer *Group 3 – Barriers and enablers:* barriers, hindrances, challenges, incentives, drivers, motivations, opportunities, benefits
	Databases	*Scopus, Web of Science, Science Direct,* and *Google Scholar.*
4	**Determining and then executing a coding strategy or analytical protocol**	
5	**Analysing or synthesizing the collected evidence**	

Fifty-two structured and semi-structured interviews were also conducted with commercial property owners in Sweden. The topics covered in the interviews addressed different themes, but in this presentation we will focus on the perceived barriers to and enablers of PV installation. The categories for enablers and barriers are based on the literature review and the enablers and barriers discussed during the interviews. The interviewees were asked two structured questions with predefined barriers and enablers, as well as open questions about which hindrances and driving forces they had experienced in relation to PV installations. During the analysis, we qualitatively merged categories with similar content into one overarching category. This created broader categories, but in the analysis we also address which barriers each category covers.

3. Results and Findings

The most common type of barrier found in earlier research was related to economy (mentioned in twelve of the 28 papers). This barrier covered many different aspects, such as transaction costs, insurance costs, insufficient funds, and long pay-back periods. Information and knowledge barriers were often mentioned (in eight papers). This category includes difficulties in finding information about PV systems and a lack of awareness of the possibility of installing PV. Administrative or organizational barriers were also fairly common (five papers) and included, for example, split incentives and difficulties in sharing PV installation costs among tenants. The type of enabler most often mentioned in earlier research was the existence of subsidies, tax waivers and feed-in tariffs (nine papers). Other common enablers were environmental concerns (five papers), recognition that PV was a mature technology (three papers) and the possibility to earn money by producing electricity (three papers). These categories and what is included with each of them will be discussed further in the presentation.

Many of the barriers and enablers found in earlier research were also found in the Swedish study. Barriers mentioned in Sweden not found in earlier research included building construction barriers, lack of electricity storage and tenants' electricity supply contracts. Enablers found in Sweden that were not dealt with in earlier research included tenant demand, when the PV installation can be combined with renovation, and the possibility of selling own-produced electricity to tenants.

4. Discussion and Conclusions

This study advances our understanding of the barriers to and enablers of the deployment of PV perceived by non-residential property owners. A main barrier to PV adoption is related to economic factors. This barrier can be addressed through subsidies, tax reductions, feed-in tariffs, etc., Many barriers discussed by our respondents concerned the lack of easily accessed information and a lack of trust in the information given. This barrier could be addressed by a neutral third party tasked with disseminating information on PV.

This study is just a first step towards gaining a fuller picture of the barriers to and enablers of PV adoption facing non-residential property owners. Future research could study the non-residential buildings and their ownership in more detail in order to acquire a more differentiated understanding of non-residential actors. Different buildings have different barriers and enablers, and a comparison of, for example, hotels, schools, offices and large storage facilities is one approach lacking in research today. More empirical studies of barriers and enablers are also needed.

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3.4 A Gap Analysis of the Literature on Energy-saving Behaviours in the Commercial Sector

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KEYWORDS

energy efficiency, behaviour, hard-to-reach, underserved, commercial sector

1. Introduction

As a means of enhancing sustainability, reducing demand on the power grid and saving energy costs, influencing energy-saving behaviours (ESB) has gained in popularity in recent years. While enthusiasm stretches across stakeholder groups (e.g., utilities[1], policy-makers[2], consumer groups[3], and more), action and attention have largely focused on the residential sector, being limited at best in both quantity and quality when applied to the commercial sector. This disparity between the effective identification, study and promotion of ESB in the residential as opposed to the commercial sector suggests a potential opportunity for significant energy savings along with all their associated benefits by giving ESB in the commercial sector increased attention and focus.

ESB in the commercial sector comes with inherent difficulties in defining opportunities and identifying optimal measures for the wide variety of commercial sub-sectors that exist and the actors engaged with them. This affects what the commercial sector as a whole is like and how it should be treated for research and intervention purposes. These challenges explain, at least in part, why the commercial and residential sectors are treated quite differently regarding ESB. In this paper, we provide a gap analysis of the literature on commercial ESB and call for action to address and overcome them.

2. Methodology

The methodology for this work consisted of a comprehensive, narrative literature review of primary and secondary literature on the topic of commercial energy behaviour from the last fifteen years. Articles were identified via keyword search, outreach to professional networks and backward and forward reference searches of key references. All articles were reviewed by one or more primary authors and coded for the inclusion of specific commercial building types and ESB. We then summarized the findings into a summary report, which was delivered as a technical report to the study funders[4].

3. Findings

Overall, we identified three key gaps in the literature.

3.1. Generalization of Commercial Building Use

One evident trend was the tendency to treat the commercial sector as a single, homogeneous entity[5]. While the residential sector can reasonably be addressed holistically (despite differences in home and types of tenure, general cross-over of ESB applies across most households), the commercial sector is made up of too many unique types of buildings and business uses for such a one-size-fits-all strategy to be effective[6]. The diversity of the commercial sector and even its sub-sectors (e.g., fine dining will have different opportunities than fast food) makes it difficult to take all commercial building types into account at once, while addressing each unique sub-sector individually requires significantly more investment than simply tackling the more homogenous residential sector.

3.2. Overrepresentation of Research on Office Buildings

When the available literature does drill down into the specifics of commercial buildings, most papers focus solely on office buildings[7]. While office buildings are ubiquitous and have many opportunities for energy-saving interventions, this focus neglects the significant opportunities that can be achieved in other commercial sub-sectors. While a smaller body of literature was found to address sub-sectors like hospitals[8], education[9] and retail[10], the quantity of this literature was significantly less, the usefulness of the recommendations more questionable, and other areas of the commercial sector (e.g., food services, grocery stores, lodgings and many more) were left largely unexamined.

3.3. Focus on Equipment and Purchasing

When discussing specific forms of ESB, the available literature tends to focus on upgrading equipment[11] and does not delve into less obvious but equally significant energy-saving opportunities. The existing literature tends to overlook opportunities for maintenance and curtailment behaviours, which are much less capital-intensive and can be implemented in between purchasing cycles[12]. When research does include non-purchasing behaviours, it tends to use a predefined set of assumed opportunities (e.g., lighting, computers, heating and cooling), rather than studying what the ideal target behaviour should be, especially when moving beyond these surface-level opportunities.

4. Conclusions and Recommendations

To realize the significant savings potential of commercial unexplored ESB, additional research is needed. Rather than continuing to focus on the overall sector, we recommend significant investment in "small science", that is, numerous smaller and more focused studies of individual sub-sectors and/or ESB within the commercial realm. Unfortunately, a one-size-fits-all approach will continue to neglect potential ESB that is unique to hospitals, grocery stores, restaurants, dry cleaners and the dozens, even hundreds, of other unique commercial building uses in the world. We encourage more funders to support this work and more researchers to undertake it because our planet is depending on it.

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3.5 What Can Entrepreneurs and Their Business Models Contribute to Accelerating the Energy Transition?

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KEYWORDS

new business models, institutional work, flexibility services, entrepreneurship, transition, system change.

1. Introduction

Given all the attention the energy transition attracts nowadays, one could easily imagine that doing business in this market is an easy ticket to success. Sadly, this is not the case. In reality, only a relatively small group of entrepreneurs is able to take advantage of this sense of urgency or even to challenge the current unsustainable institutional arrangements. We found that those energy service entrepreneurs that manage to build strong business models are successful in making their innovations legitimate and accepted, and thus demonstrate very specific behaviour. This behaviour can be defined as the capacity to act for change[1,2], which involves the ability to align resources, discourses and social position.

2. Background, History, Review of Literature and Methodology

Previous research on the apparent lack of market uptake of energy-efficiency facilities found that entrepreneurs that adopt a service-oriented business model and that have the skills needed to deliver a service (sensing, conceptualizing, orchestrating and scaling) are usually more successful at creating mass uptake (growing a market share) than those with a traditional product-push approach[2,3,4]. Given the important role entrepreneurship can play in the energy transition, we set out to improve understanding of how the uptake of more radical business models and services, (i.e. those that challenge the existing system, such as community virtual power plants or microgrids, retrofitting as a service, heating as a service, or demand response as a service) can benefit from the servitisation-directed behaviour of the organisation. We explored this question with a research team from four countries: the Netherlands (coordinator), Australia, Ireland and Sweden. The research was based on a dynamic, qualitative research methodology involving desk research, a literature review, more than 75 interviews and more than 60 case studies[2].

2 *As part of the annex 'Energy business models and systems' under the Technology Collaboration Programme 'User centered Energy Systems' by the International Energy Agency.*

3. Results and Findings

Our research found that only a few of the more radical types of energy services and business models are successful at being accepted and embedded, and that this usually involves successful attempts by the entrepreneurs to create changes to technological, infrastructural, regulatory, institutional or cultural arrangements to help embed the service. Most radical services, however, are not successful. Instead, these business models and services need to adjust to survive, tone down their level of innovation and become more "business as usual", with the result that the potential transformative contribution they could make to the energy transition does not materialise[5,6].

Those entrepreneurs that are successful at delivering innovative services demonstrate a very specific set of skills or practices. What characterises these entrepreneurs, or entrepreneurial teams (some of them are consortia or energy communities), is first of all that they have a set of skills that allow them to deal with the specific characteristics of a system in transition, such as the energy sector: complexity, uncertainty, technocracy, organised irresponsibility and contestation. These skills include the ability to mobilise diverse actors and promote collective action, create strong formal and informal social positions in relevant networks, cultivate strong relationships with key stakeholders, secure important resources, and frame discourses within those networks and on a more social level.

The second clear characteristic of these entrepreneurs is that they are very capable of turning systemic challenges into opportunities. They use the system barriers as the raison d'être and legitimation for their business model. Some of them even go a step further to develop their service and business model with the explicit aim of contributing to changing policy or regulations, providing answers to social problems and contributing to social discourses. This type of entrepreneurship is called "", and the skills discussed above, when combined, create institutional power or agency[2,7,8,9,10].

One example of such an institutional entrepreneur is the Microgrid Electricity Market Operator or MEMO in Australia. MEMO was set up by Monash University in collaboration with several market actors to contribute actively and strategically to the reconfiguration of the electricity system in Australia. MEMO was successful in achieving this, with new regulations stemming from this experiment. They demonstrated strong systemic thinking and strategic capabilities, analysed the market in-depth, positioned themselves in a new role in a changing market, took the lead, were very agile and adaptive, used their strong lobbying capabilities, mobilised networks, and informed policy and reforms of regulatory and market design at the state level by framing discourses from a strong formal social position.

4. Discussion and Conclusions

These types of institutional entrepreneur are very important in accelerating the energy transition. One way of approaching this is to increase the number of institutional entrepreneurs. Training and developing capabilities and adjusting business models so they are more oriented towards service and the transition will certainly help. However, apart from the fact that institutional skills are only transferrable to others to a certain extent, despite their success, and that much more research is needed to understand this specific agency, these entrepreneurs are operating in a system that falls short in supporting them and their transformative or transition-supporting service. At the moment this system is not yet "fit to serve" these more radical energy services, and much more research is needed on what such a supporting system could look like.

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SECTION 4

BEHAVIOURAL INSIGHTS AND APPLICATIONS IN DEVELOPING COUNTRIES

4.1 Lighting and Occupancy Behavior of Preschool Classrooms: A Field Study in Brazil

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KEYWORDS

kindergarten classrooms, behavioural observation, occupancy, illuminance.

1. Introduction

The built environment is a key part of any education programme that influences the learning processes and behaviour of children[1]. Some studies have revealed differences in children's behaviour due to the spatial definition of the classroom[2,3], as well as some associations between classroom densities and aggressive attitudes in toddlers[5]. Recently, researchers have found that variables in environmental comfort influenced children's academic performance up to 50% and that the lighting and flexibility of the classroom had a greater impact on children's general progress[4,8]. Furthermore, a previous study found that in free choice situations children stayed in the classroom area when illuminance was greater than the average illuminance of the space[9].

Studies of environmental comfort with children in the early years of schooling are still scarce due to the challenges of data collection. Behavioural mapping has been shown to be a useful technique for gathering information that cannot be acquired through users' self-reporting[10]. In classrooms, especially in kindergarten or pre-school, teachers usually control the environmental settings and spatial configurations, leaving the children with only a passive role. This suggests that understanding young children's behaviour in the classroom could be an alternative pathway to creating better indoor educational environments.

This paper aims to identify the use and occupation characteristics of kindergarten classrooms. The characteristics of the luminous environment during different activities are identified, and the relationship between the occupied areas and the illuminance range are further analysed.

2. Methodology

The data were collected through field studies in pre-school classrooms located in Florianópolis, Brazil (Latitude: -27,60°, Longitude: -48,54°), from March to December 2016 and involved the participation of 84 children between four and six years of age. In each of the three kindergartens considered in this study (identified as "A", "B" and "C") two classrooms were assessed (identified as "1" and "2"). The specifications of the classrooms are shown in Table 1 and Figure 1. Table 1 also gives the periods of data collection for each classroom.

Table 1. *(a) Classrooms characteristics and, (b) Months and number of days for data collection*

Kinder ID	A	A	B	B	C	C
Classroom ID	1	2	1	2	1	2
Plan shape	Rectangular		Irregular		Square	
Area (m²)	44.5		37.6		26,01	
Room height (m)	3.4	3.4	2.8	2.8	2.4	2.4
Orientation	SW	NE	NE	NE	NW	SW
External glazing area (m²)	0.25	0.22	0.16	0.16	0.12	0.14
Window-sill height (m)	1.04	1.04	0.7	0,7	1.3	1.0
Number of luminaires	8	8	3	3	2	2
Lamp type	Fluorescent T8					
Number of children	21	20	26	25	11	12
Children age (yrs)	4.6	5.7	5.0	5.9	4.6	5.8

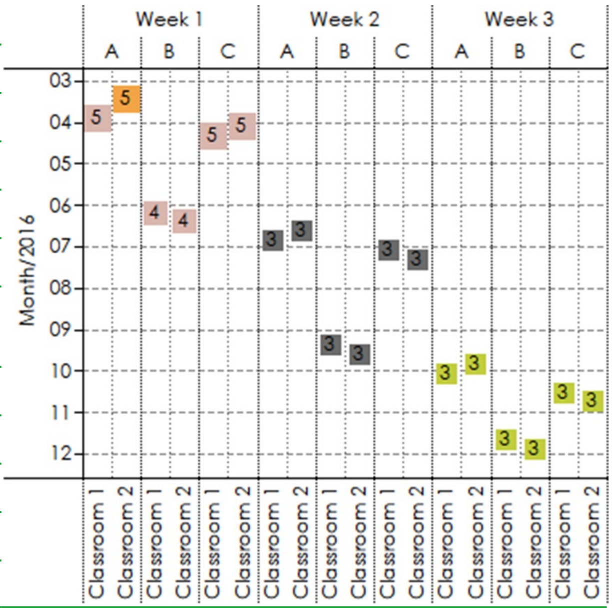


Figure 1. *Pictures of the selected two classrooms in each kindergarten.*

The information on the time and occupancy characteristics of the classrooms was surveyed by direct and indirect methods of behavioural observation and examined through behavioural mapping. Simultaneously, illuminance measurements were taken using a grid of nine Hobo U-12 data loggers. The illuminance data were plotted in iso-illuminance maps, and the mean illuminance values during the activities were calculated. The illuminance data and the classroom areas occupied by the children were studied together.

3. Results and Findings

3.1 Occupancy behaviour

The activities performed in the classrooms ranged from an organized arrangement involving the whole class to free activities in smaller groups. The behavioural maps allowed us to identify the different ways in which the classrooms were occupied by the children. In Kindergarten "A" the main configuration for classroom occupancy was to have children in a rectangular, since most of the activities were directed by the teacher. In these two classrooms, the teachers also placed the children in the middle of the space, leaving some areas unoccupied (see Figure 1).

In kindergartens "B" and "C", by contrast, each child was free to choose any spot in the classroom to perform the activities. In the four classrooms in "B" and "C", the most common occupancy configurations were a large circle containing all the pupils and small groups of children (see Figure 1). In kindergarten "B", children occupied the classrooms homogeneously during the activities. However, during those activities that were performed in circles, those areas next to the windows were the most heavily occupied. Although the classrooms in Kindergarten "C" were the smallest, during most of the observation time the children in this kindergarten were more homogeneous in their arrangement within the classroom area than in the other kindergartens.

3.2 Lighting in the classrooms and daylight illuminance ranges

Under daylight conditions between 1 pm and 5 pm, the average illuminance value of the classrooms was 479.5 lux (DP= 295.7 lux). For those periods in which artificial lighting was used, the average illuminance value was 461.4 lux (SD= 743.8 lux). Figure 2a shows, per classroom, the average illuminance during each activity. Regarding the use of artificial lighting system, with the exception of classroom "B1", the lamps were turned on for more than 50% of the observed period (Figure 2b). Conversely, the blinds remained open in all classrooms on average for 92% of the observed period, being closed only at specific moments.

In a preliminary analysis, lighting distribution was assessed based on the average illuminance and occupancy area of each activity, through three illuminance ranges. The iso-illuminance maps were used to calculate the areas within each of the following ranges:

- "Superior" for areas with illuminance greater than 3000lux

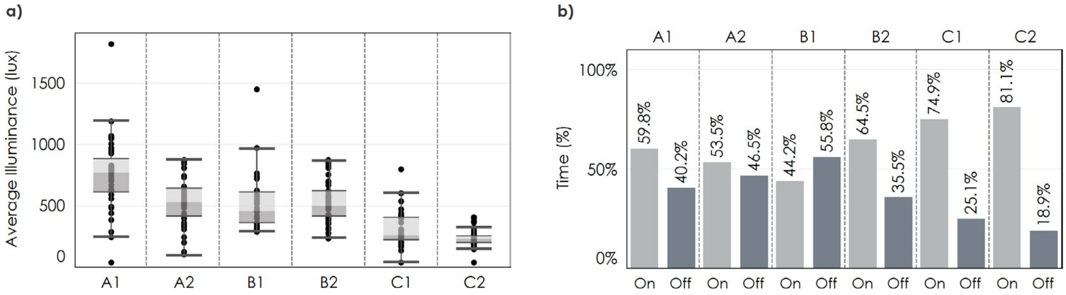
- "Useful" for areas with illuminance less than 3000lux and greater than 300lux

- "Inferior" for areas with illuminance equal to or less than 300lux.

Figure 2:

a) Average illuminance during activities;

b) Time of use of artificial lighting in each classroom.



Due to the use of average illuminance during classroom activities, the classrooms did not have areas with illuminances within the "Superior" range. The overlapping of the occupancy maps with the iso-illuminance maps allowed us to determine that the highest children's occupancy was in those areas of the classroom with illuminances in the useful range (Occupied areaavg= 60.7%; SD= 37.3%), not in the inferior illuminance range areas (Occupied areaavg= 39.3%; SD= 37.5%).

4. Discussions and Conclusions

During 64 days of data collection in six preschool classrooms, it was revealed that, despite the differences derived from each kindergarten's pedagogical model, the average classroom area occupied by the children varied from approximately 44% to 51%. a preliminary analysis of the illuminance range showed that the studied classrooms had most of their areas in the "Useful" illuminance range, meaning that the children tended to be located in those areas with illuminances greater than 300lux. However, in this study the average illuminance during an activity was used to analyse the lighting distribution, which is a limitation of this approach. Even when the classroom's use characteristics are guided by the pedagogical models, the teachers are in charge of the spatial configurations and environmental settings. This highlights the importance of observational studies in this type of building to improve the technical criteria and design of the facilities. In future steps, the methods of analysis will be extended in order to identify occupancy behaviour in relation to illuminance levels.

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4.2 Understanding Occupants' Behavior and the Mixed-Mode Strategy in Office Buildings in Southern Brazil

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KEYWORDS

mixed-mode buildings, behaviour, subtropical climate

1. Introduction

Occupants' behaviour is one of the most important factors to impact on indoor building environments and energy use[1]. Studies have shown that there is a gap between predicted and actual energy use due to poor consideration of the occupants' behaviour[2,4]. The objective of this study is to improve understanding of occupants' behavior and describe a mixed-mode strategy for ventilating and climatizing office buildings in southern Brazil. Mixed-mode or hybrid ventilated buildings integrate the natural ventilation and the air-conditioning system by responding to thermal conditions (e.g., through an automation system) or through occupant intervention (e.g., opening windows). Models of adaptive behaviour often focus on actions aimed at adapting the environment to the occupant's needs (e.g. window and solar-shading operations, adjusting thermostats, etc.)[5,8]. Few papers have focused on actions aimed at occupants' adaptation to the prevailing conditions such as adjusting one's clothing or the consumption of hot and cold beverages[9,10]. In this work, we intend to go beyond the typical behavioural models of building simulation to provide insights into other adaptive actions, such as changing clothes and drinking habits during working hours.

2. Method

This research is based on data collected during two years in three mixed-mode office buildings located in southern Brazil. The buildings are located in the humid subtropical climate of Florianópolis (latitude: -27° 36', longitude: -48° 33' and altitude: 7m). The mixed-mode strategy was manually controlled, that is, the occupants decided themselves when to shift between natural ventilation and air-conditioning (AC) mode.

Classic field studies were carried out of thermal comfort, along with simultaneous indoor environmental measurements and the circulation of questionnaires. The detailed methodology and the results were published in[11]. Questionnaires included background questions and asked the occupants about their thermal perceptions and adaptive actions (e.g., drink intake and clothes adjustments) just before answering the survey. During the field studies, the researchers monitored the operation of the AC system, fans and windows, and occupants' drink intake and clothes adjustment in real time and then analysed these data.

In order to understand occupants' behaviour and the principle of mixed-mode operation, multiple logistic regressions were performed with environmental variables (e.g., indoor and outdoor temperatures) as predictors, and windows, fans or AC operation as the binary outcome (0 = windows closed, fans off or AC system off; 1 = windows open, fans on or AC system on). Also, four sets of multiple logistic regression analyses were conducted with environmental variables and thermal responses (e.g., thermal sensation vote) as predictors and drink intake (hot or cold beverages) or clothes adjustments (adding or removing an item of clothing) as the binary outcome (Table 1). We also performed simple logistic regression between the outdoor temperature and AC operation with the aim of providing some guidance for building energy simulation practitioners.

3. Results and Findings

The data we collected consist of 5,470 indoor environmental measurements linked to subjective data and behavioural observations.

We found that the probabilities of either adding or removing an item of clothing were associated with the thermal sensation vote and the outdoor air temperature (Table 1). The probability of drinking a cold beverage was associated with the indoor operative temperature, outdoor temperature and mode of operation (natural ventilation or AC) (Table 1). The probability of drinking a hot beverage was related to the thermal sensation vote and indoor operative temperature (Table 1), but this model cannot be generalized beyond the actual data due to local cultural aspects influencing the consumption of hot beverages. A statistically significant model was not achieved for the fan operation.

The outdoor temperature and indoor operative temperature were strong predictors of AC operation (Table 2). The AC operation (i.e., AC is turned on) is 2.09 times (OR=2.09) more likely to happen for each 1.0°C increase in the outdoor temperature. In contrast, the AC operation is 0.64 times less likely to happen for each 1.0°C increase in the indoor operative temperature.

The negative association between indoor temperature and AC operation may lead to the counterintuitive conclusion that occupants were less likely to turn on the AC at high temperatures. However, the negative correlation may simply be an effect of the lower indoor temperatures caused by AC. As a consequence, measurements of indoor conditions cannot be used to predict the AC operation, since they are affected by the variable they are predicting. In contrast, climate data used for building energy simulation is not affected by the AC operation and may be used as a predictor. We derived a logistic model that treated only the outdoor temperature as a predictor of AC operation. Figure 1 shows the probability of AC operation as a function of the outdoor air temperature. As expected, the AC operation occurred mainly in warmer outdoor conditions. Above 25.0°C it was highly likely (>90% probability) that offices relied on cooling. Below 19.0°C, there was a lower probability (<10%) that the AC was operating.

Table 1.

Logistic regression models of drink intake and clothing adjustments as a function of environmental variables and thermal responses.

Outcome variable	Binary outcome	Logistic model
Probability of drinking a hot beverage - P(Hdri)	0 - Drank nothing 1 - Drank a hot beverage	$P(Hdri) = \frac{1}{1+e^{-(1.55-0.16To-0.13TSV)}}$
Probability of drinking a cold beverage - P(Cdri)	0 - Drank nothing 1 - Drank a cold beverage	$P(Cdri) = \frac{1}{1+e^{-(-3.78-0.27MO+0.09To+0.05Text)}}$
Probability of adding an item of clothing - P(Aclo)	0 - No clothes changed 1 - Add an item of clothing	$P(Aclo) = \frac{1}{1+e^{-(-1.99-1.15TSV-0.11Text)}}$
Probability of removing an item of clothing - P(Rclo)	0 - No clothes changed 1 - Remove an item of clothing	$P(Rclo) = \frac{1}{1+e^{-(-0.93+0.84TSV-0.16Text)}}$

Note: all parameters and models with $p<0.001$. N=5,470. *To:* indoor operative temperature; *Text:* outdoor air temperature; *TSV:* thermal sensation vote (seven-point scale from -3 to +3); *MO:* mode of operation (0=Natural ventilation; 1=AC).

Table 2.

Logistic regression model of air-conditioning operation as a function of outdoor temperature and indoor operative temperature.

AC operation	Coefficients (*b*)			95% CI of Odds Ratio (OR)		
Predictors	*b*	Wald	Sig.	Lower	OR	Upper
Outdoor temperature (°C)	0.74	1168.87	$p<0.001$	2.00	2.09	2.18
Indoor operative temperature (°C)	-0.45	163.87	$p<0.001$	0.59	0.64	0.68

Note: Model intercept= -4.91, p<0.001. Model $\chi^2(2)=3058.96$, $p<0.001$. $R^2=0.57$(Nagelkerke). $N=5,470$.

4. Discussion and Conclusions

The study produced some insights into occupants' behaviour, such as patterns of changing clothes and drink-intake habits. Further studies are needed to assess the impact of such actions on workers' productivity and well-being and to perform a thorough evaluation of the indoor environmental quality (e.g., air quality) of mixed-mode buildings.

Figure 1 may provide a better understanding of the mixed-mode strategy in office buildings in southern Brazil. As expected, the air-conditioning was more likely to be operating in warmer outdoor conditions. A logistic model was generated for office buildings in southern Brazil, which may be used as input to building simulations, improving the prediction of energy use. It is important to stress that during the field studies more than 80% of the occupants reported being in thermal comfort, i.e., the mixed-mode strategy provided good indoor thermal conditions. In the studied climate, it was predicted that mixed-mode buildings could save 30-35% of energy used for climatization in comparison with fully air-conditioned buildings[12]. Besides the energy savings potential, this work shows that adoption of the mixed-mode strategy provided thermal comfort to occupants.

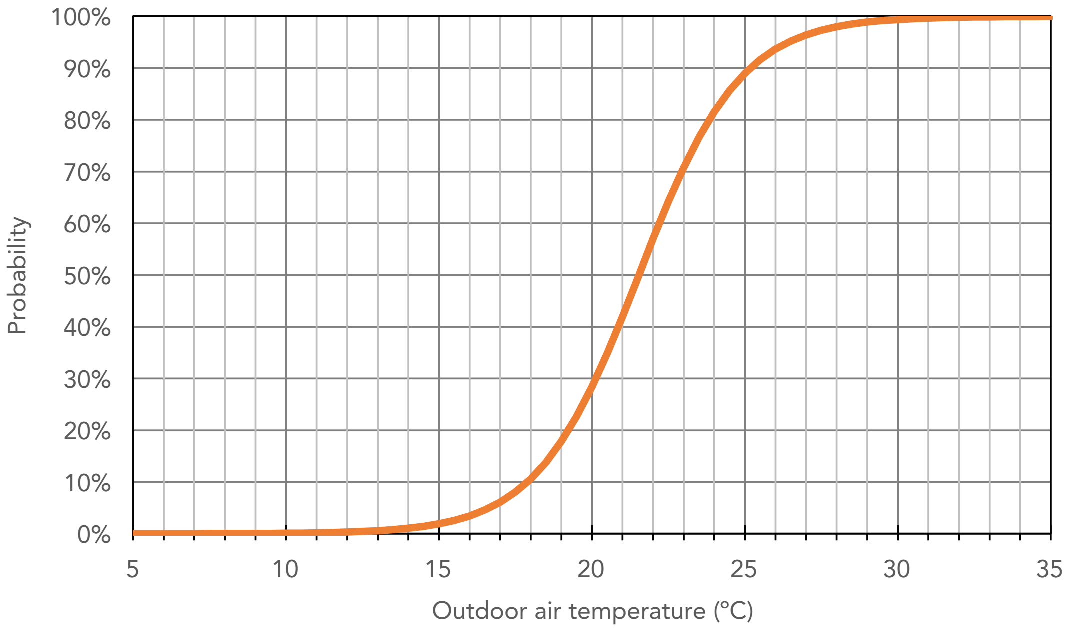

Figure 1.

Probability of air-conditioning operation as a function of the outdoor air temperature for mixed-mode office buildings in southern Brazil (Logistic model intercept= -12.99; b=0.60, p<0.001).

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4.3 Sustainable and Liveable Cities for People: Insights in Energy Consumption Patterns, Sustainable Buildings and Neighbourhoods in Phnom Penh, Cambodia

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KEYWORDS

pro-environmental behaviour, energy consumption, behaviour change, new consumers, sustainable urban transformation

1. Introduction

Recently, Cambodia's rapid urbanization has been continuing alongside a construction boom and widespread socio-economic changes. Given the increasing purchasing power of the emerging urban middle class (the so-called new consumers) and associated lifestyle changes, social impacts on the environment have been substantially increasing[1]. Despite high electricity prices, newly constructed buildings are usually neither energy-efficient nor adapted to the tropical climate and have massive direct and indirect environmental impacts. In order to confront this problem, the aim of the trans-disciplinary *Build4People* project is to take into account the urban context and socio-cultural and technical dimensions when supporting sustainable strategies and planning processes to enhance energy-efficient buildings and lifestyles. The social science research within the *Build4People* project focuses on analysis of the constraints on and motives for sustainable lifestyles, the demands for housing and the urban built environment in Phnom Penh on the part of urban citizens, and pathways towards transformations of sustainability in urban spaces.

2. Background, History, Review of Literature and Methodology

Understanding and explaining behaviour can be considered the initial condition for being able to find ways to change a certain individual in an environmentally friendly direction[2]. Behavioural change can occur in different domains of life, both individually and collectively. Since behaviour is always shaped by its context, the aim of changing a certain type of behaviour needs to take such contextual determinants and dynamics into account[3]. Furthermore, behavioural change can be understood as a part of a wider transition of socio-technical and socio-political (sub-) systems such as the building sector. A better understanding of such systems (in our case the building system) also increases our understanding of individual behaviour, making possible better intervention strategies. At the same time, a better understanding of socio-psychologically determined norms, values and behaviour refines the analytical depth of the system from the perspective of transition studies. This enables the development of suitable transition strategies beyond a focus on individual behaviour (i.e. other actors, institutions, policies, etc.). Linking the micro- and macro-scales by analysing individual behaviour and the wider building system in urban areas from the environmental psychological, transition and urban studies perspectives, our research addresses the key challenge of *bridging scales* in the context of sustainability transitions[4,5].

We aim to address behavioural change in the direction of sustainable lifestyles through different interventions and modes of dissemination, and towards transformative change in the building sector's socio-technical and socio-political systems that will encourage pro-environmental behaviour and consumption. With regard to the building system, Durdyev et al. (2018) report low levels of awareness and knowledge of sustainable construction practices within the industry and the tendency to associate sustainable construction with environmental sustainability, as well as "life quality"[6]. It is still unclear what kinds of knowledge or awareness of which elements of green building need to be considered. Furthermore, research on the transition and system thinking suggests that the underlying interconnections between the different factors and causal relationships should be accounted for in a more systemic way[7]. It becomes clear that a much deeper understanding of the Cambodian building sector, including the user's perspective, its cross-linkages to other sectors, the urban development regime and its rural-urban interlinkages, are necessary to initiate and support transformational change towards urban sustainability.

Our empirical approach uses a mixture of different methods. Through qualitative interviews with representatives of local universities and NGOs (N=6), initial insights into the relevant cultural and contextual factors that influence perceptions of environmental problems, the energy consumption of households and the social norms of pro-environmental behaviour were obtained. Semi-structured interviews with stakeholders from the building sector (N=20) have complemented the insights on the individual level and extended our understanding more systemically. This included interviews with local and national state actors, architects, NGOs, investors, consultants and representatives of real estate and construction companies. In addition, the pre-test results of a standardized questionnaire conducted among urban households (N=30) provided insights into the culturally specific aspects, the environmentally relevant mind-set and pro-environmental behaviour.

3. Results and Findings

Based on the initial results of the pre-test and the elaboration of our questionnaire with our Cambodian research partners, we will adapt psychological measures to Cambodia's social context. The development of more environmental education is suggested as a way of raising awareness of environmental concerns. Energy-relevant behaviour and underlying factors that could contribute to changing attitudes more in the direction of pro-environmental and energy-saving behaviour will be discussed based on the survey's results. The specific characteristics of Cambodia's socio-cultural and political contexts will be taken into account, as will the role of social norms and behavioural constraints in relation to pro-environmental behaviour. The survey results provide insights into the culturally dependent psychological mechanisms that need to be considered when using psychological models of behaviour that are derived from and frequently applied in studies of western cultures rather than the regional context of Cambodia.

The interview results suggest that approaches by combining attractive (economic) incentives, capacity mobilization and innovations in governance to counter institutional and market disjointedness will be the most promising in supporting energy-efficient behaviour and facilitating a sustainability transition in the context of Cambodia's built environment.

4. Discussion and Conclusions

A deeper understanding of the factors that influence environmental awareness and pro-environmental behaviour in Phnom Penh will support the development of tailored behavioural interventions for energy-saving and educational programs to promote sustainable lifestyles and environmental awareness. At the same time, behavioural insights may inform the development and discussion of approaches to transition governance and transition strategies, including policy instruments and business models.

We regard saving energy as one potential behavioural domain that can be achieved through tailored interventions with new consumer households that would have a relevant impact on environmental issues. Besides, consideration of the above-mentioned approaches to the economic, political and technical paths towards a sustainable urban transition within the building system may lead to the development of supportive contextual factors for energy-sufficient lifestyles.

The transdisciplinary research evidence discussed here indicates that a combined consideration of individual behaviour and of the general socio-technical and socio-institutional system of the urban built environment can contribute to more holistic understandings and more promising interventions and policy mixes than isolated studies.

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4.4 Empirical Assessment of Sociotechnical Factors Influencing Residential Electricity Use in India

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KEYWORDS

residential energy use, households, India, behaviour

1. Introduction

Residential energy use (i.e. electricity) in India is projected to increase four-fold by 2030, yet there is limited data or understanding of how electricity is used in Indian households. This paper investigates empirically *how* and *why* electricity is used in Indian dwellings with and without air-conditioning (AC), using an interview-based survey approach applied in 41 dwellings located across two cities (Hyderabad and Jaipur) representing the composite climate of India. Statistical analysis (multi-variate regression) is used to analyse the co-relations between the physical characteristics of dwellings (such as built form), income group, occupancy patterns, socio-demographics and appliance usage in AC and non-AC dwellings that influence household electricity-using behaviour. The study is part of a wider Indo-UK research programme called RESIDE – Residential Building Energy Demand Reduction.

2. Background and methodology

Residential electricity consumption (REC) in India has nearly tripled in the past two decades and accounted for 24.2% of overall electricity consumption in 2019[1,2]. This increase was due to an increased use of space cooling and other electrical appliances driven by increased access to electricity, improved socio-economic status and rising expectations concerning thermal comfort[1,3,5]. In order to develop residential energy policies or programmes, a deeper understanding of REC and end-use energy behaviour is essential[6]. Internationally, various studies have examined the determinants of residential energy-use that include the physical characteristics, socio-demographics, occupant behaviour and electricity tariff subsidies[7,9]. However, such studies on India are lacking. In 2013, a review of data quality related to building performance for residential and commercial buildings in four world regions (India, China, the United States and EU) found that building performance data for the residential and commercial buildings sectors was weakest in India. Accessibility to such data, whether national, regional or local, is very limited due to the lack of substantial funding, a general lack of interest and the absence of the requisite technology[10,11]. Recently the India residential energy survey (IRES) has investigated the level of energy access in rural and urban dwellings, with a limited focus on the sociotechnical factors that shape urban residential electricity use[3].

This study was designed to gather bottom-up sociotechnical data for 41 dwellings accomodating 41 households) using an interview-based questionare survey implemented online on Google form. Data were gathered about physical and household characteristics, socio-demographics, occupancy and appliance usage. Historic electricity bills were collected for one year (2018-2019). Initially 47 dwellings were recruited using purposive sampling, however, a complete set of data were only available for 41 dwellings, of which 22 were located in Hyderabad and 19 in Jaipur. Low-income (LIG), middle-income (MIG) and high-income groups (HIG) were defined using the income slabs recommended by the Government of India (Pradhan Mantari Awas Yojana). The empirical data were prepared for regression analysis through checking for collinearity, normality, removing highly correlated variables and transformation of variables where necessary for an unbiased result[12]. Multi-variate regression analysis was conducted to establish the strength of the relationship between the different variables and annual residential electricity use.

3. Results

The 41-dwelling sample was split into 16 LIG, 16 MIG and 9 HIG households occupying a total of 12 apartments and 29 detached houses. While 28 dwellings had one or more ACs each, 13 had no ACs, especially in the LIG dwellings. As expected, mean annual REC was observed to be highest in HIG dwellings (5618 kWh), followed by MIG dwellings (3870 kWh), and was lowest in LIG dwellings (2169 kWh). The difference in electricity use across the seasons was evident since average monthly electricity use and cost across the 41 dwellings were found to be 375.23 kWh and US$29 respectively in the summer or monsoon season, falling to less than half in the winter at to 182.12 kWh and US$11 respectively.

Electricity consumption with respect to the income group and AC/no-AC dwellings is represented in Figure 1below.

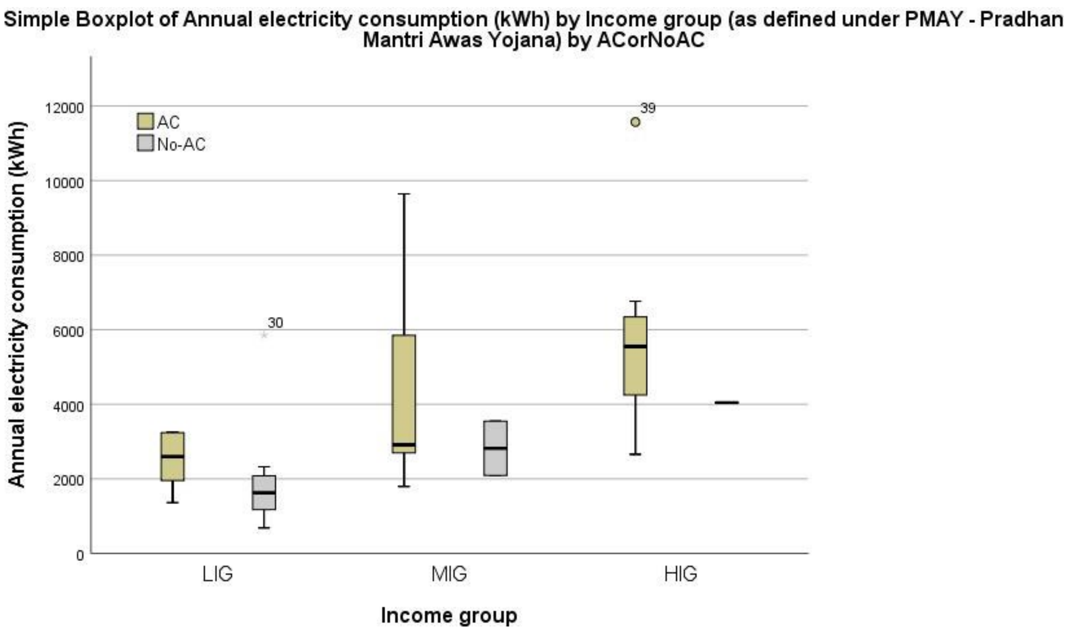

Figure 1.

Distribution of annual electricity use across different income groups with and without ACs

Appliance ownership data showed that 98% of the households owned a refrigerator and television, while 68% owned an air conditioner. The mean annual REC for AC dwellings was found to be 4,208 kWh, nearly double that of dwellings without ACs (2,260 kWh). Although HIG dwellings reported higher use of AC in the summer than LIG and MIG dwellings, about 7% of AC dwellings reported non-usage of AC, implying that having an AC does not mean it is also being used regularly. Analysis of annual hours of use for appliances excluding ACs by different income groups revealed that LIG dwellings had higher annual use hours, despite owning a smaller number of appliances.

A regression model was developed to examine the variation in electricity use across the dwelling sample, as shown in Table 1. The number of occupants, the presence of AC, total appliance hours, number of rooms (dwelling size) and income group were found to explain 81% of the variation in REC, with 76% of the variation being explained through the presence of AC and income group.

(Dependent variable)-Annual e/ectricity consumption (kWh)	Unstandardized Coefficients		Standardized Coefficients	t
	B	Std. Error	Beta	
(Constant)	6.09	0.19		31.29
Number of rooms	0.05	0.02	0.29	2.95
Presence of ACs	0.48	0.11	0.37	4.44
Number of occupants	0.09	0.02	0.39	4.9
Appliance hours	0.0001	0	0.31	3.41
Income group	0.28	0.12	0.19	2.27
R Square	**0.808**			
Durbin-Watson	1.758			

Table 1.

Regression mode

4. Discussion and conclusions

Statistical analysis of the empirical data by income group, ownership of ACs and appliance use hours has helped give us a deeper understanding of the causes of variation in electricity use across 41 dwellings. It is evident that dwellings with AC and higher incomes use two to three times more electricity than those on lower incomes and with no ACs. These findings have implications for designing energy-efficiency programmes in India. It will be worthwhile focusing on HIG and MIG dwellings, 80% of which are found to own ACs.

This study also provides important process lessons for scaling-up survey-based techniques in India and the challenges that need to be addressed in terms of the time taken to do the survey, internet connectivity when using online survey forms and correlating survey findings with measured electricity data.

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SECTION 5

DIGITAL SOLUTIONS FOR BEHAVIOURAL CHANGE

5.1 Enhancing User Engagement in Local Energy Initiatives Using Smart Local Energy Engagement Tools

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KEYWORDS

user engagement, local energy projects, smart energy tool, climate change,

1. Introduction

To address the growing concerns over the climate emergency, the UK government has committed itself to a net-zero emissions target by 2050[1] by limiting the temperature rise to 1.5°C[2,3]. Local energy initiatives can help in meeting this target by delivering cleaner, cheaper and desirable energy services for end-users[5] by integrating the smart (digital) use of data and communication technologies to interact with users[6]. Deploying effective Smart Local Energy Engagement Tools (SLEETs) in local energy projects that allow users to manage, control and observe energy better will help to reduce this pressure, while encouraging users to become active participants[6]. SLEETs are enabling smart tools that enhance user engagement by supporting energy users to reduce energy use and costs, match energy demand with supply and improve energy efficiency and management[7]. They also allow users to measure their own energy consumption and investigate energy efficiency measures and the environmental impact of energy systems[8]. These tools can provide advice and support to improve energy behaviour and help users participate in local energy markets such as peer-to-peer trading and grid balancing[9]. For SLEETs to be effective, they should address engagement between *people and people*[10] and *people and technologies*[11]. It is also important to improve the inclusiveness of SLEETs by including vulnerable users and those who are not digital and therefore ensure no one gets left behind in the local energy transition.

This paper examines the prevalence, effectiveness and inclusiveness of smart local energy engagement tools (SLEETs) that have been deployed in local energy projects both across the UK and internationally to enhance user engagement and participation in local energy management. This includes supporting users to engage with energy efficiency, energy generation and demand-side response.

2. Methodology

A meta-study approach was adopted to identify what types of SLEETs were deployed in local energy projects during the period from 2008 to 2019 and the major programmes funding local energy projects, such as *Low Carbon Communities Challenge* (LCCC), *Localised Energy Systems*, *Network Innovation Allowance* (NIA), *Horizon 2020* and the *Local Energy Action Fund* (LEAF).

About 86 local energy initiatives were identified that used SLEETs to enhance user engagement. These projects were undertaken in the UK (73), EU (7) and outside the EU, i.e. internationally (6). They were characterised by *lead actor* (e.g. DNO, university, private sector, community group, local authority, partnership collaboration), *funder* (e.g. government, research council, DNO, regulator), start year (2008 to 2019), *type of initiative*, namely community energy (CE), local energy (LE) and smart local energy systems (SLES) and *energy vector* (electricity, heating, transport).

An analytical framework was devised to classify SLEETs in terms of their *interface design* (numeric, visual or aural) and *type of interaction* offered, namely information-driven (one-way), information & interaction (two-way), and information & control or decision support (Table 1). A total of 111 SLEETS were identified across the 86 projects. These were grouped into eight types of SLEET, including in-home-display (IHD), digital energy platform (DEP), digital voice assistant, spatial mapping, thermal imaging, gamification, mobile app and online energy dashboard.

Table 1

Analysis framework classifying SLEETs

Extend of interaction	**Interface**		
	Numeric	**Visual**	**Aural**
	Example of SLEET	Example of SLEET	Example of SLEET
Information driven (one-way) -could be numeric or spatial.	In-home-displays (IHDs)	Spatial map (energy flows a cross scale)	—
	—	Thermal imaging	—
Information & interaction (two-way)	Online dashboard/ web portal	Gamification (Energy mapping tools that require input from users for example to assess solar potential)	Digital voice assistant
	Mobile app	—	
Information & control – could be manual or automated	—	—	
Decision support – to help operation of systems by providing energy related data to users	Digital energy platforms (DEP)	—	—

3. Results

Statistical analysis revealed the prevalence of different types of SLEET across 86 local energy initiatives. Digital energy platforms that visualise energy data were most popular (30 out of 111 SLEETs), followed by in-home displays (IHD) that provide energy feedback (29 out of 111 SLEETs) and thermal imaging that identifies heat losses from the building fabric (23 out of 111 SLEETs). Interestingly, *information driven* (54) and *decision support* (31) tools with *numeric* and *visual* interfaces were dominant. *Information & interaction* tools were less popular: these included mobile app (10) and gamification (9), followed by online dashboard (5) and digital voice assistant (2).

The majority of SLEETs (34%) were deployed in project areas with network constraints, including South East (20 out of 86) and South West (9 out of 86 projects) of England (Figure 1). Interestingly there were active community energy groups in these areas, as well as local authorities with local energy action plans, who acted as intermediaries to improve user engagement[17,18]. Projects funded by government, the regulator or research councils were found to be deploying SLEETS to engage users in energy management. However, only 27 out of 86 projects took into account the inclusiveness of SLEETs in relation to low-income groups and vulnerable users.

Figure 1.
Distribution of SLEETs in the UK at spatial resolutions of counties

Statistical analysis revealed a significant correlation between types of energy initiative, whether CE, LE and SLES and type of SLEET. Thermal imaging was widely deployed in CE projects to encourage behavioural change (p<0.001), while digital energy platforms (DEPs) were prevalent in SLESs as decision support tools for improving energy management (p<0.001) (Figure 2). There was also some correlation between SLEETs and the engagement pathway adopted in local energy initiatives. In-home display and gamification were adopted as engagement tools for *communication* (p-values < 0.05), while DEP and thermal imaging were used as *informing* tools.

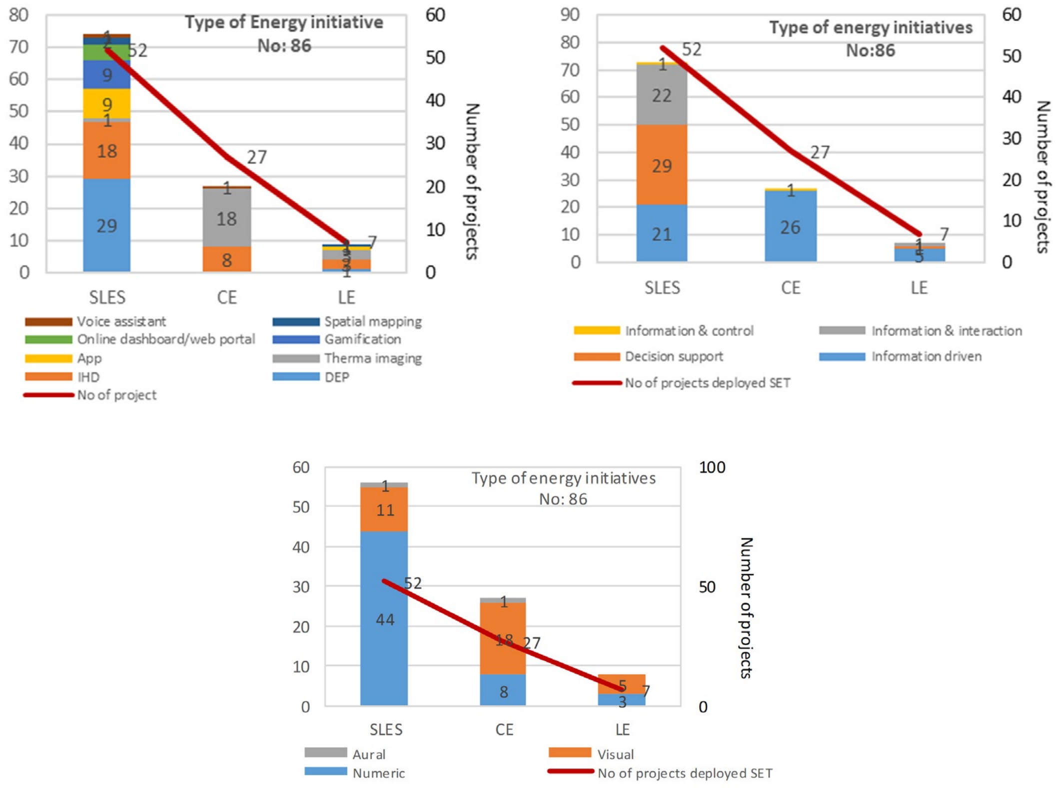

Figure 2.

Type of local energy initiatives and (a) SLEETs (b) extent of interaction (c) interface design

4. Discussion and conclusions

It was evident that the majority of the energy projects that deployed SLEETs were SLES (61%), since these projects focused on the digitalisation of energy and the smart approach to integrating heating and electricity generation, distribution, storage and EV infrastructure[15]. Spatial distribution of SLEETs in relation to local energy initiatives confirmed that SLEETs were deployed in areas with a high capacity for adopting renewable energy technologies, while having an issue with grid constraints[16], as well as a prevalence of active community energy groups and local authorities.

Integrating the social aspects with interactive engagement tools such as mobile apps, online dashboards, gamification and digital voice assistants can empower users to manage energy services. For this to happen, transparency should be improved to allow users to learn what data are being collected and how they are being used (Döbelt et al., 2015) alongside developing energy platforms by trustworthy intermediaries to foster trust. Digital voice assistants may be more appropriate for vulnerable users and those who prefer not to use a thermostat or smart app. Most importantly, SLEETs also have a new role at this time of the COVID-19 pandemic, since they can allow long-term user engagement with less face-to-face interaction.

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5.2 Social Influence in the Adoption of Digital Consumer Innovations to Mitigate Climate Change

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KEYWORDS

low carbon; interpersonal communication; diffusion of innovations; information sources; electronic word-of-mouth

1. Introduction

To meet international climate change targets and develop a sustainable energy transition, economic and social transformations are urgently required across all areas of daily life. According to the UK Committee on Climate Change, two thirds of the necessary measures are social and behavioural, with the single most important category being the adoption of low-carbon technology[1]. In recent years, digitalisation has enabled a surge of consumer innovations to emerge which challenge high-energy consumption norms and offer additional benefits, such as support for local economies (e.g., digital food hubs), relational networks (e.g., ride-sharing), social capital (e.g., neighbourhood electricity trading) and healthy living (e.g., food-pairing apps). However, many remain trapped in small market niches[2]. As their impact has been limited thus far, insights are needed in devising diffusion strategies for rapid extensive adoption. To help accelerate innovations into the mass market, this paper investigates the diffusion of information through social influences for a wide range of digital consumer innovations to mitigate climate change.

2. Background and Methodology

A large body of innovation studies[3] has confirmed the central premise of the diffusion of innovations theory (DoI) that the adoption of new technologies is heavily influenced by those around us exchanging both functional and social information[4]. We extend this evidence base in two important ways: 1) we collect and analyse comparable data on a wide range of innovations, allowing us to control for variations in context when analysing social influence on the adoption of innovations; and 2) we focus on the emerging intersection between digital technologies, and low-carbon goods and services. In combination, these two contributions allow us to assess the importance of social influence in diffusing digital consumer innovations to mitigate climate change.

We conducted a large online survey with over three thousand UK respondents, purposively sampling adopters and non-adopters of sixteen innovations across four consumption domains: mobility, food, homes and energy. Standardised blocks of questions established respondents' perceptions of innovation attributes and measured the relative importance of four mechanisms of disseminating information: word-of-mouth (WOM), electronic-WOM (eWOM), neighbourhood effects and injunctive social norms. We distinguish adopters from high- and low-propensity non-adopters to capture heterogeneity. We then test differences between the two non-adopter samples using Mann Whitney U tests (with effect sizes) to understand the relative importance of different mechanisms of social influence on adoption propensities. We then cluster the innovations into three groups defined by their perceived attributes and create binary logistic regressions, one for each cluster, to test the links between specific attributes and influence mechanisms.

We then conduct surveys, interviews and focus groups to examine further three targeted case-study innovations with distinct characteristics: peer-to-peer (P2P) ride-sharing (strong requirement of trust), smart home technologies (lack of public visibility) and digital food hubs (community-based). Our quantitative and qualitative analysis provides detailed insights into the moderating roles of these characteristics, thus helping identify the contexts that shape social influence and adoption.

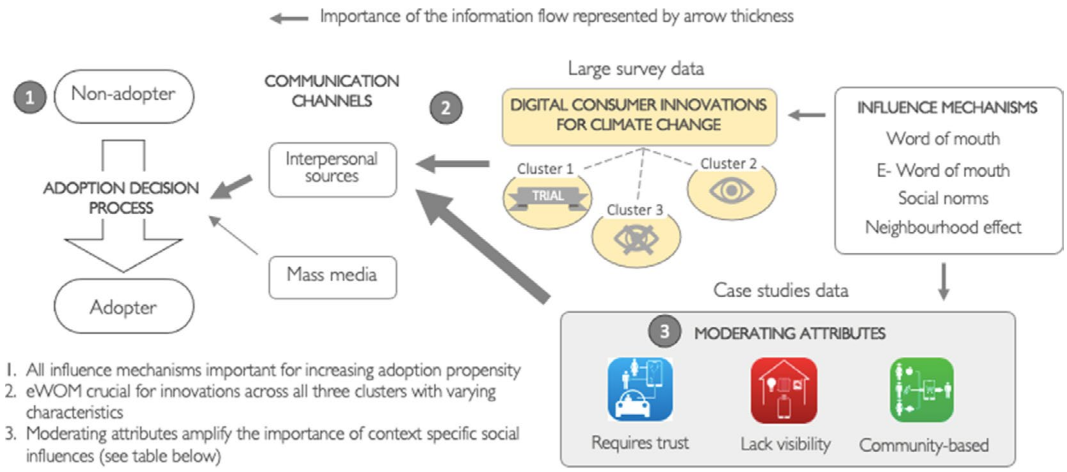
3. Results and Findings

The results from the large survey show that all influence mechanisms are significantly important ($p<.05$) for non-adopters when high propensity is compared to low propensity. Analysis of the innovation clusters (Table 1) reveals that eWOM and social norms significantly increase the likelihood of adoption for highly trialable (cluster 1) and highly visible innovations (cluster 2), whereas only eWOM is significant for innovations with low trialability and low visibility (cluster 3).

Our in-depth case studies identified the most important social influence mechanism and the potential barriers hindering wider adoption for each specific innovation. Figure 1 summarises the key findings from both the large survey and the case-study investigations.

***Table 1.** Binary logistic regression models predicting adoption propensities (with example innovations in each cluster)*

	Cluster 1 (e.g. car clubs, 11th hour apps)		Cluster 2 (e.g. ride-sharing, home energy generation)		Cluster 3 (e.g. smart home lighting and heating)	
Variables	Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value
Word-of-mouth	.986	.930	1.193	.211	1.399	.292
eWord-of-mouth	2.199	**.001***	2.595	**.001***	3.782	**.001***
Social norms	1.679	**.001***	1.589	**.001***	1.520	.133
Neighbourhood effect	1.234	.159	1.169	.213	.775	.426
Pseudo R2	0.497		0.552		0.615	
Correctly classifies % of cases	78.8%		81.9%		84.2%	



Case study innovation	Social influence mechanism	Social barriers hindering adoption
P2P ride-sharing (requirement of trust)	Social norms crucial for trust. Adoption in workplace culture reduced anxieties, reassuring additional colleagues to adopt.	For one-off users, frequent accounts of social contacts perceiving them as 'crazy' indicates a lack of societal norms still exists in the wider community.
Smart home technologies (lack of visibility)	eWOM from adopters to non-adopters increases salience and encourages adoption. Adopters reported as opinion leaders and frequent users of social media.	Non-adopters found to lack exposure and social connection to adopters for first-hand knowledge.
Digital food hubs (community-based)	WOM most important for shaping opinions in communities. Adopters reported as opinion leaders persuading others to adopt.	Low propensity non-adopters rely upon eWOM to shape opinions rather than locally relevant WOM.

Figure 1. *Summary of key findings on the importance of mechanisms of social influence in the adoption of digital consumer innovations to mitigate climate change*

4. Discussion and Conclusions

Overall, we find that social influences are important determinants of adoption propensity. With our novel emphasis on a diverse set of digital consumer innovations for climate change, we find that eWOM has the greatest importance, highlighting the ever-increasing need to improve digital skills, as well as equitable access to digital infrastructure for the wider adoption of innovations. We also stress the importance of social norms, even though the current lack of norms surrounding many of the innovations concerned emphasises the need for behavioural interventions which shift perceptions of social acceptance of the adoption of innovations. For example, our study of P2P ride-sharing found that altered social norms in a workplace environment reassured employees that this is a safe, trustworthy and beneficial scheme to use.

Other findings from our case studies indicate that innovations with low visibility (e.g. smart home technology) would benefit most from strategies that create supportive infrastructure in order to expose non-adopters to adopters, such as using digital social media platforms and influencers, thus increasing visibility and reaching wider audiences.

To accelerate the diffusion of digital consumer innovations to mitigate climate change, our findings highlight where generalisable insights exist for harnessing social mechanisms. We also identify where context shapes social influence factors and adoption, which requires targeted marketing and policy-driven diffusion strategies to fast-track a transition to low-carbon energy.

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5.3 Social Power Plus: Empowering Households to Energy Sufficiency through Co-designed App-based Community Energy Challenges

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KEYWORDS

behaviour change, households, electricity, heating, co-creation, living lab

1. Introduction

In Switzerland, as in many Western countries, households are responsible for 31.4% of total energy consumption[1] and are therefore an important intervention point for 'Energiestrategie2050', for achieving the country's energy transition. Acknowledging that the widespread technical measures targeting the energy efficiency of buildings tends to neglect the impact of occupants' behaviour in overall energy usage, a growing body of research has focused on behavioural measures targeting reducing energy consumption and exploitation of the potential for increased energy sufficiency. Social interventions targeting energy savings at home were in fact observed to reduce energy consumption by as much as 20% when several behavioural and engagement initiatives were implemented[2,3,4,5,6,7].

Thanks to recent progress in information and communication technologies (ICTs), with smart meter rollouts by utility companies, ease of installation of sensors and the widespread diffusion of smartphones among consumers, energy-saving interventions are increasingly being performed by means of applications (apps) for mobile technologies. This allows customized, (nearly) real-time energy feedback and interaction with and between the users. One particular growing tendency is to approach consumers no longer as individual agents for change, but rather as socially situated individuals who are part of a wider community[8].

In previous research, our team developed an app-based energy-savings challenge, called Social Power[9], that allowed households to monitor their electricity consumption in real time through a gamified, lay-person visualisation, which connected actions to energy use without the need for a more complex understanding of the energy system[10]. Households were placed in teams, within which they were invited to collaborate to save a given amount of energy collectively or to save more energy than a rival team (compared to their historical average consumption). While the real-world test of the app-based energy savings challenge successfully resulted in approximately 8% in electricity savings in two Swiss cities, the savings were not being maintained one year after the intervention ended[11].

We hypothesize that such relapses into previous behaviour are due to a failure to explicitly incorporate user knowledge, practices and preferences into the design of the Social Power challenge. To explore this hypothesis, we have launched the Social Power Plus follow-up project, in which we overcome the expert-based approach and actively engage potential target users in the design of the behaviour change intervention itself, using a living lab approach.

2. Literature Review

Living labs are processes aimed at co-creating and validating innovation within collaborative, real-world environments[12,13,14,15]. They make possible 'participatory mindsets', in which users become active partners in the value creation process[16,17]: beyond 'designing for the users', living labs support 'designing with the users'. The approach involves users during the design process (e.g. through interviews, surveys, focus groups, pilot testing). This results in the product being designed for its intended use, the argument being that this is ultimately more effective and efficient[18].

Designs involving users have been previously applied to energy transition research in order to improve smart meter-based behaviour change interventions: in this case, 'users' are household energy consumers receiving feedback on usage from their smart meters. For example, consumption data have been used as feedback to provide support for energy-efficient purchasing decisions based on household appliance use[19], improve energy-efficient appliance use behaviour[20,21], or capture multi-faceted benefits, including increasing comfort, energy savings, transparency and overall consumer awareness[22].

3. Results and Findings

The Social Power Plus community energy-savings challenge and the related app will be designed together with interested community members within the Social Power Plus living labs being run in three Swiss regions in early 2021. The living lab engages three Swiss utilities and a sample of their household customers, recruited through an open communication campaign targeting all the residential customers of such utilities. Three to four workshops will be held between February and June 2021 to co-design a new version of the app and the community energy-savings challenge.

The first workshop focuses on an introduction to the app and the energy-savings challenge, connecting this to individual energy practices at home. This workshop aims to identify the material and immaterial factors that influence and drive practices, as well as possible ways they might evolve to support the energy transition. The second workshop focuses on co- design and getting specific feedback for possible new or adapted features of the app and challenges from the household participants. In addition, in these two workshops we will explore what incentives, features or interactions might support a longer lasting and continuous use of the app and hence probably a longer lasting engagement with their own energy consumption. In parallel, professional software developers will turn such proposals into app prototypes, which will be tested in the final meetings, providing feedback for additional improvements. This iterative process is novel and potentially impactful in realising a user-centred design. We expect to adopt a mixture of in-person and online formats to enhance interaction possibilities, while also dealing with the social-distancing norms imposed by the COVID-19 crisis.

4. Discussion and Conclusions

While results of the entire co-creation process are not yet available, preliminary results concerning the first design workshops, as well as lessons on how to engage customers, will become available in spring 2021 for presentation at the conference.

Social Power Plus aims at improving personal engagement in the app-based energy challenge through co-creation workshops, which are in turn intended to optimize the app's retention rate and to encourage the embedding of the energy savings in the long term. Promoting co-creation and knowledge generation, the living lab is in fact expected to support the transformative potential of socially embedded behaviour change interventions[23]. This participatory approach supports an initial alignment of goals and interests with potential participants to save energy, its aim being to understand the surrounding contexts, limitations and opportunities. Furthermore, the living lab allows the app's and community energy-savings challenge's features to be tested, and ideally inter-locking practices that are relevant to household energy savings to be identified[24], thus supporting long-term impacts.

The app and community energy-savings challenge resulting from co-creation in the living labs will finally be tested in 2022 in three real-life trials engaging a large number of customers in order to assess their long-term effectiveness in supporting the energy transition.

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5.4 Optimizing Energy Feedback Messages Using fNIRS

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KEYWORDS

energy feedback messaging, energy efficiency, energy consumption, fNIRS, functional near-infrared spectroscopy, prefrontal cortex, brain network analysis

1. Introduction

Energy feedback devices and their messaging capabilities can lower monthly energy bills and help consumers save money. Energy feedback messaging is an emerging socio-technical innovation that can help consumers save 5–20% on their monthly energy bills. These messages, which are generated by energy feedback devices, can help consumers improve the energy efficiency of their homes. However, the effectiveness of energy feedback messages is undermined by their being no definite structure for delivering energy feedback. An opportunity therefore exists to optimize the impact of message design on the delivery of energy feedback messages by building on earlier literature on such messages (Barreto et al. 2013; Delmas et al. 2013; Hargreaves et al. 2013; Ehrhardt-Martinez et al. 2010). The motivation of this research study is to improve consumers' energy consumption by personalizing energy feedback messages that highlight concepts people care about (e.g. comfort, loss of income, preserving the environment). To measure cognitive resposes to energy feedback messages, an fNIRS study was conducted of thirty participants to measure their cognitive responses to viewing energy feedback messages. Cognitive responses show that people are thinking about the content that is being presented to them. Also, we introduce a novel multidisciplinary approach to improve the effectiveness of current energy feedback message design by investigating cognitive responses.

The framework we develop for this research will build upon earlier studies of energy feedback messages and use concepts from civil engineering, psychology and sociology. In this framework, we combine existing message design theories (e.g. choice architecture, message types, colour, text type and size), earlier literature on each of these messages and a fNIRS instrument to arrive at a more accurate representation of the messages that trigger the highest number of cognitive responses. Our framework will uniquely utilize ideas and concepts from multiple disciplines (e.g. engineering, sociology, psychology, public works) to solve complex problems. This framework can help energy feedback devices excel in producing energy and financial savings. Ultimately, it can use energy feedback messages to improve consumers' energy behaviour and reduce their carbon footprints.

2. Methods

By measuring cognitive responses with an fNIRS cap, researchers were able to measure brain activity while participants analysed energy feedback messages. fNIRS is a neuroimaging instrument that quantifies neurocognition (the functionality of one or more brain regions) via changes in blood flow patterns in the brain. The instrument operates by emitting near-infrared light into the human cortex, and the refracted light is detected by the sensors on the cap (see Figure 1).

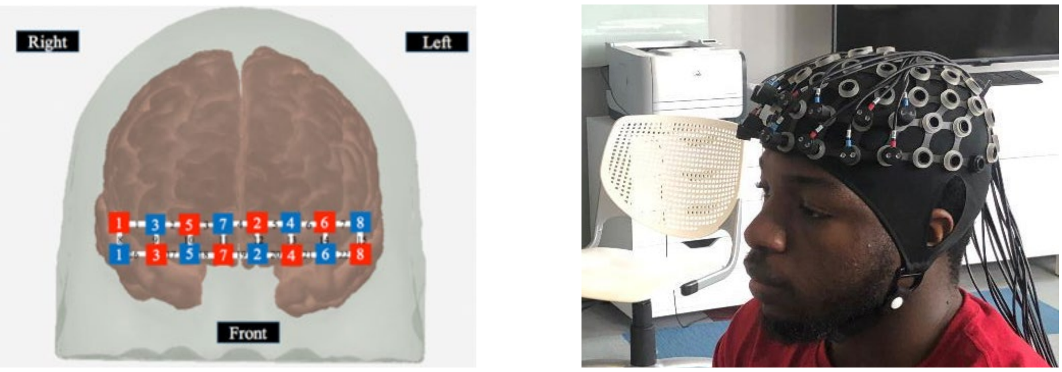


Figure 1.

fNIRS Sensor-Covered Cap

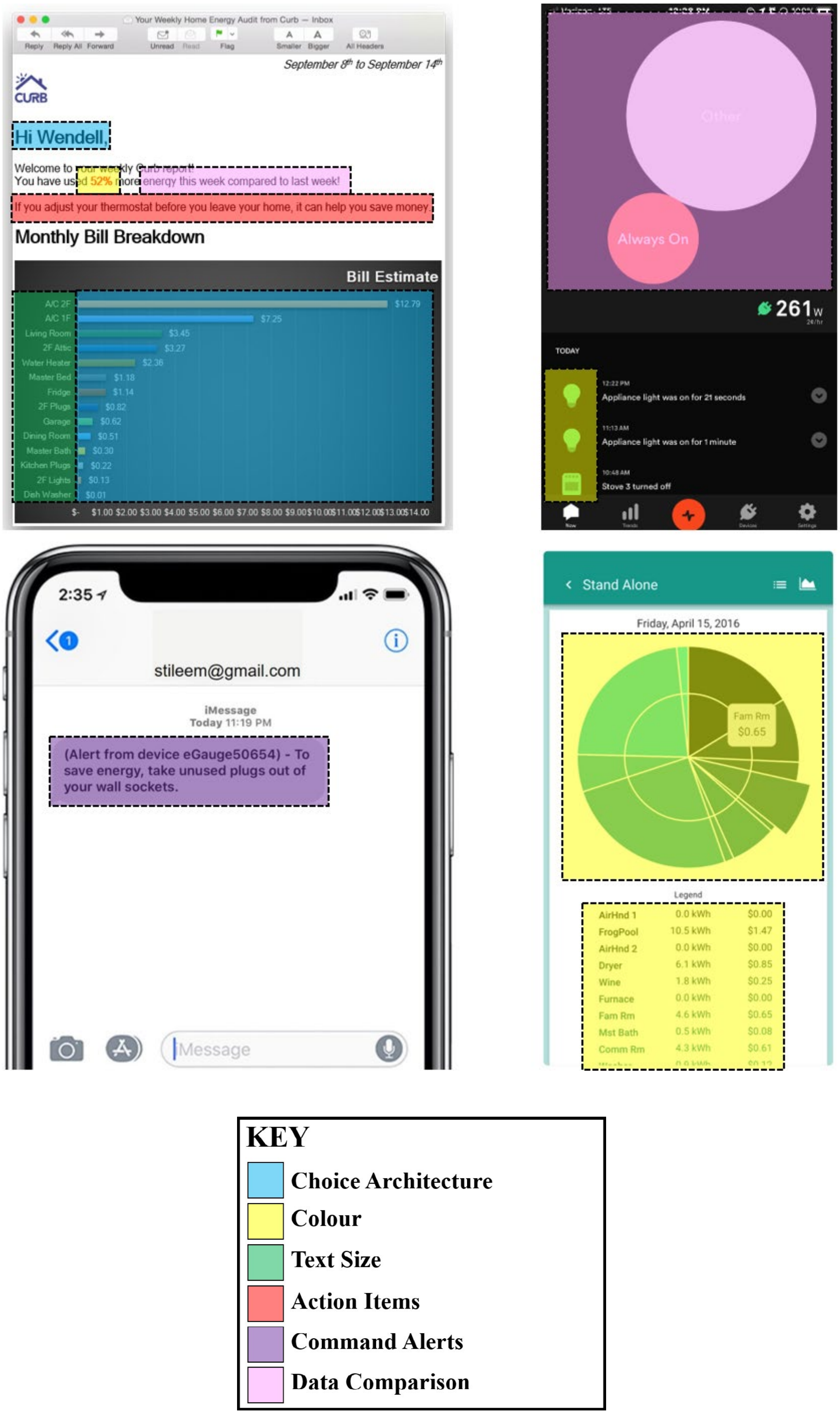
The brain data were used to create brain network analysis figures for each of the energy feedback device message formats. Using this brain data, researchers were able to determine which prefrontal cortex subregion was most recruited, as well as perform different methods of data analysis to justify this claim. Each prefrontal cortex subregion is related to an executive function. Through these executive functions and the results of the data analysis, researchers were able to compare the different message formats to determined which messages contained more cognition, which were most comprehensive and messages were most memorable.

Participants were asked to wear the fNIRS device while reading feedback messages. Our sample, more specifically, consists of thirty Virginia Tech students because this study is the first of its kind and can open the door to studies with larger sample populations. The study was conducted during COVID-19, therefore, the lab contained cleaning equipment with which to sterilize the entire lab after each participant had completed the experiment. We also performed a literature review in order to formulate these energy feedback messages. The literature analysis collected information on existing energy feedback devices, their messaging capabilities, and existing message design theories to determine opportunities for improvement. Our study draws messages from energy feedback devices that are available on the market and provide whole home energy-consumption data.

Figure 2 shows our use of existing message design theories such as choice architecture (Sanguinetti et al. 2018 Wilhite et al. 1995), text colour (Buchanan et al. 2014; Alahmad et al. 2012), action items and text size (Darroch et al. 2005). These design theories were applied to improve existing energy feedback messages. Also, our proposed feedback messages were shown to participants while wearing the fNIRS cap.

Figure 2.

Updated Energy Feedback Messages



3. Results

Pilot results for this study generated network analysis figures to show the relationships between the 22 fNIRS channels and the PFC subregions recruited out of the thirty participants who participated in this pilot study. Our preliminary findings show that the effectiveness of existing message design theories, such as choice architecture, text colour and action items, is based on increases in brain activity. Increased brain activity indicates increased thinking and increased attention being paid to energy feedback messages, which can improve consumers' willingness to purchase and utilize these energy feedback devices.

To find the correlations between the 22 fNIRS channels, PFC subregions and feedback messages from the four energy feedback devices, we generated brain network analysis figures, as shown in Figure 3 below. Researchers used pilot data to ensure that the messages being shown to the sample population for this experiment are optimal. Figure 3 below shows that the pilot study's participants found messages from Sense to be the most effective because these messages produced the most brain activity.

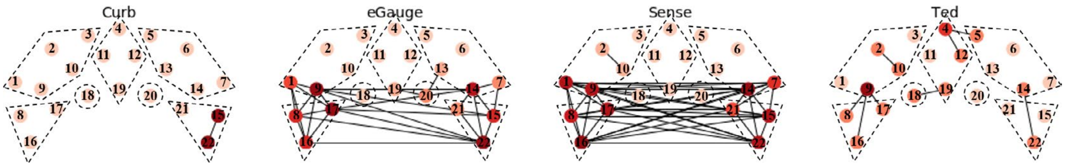


Figure 3.

Preliminary Network Analyses for Selected Energy Monitors

4. Conclusions

Preliminary findings of the content analysis of energy feedback messages found that existing message design theories, such as choice architecture, colour, two-way communication and customized data visualizations, apply to energy feedback messages. Also, the findings of our pilot study show that different message design theories apply to energy feedback messages, as well as different types of messages based on their design. This exploratory research study provides an opportunity to find the best avenue in which this research can thrive. Nevertheless, given a better understanding of how energy feedback messages influence consumers' brain behaviour, it will be possible to capitalize on message features and characteristics drawn from theory. In addition, these improved messages can be used to target specific types of energy consumers. The customized energy feedback design framework used in this study can be used by energy researchers to fill the gap between perceived and actual energy use.

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5.5 Same, Same but Different: Academic and Commercial Perspectives on App-based Changes in Energy Behaviour

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KEYWORDS

digitalisation, behaviour change, design, practice

1. Introduction

Digitalised individual information feedback has emerged in the last ten years in the energy sector. Typically embedded in existing services and enabled with ICT capacity, digital tools allow high resolutions of energy consumption data. Previously intangible behavioural impacts by consumers can now be quantified cheaply and ubiquitously[1]. This has sparked great interest in both research, particularly in behavioural changes in environmental psychology[2], and commercial practice.

In the last five years, several EUi research grants have supported smart-phone app development for energy reductions, resulting in many research teams providing consumers with engaging and (almost) real-time feedback. In parallel, the commercial sector has also jumped on this opportunity, and in 2019 more than two thousand apps supporting sustainable energy behaviour change could be found in Apple's US Store[3].

With so much activity happening both within and outside academia, this project seeks to improve understanding of the different design principles and theories of behaviour change used in both

i See, for example, the H2020 research and innovation programme grants that are funding energy-savings apps: http://www.beneffice.eu/Related-Projects

settings. While environmental psychology focuses on implementing specific techniques to address the relevant barriers and drivers for changing behaviour, such as goal setting, social comparison or information feedback[4], design science in commercial practice takes a more context-embedded and problem-oriented approach to behavioural change[5]. No comparison between these two fields has yet been carried out, but doing so could elicit relevant lessons to be shared between disciplines.

2. Background

In behavioural psychology there are many long-standing theories attempting to explain the mechanisms of changing energy behaviour. However, information feedback is often used as an intervention strategy to bridge the gap between behaviour and impact[6].

Despite the history of information feedback, many challenges remain, such as biases in self-reported behaviour, low participation rates, high attrition, energy saliency and the cost-effectiveness of interventions[7]. Herein, the digitalisation of energy consumption data allows relevant temporal and spatial behavioural aspects to be included, compared to earlier non-digital forms of information feedback.

While seemingly promising, apps for changes to energy behaviour have limitations. Johnson et al.[2] note that the positive effect differs depending on the context in which an app is used, for example, if the focus is placed on actual behavioural change rather than on improving energy literacy. Furthermore, Beck et al.[3] criticize behaviour change apps for underusing the potential of verified behaviour change techniques in combination with typical gamified approaches (gamification). Thus the variations in app-based intervention design need further investigation.

3. Methodology

While there are many new digital energy innovations, this study focuses on smart-phone app-based approaches related to direct (e.g. electricity) and indirect (e.g. food) energy savings. Two sources of data are used to compare design approaches: a literature review of research-based apps developed since 2015, and semi-structured interviews with commercial app developers.

The literature review focuses on scientific and non-scientific (e.g. on websites) publications reporting studies of research-based energy savings apps to determine their theoretical approach, design elements and impact. In a systematic review of EU funding for research projects on digital tools for energy behaviour change since 2010, 39 projects were identified, of which nineteen were chosen for evaluation based on use of the digital tool in an intervention context, similar target audiences and having a focus on energy reductions.

The semi-structured interviews were held with six European commercial app developers concerning their app design, theory of change for inducing energy savings, challenges faced, impacts measured and any academic collaborations. The developed apps focus on saving energy by making alternative food and mobility choices to enable household electricity savings.

The approaches and design principles collected in the literature review and interviews are contrasted with a modified version of a well-established framework of intervention techniques in psychology which covers both antecedent and consequent approaches to behavioural change[8]. In this paper, the framework will be developed further to account for digital relevance and relation to gamification. The results will outline which design principles address existing intervention challenges, potential overlap or the need for more knowledge transfer, as well as expanding on theories of behavioural change.

4. Preliminary Results and Conclusion

While the study is ongoing, some preliminary results contrasting the academic and commercial app approaches can be highlighted here. As one advantage of digital tools is the ability to experiment and repeatedly make changes, the commercial app designers continuously try various tools following design science to find an optimised approach. This differs from research-driven behaviour interventions in environmental psychology, which often test a specific theory and report on the results much later, whereas an app may have experienced many revisions in the same time period.

Secondly, commercial app designers place less emphasis on automatic data collection, for example, through a smart meter, as such data are complicated to obtain. This opens up the possibility of tracking even more behaviour where there is currently no approach to digital measurement. In contrast, academics take advantage of automatic data collection in order to remove bias in reporting the impact of an intervention. This, however, often limits the focus to household electricity use.

While we continue to learn about how apps can be effective for changing behaviour, there are emerging issues around the longevity and saturation of apps, as well as data privacy. Additionally, there is a fundamental difference in the motivations of commercial app developers, who need to have a viable business structure, as well as a behavioural impact. On the other hand, an app designed as part of a research project is often abandoned after the project ends, thus missing the potential for cost-effective repetition. It appears that there is a need for more knowledge transfer between disciplines. The differences and advantages of the two fields are relevant for policy and funding bodies interested in impacting individual behaviour.

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5.6 Probablistic Machine-learning for Occupancy Prediction based on Sensor Fusion

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KEYWORDS

probabilistic machine learning, mc dropout, occupancy prediction, sensor fusion

1. Introduction

A substantial corpus of research has shown that occupancy-related factors, such as the presence or absence and movements of occupants, significantly influence energy use and the indoor environmental quality of buildings[1,4]. Targeting reliable occupancy information is therefore a key to achieving efficient HVAC system operations and building management systems, as they are designed to maintain occupants' comfort[5].

Occupancy prediction has been recognized as one of the most inspiring aspects of energy saving in buildings[6]. Different approaches have been used for occupancy prediction, such as statistical models[7] or a combination of statistical and physical models[8]. Another common and state-of-the-art approach in this context is deep learning[9]. However, typical deep neural networks, which are deterministic models, do not provide any information on the uncertainty of predictions or can predict a value confidently. Although studies that have used deterministic deep learning sometimes show an acceptable degree of accuracy[10,11], it can be seen that the exact number of occupants is not predicted most of the time. Therefore, in such highly stochastic applications, deep-learning models can be further enhanced by providing information about how the model can predict with certainty. The objective of this paper is therefore to investigate the use of probabilistic deep learning in the context of occupancy prediction, a topic that has been overlooked thus far.

2. Methodology

The probabilistic modeling approach described in this paper is based on Monte-Carlo Dropout presented by Gal and Ghahramani[12]. In typical neural networks, the Dropout is used only in the training phase to inactivate some nodes and prevent overfitting. However, this approach can also be used during the testing phase to account for the uncertainty of predictions. To develop the Monte-Carlo probabilistic model, the following considerations are made:

I. Using probabilistic loss function: negative log-likelihood is used, calculated as below:

$$-log\ \varphi_\theta(x) = \frac{log\ \hat{\sigma}_\theta{}^2(x)}{2} - \frac{(y - \hat{\mu}_\theta(x))^2}{2\hat{\sigma}_\theta{}^2(x)} \quad (1)$$

where is the true value, is the mean of predicted values, and is the variance of predictions.

II. Activation of Monte-Carlo Dropout during test phase: In the testing phase, multiple passes of input data are performed to obtain the predictions for input data x. In each pass, a different dropout mask is implemented, causing variations in output. The final mean and variance are therefore calculated as below:

$$\bar{\mu}(x) = \frac{1}{N} \sum_{n \epsilon N} \bar{\mu}_n(x) \quad (2)$$

$$\bar{\sigma}^2(x) = \frac{1}{N} \sum_{n \epsilon N} (\hat{\sigma}_\theta{}^2(x) + \bar{\mu}_n{}^2(x)) - y(x)^2 \quad (3)$$

where N is the number of different passes, is the prediction of each pass, and is the variance of each pass.

The dataset for this research comes from the study by Hobson et al.[11] on the occupancy prediction of an academic office building in Ottawa, Canada, including measurements of CO_2 concentration, detected motions, plug and lighting power use, total power use, and the number of connected WiFi devices on four floors. The ground truth occupancy data for this building is captured by installing a camera at the entrances and exits. This study will focus on floors 3 and 4 of the building. Figure 1 shows the floor plans and location of different installed sensors on each floor.

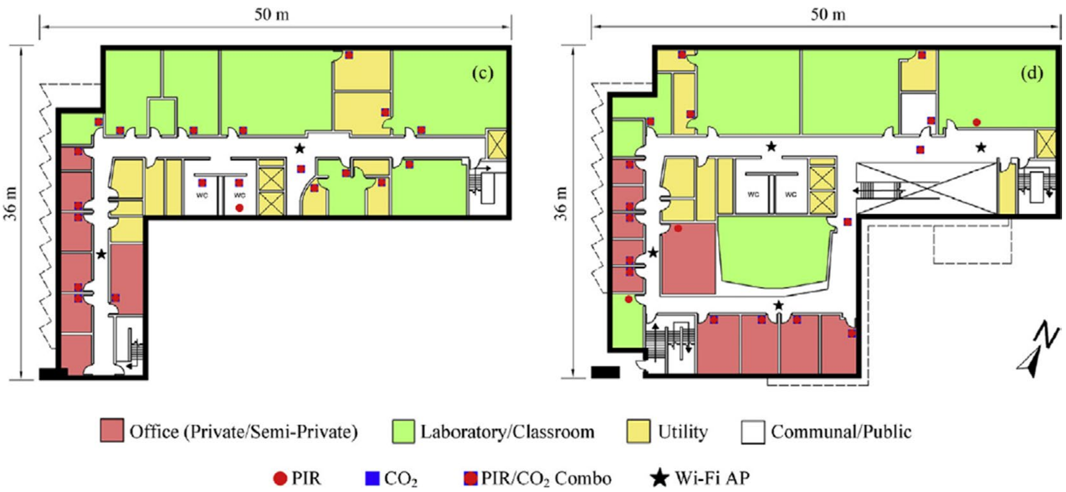

Figure 1.

Location of different sensors on floors 3 and 4 (plansadopted from [1])

Two probabilistic models are developed in this study, one based on the Feed-Forward Neural Network model and the other based on the Long-Short Term Memory (LSTM) Neural Network, which is developed and then compared with a deterministic LSTM Neural Network model. Figure 2 shows the schematics of the developed models.

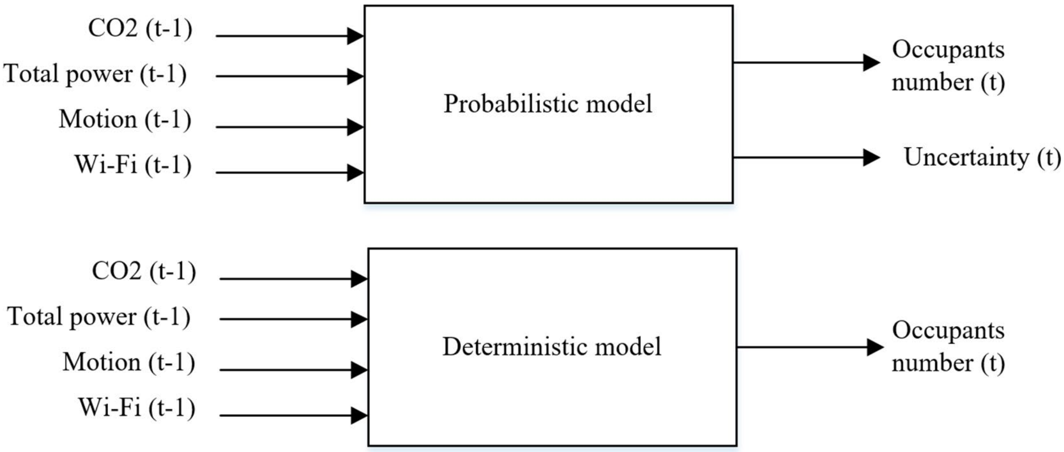

Figure 2.

Schematics of models

3. Results and Findings

The accuracy of occupancy predictions by different models is reported in Table 1. It can be seen that the probabilistic LSTM model shows greater accuracy than the other models on both floors. Only on floor 3 does the probabilistic Feed-Forward model show a higher mean squared error than the deterministic LSTM model. This is because the probabilistic models try to minimize negative log likelihood as the loss function, while the deterministic models try to minimize mean squared error. Between the probabilistic models, the model based on LSTM cells shows better accuracy. This is because the LSTM model has a better performance in learning long-term dependency between the data because of its gating model.

Figure 3 also shows the predictions by probabilistic Feed-Forward, probabilistic LSTM, deterministic LSTM and ground truth data. A visual comparison shows that the predicted mean by probabilistic models is very close to the predicted value by the deterministic model, and both of them rarely match the ground truth data. However, in the case of the probabilistic models, the uncertainty of predictions outperforms the ground truth data, which can be very useful information for decision-making purposes.

Table 1.

Accuracy of different models

Model	Mean Squared Error	Mean Absolute Error	Negative Log-Likelihood
FLOOR 3			
Probabilistic LSTM	**18**	**2.53**	**4.84**
Probabilistic Feed-Forward	18.95	2.67	2.43
Deterministic LSTM	18.03	2.86	-
FLOOR 4			
Probabilistic LSTM	**8.2**	**1.9**	**3.4**
Probabilistic Feed-Forward	9.72	2	3.29
Deterministic LSTM	10.24	2.17	-

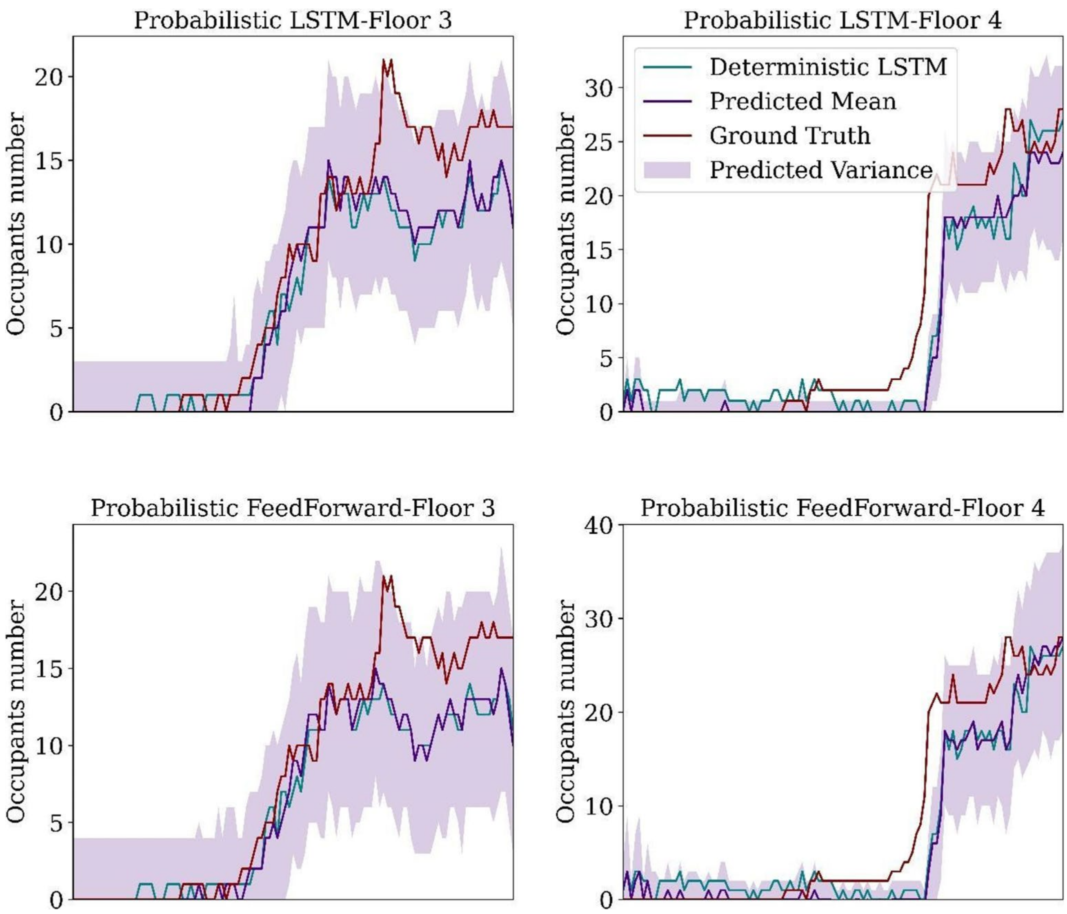

Figure 3.

Predictions by different models versus ground truth data

4. Discussion and Conclusions

The following conclusions can be drawn based on the results:

The predictions by deterministic models usually underestimate occupancy and are therefore not reliable for decision-making purposes. However, the variance of the probabilistic models outperforms the real occupancy number and is therefore very useful for decision-making.

The probabilistic models not only provide uncertainty as additional information but also show greater accuracy in the case of mean squared error and mean absolute error.

In general, it can be concluded that, for highly stochastic phenomena like the occupancy of buildings, the MC Dropout probabilistic models, which estimate the uncertainty of prediction, are more reliable than deterministic models that predict a certain value.

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5.7 Trigger Behind Human-Building Interactions from a User Perspective: Results and Effectiveness of Capturing Motivations in Real Time

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KEYWORDS

human–building interactions, window control, shading, indoor environmental quality, open-space offices

1. Introduction

Although there have been significant advances in the field of energy-related behavioural research in buildings, acquiring a more comprehensive and "multi-dimensional" understanding of the drivers behind human–building interactions is still needed in order to incorporate the user perspective better in building operations and design practice[1]. Increasing effort is being put into studying how the combined effect of IEQ (Indoor Environmental Quality) factors may affect user perceptions and behaviour in occupied buildings[2]. Often, the motivations behind actions are derived solely from physical measurements of the environment, which might not always reflect the real triggers behind their occupants' actions[3]. On the other hand, requesting feedback directly from occupants might yield valuable insights into the perceived triggers for actions, as well as increase the so-called *Hawthorne effect*, according to which the occupants' knowledge that they being studied affects their natural behaviour[4,5]. This paper provides early insights from a field study that addresses these questions precisely and that relies on a newly developed mobile application called "OBdrive". The aim of the study is to capture an extensive set of both subjective and objective multi-domain variables that are likely to drive building occupants' actions on environmental controls[6].

2. Methodology

OBdrive was specifically designed for the so-called eCOMBINE project ("Interaction between energy use, COMfort, Behaviour and the INdoor Environment in office buildings").1 In this paper, we report partial results from the eCOMBINE monitoring campaign, which was conducted for two weeks during the heating season (17-28 February 2020) in an open-space office located on the fifth floor of a six-storey commercial building with a mix-mode ventilation system in Geneva, Switzerland.

All the desk spaces in the office have access to a window within fewer than five metres, and both windows and external shading were freely operable. The mechanical ventilation system does not usually operate during the heating season. Thirty-one participants were asked to report the motivations behind their actions each time they interacted with the windows and blinds. For this purpose they used the OBdrive mobile application, which was installed on mobile phones positioned close to the windows and blinds. The sorts of answers proposed by the mobile application during the pilot campaign are shown in Figure 1a. Occupants could select multiple answers if there were simultaneous motivations for an action. The self-reporting of actions on the mobile interface was complemented with window state logging, that is, each window was equipped with a mobile phone (subjective data) and a wireless window reed sensor (objective data). The experimental set-up in the open office space is shown in Figure 1b.

Figure 1.

Experimental set-up: (a) flow of information requested by Obdrive; (b) installation of phones and wireless window state loggers on the window.

3. Results and Findings

The number of self-reported openings and closings of the windows and blinds is shown in Figure 2. The lower number of reported "closing" actions shows that participants used the application more constantly during opening actions. The same figure also shows that most of the time participants did not consult co-workers before interacting with the controls.

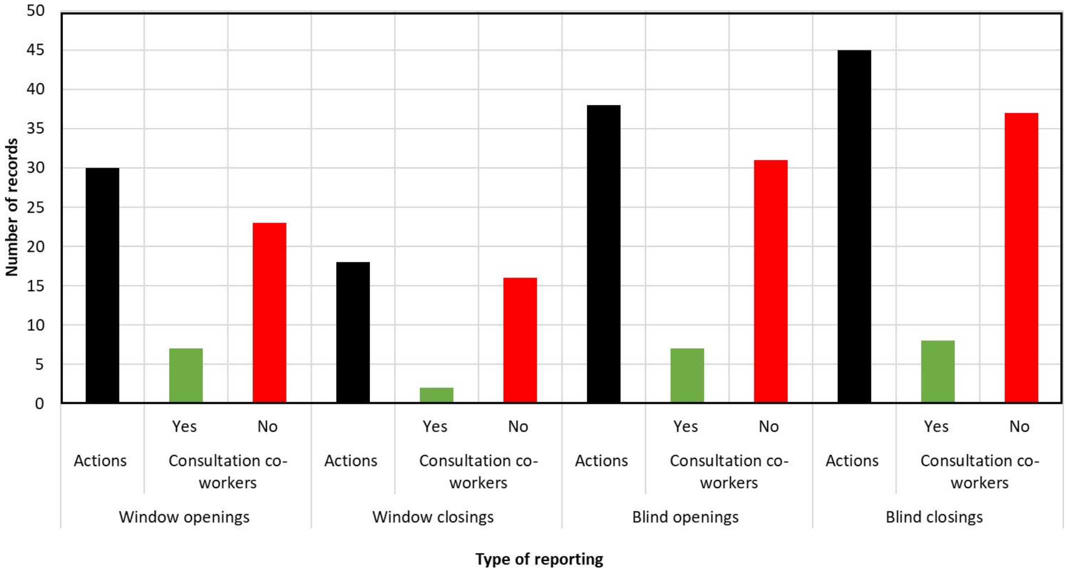


Figure 2.

Reporting of actions and whether co-workers were consulted before interactions.

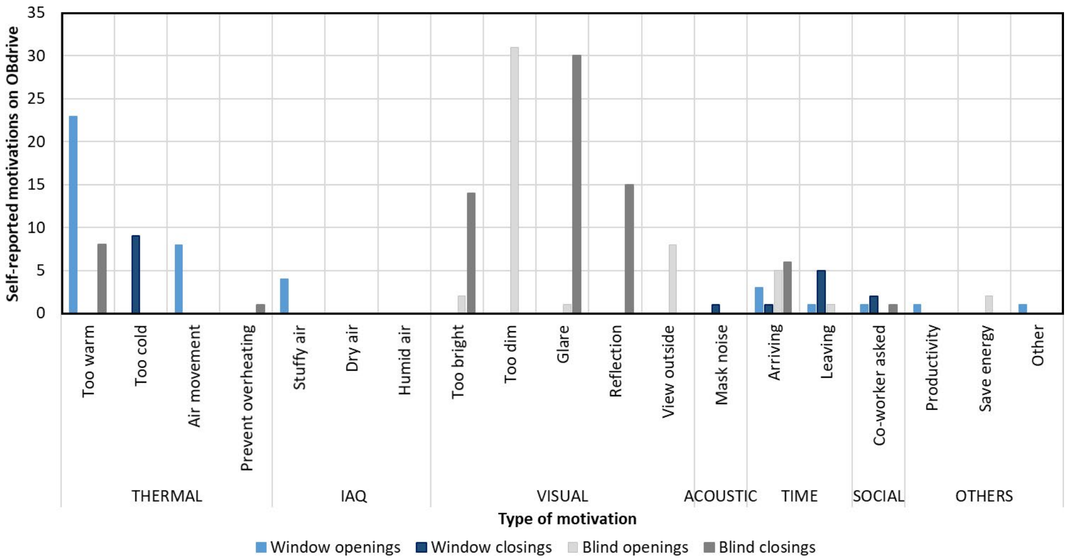


Figure 3.

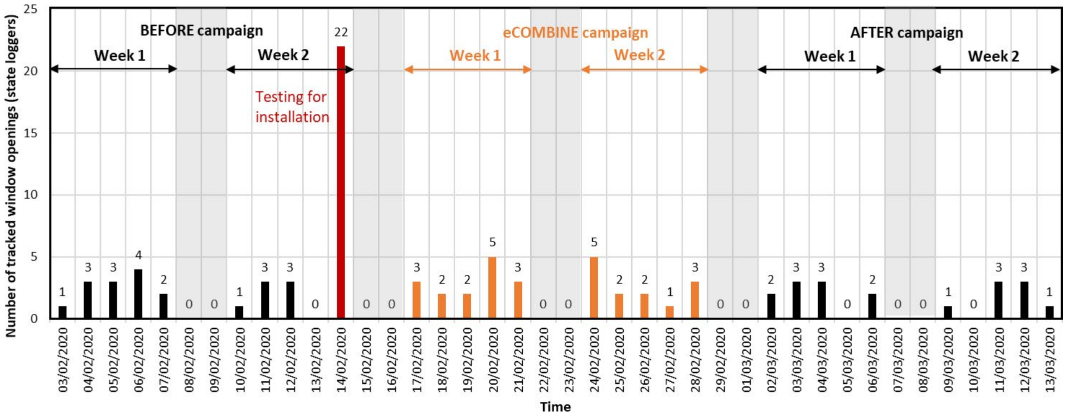
Self-reported motivations behind interactions with windows and blinds.

Self-reported motivations behind opening and closing actions are reported in Figure 3. Opening windows mainly elicited motivations related to the thermal and olfactory environment, such as "too warm", "more air movement", and "stuffy air". In 21% of all window-opening actions, the options "too warm" and "air too stuffy" were selected simultaneously by the occupants, indicating a strong relationship between these two environmental dimensions from the user's perspective. Other reported motivations were "productivity", "arriving/leaving" and "in reponse to requests from co-worker".

The most frequently reported motivations behind closing windows took the form of thermal ("too cold") and time-related drivers ("leaving"), but also to acoustic, social and other drivers. Opening blinds was mainly motivated by visual drivers ("too dim" and "view outside"). Other motivations were "save energy", "arriving" and "prevent overheating". The self-reported key motivations behind closing blinds instead took the form of visual ("too bright", "glare", "reflection"), thermal ("too warm"), and time-related drivers ("arriving").

Figure 4.

Logged window=opening actions from wireless window state loggers before (22), during (28) and after (18) the campaign.



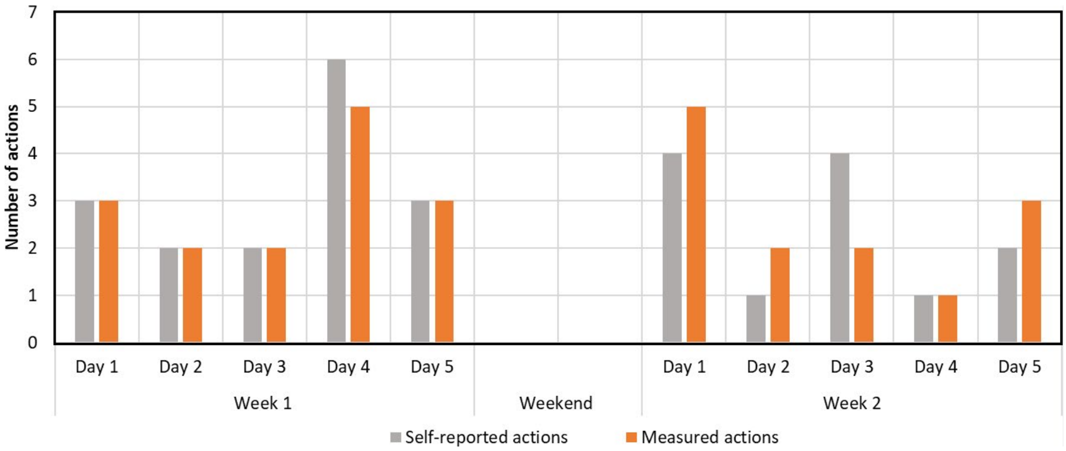
4. Discussion and Conclusions

The foregoing shows the usefulness of the OBdrive app in investigating the motivations behind the interactions with controls from the user's perspective. However, an so far unanswered question is whether the installation of visible and interactive interfaces in office spaces would influence employees to behave differently (e.g. interacting less often with controls because they might be worried by having to self-report on the mobile application, interacting more often because they might be curious, being attracted by the prospect of providing input). For this reason, the frequency of window-opening actions logged by the window sensors was compared to periods pre- and post- campaign (Figure 4). A slight but not significant increase in window-opening actions (which could also be triggered by a wide range of other influencing factors[2]) can be observed during the interactive monitoring phase. The peak shortly before the start of the campaign is due to the correct functioning of the installed window sensors being tested. The self-reported actions on the phones could be used to check the objective measured actions by window-operation sensing solutions, and vice-versa. This allows more precise information to be obtained about window control actions when sensors fail due to connection issues with the gateway. Figure 5 shows that 11% (3 out of 28) of self-reported actions were not captured by the sensors. Further, in a post-campaign survey compiled by 21 participants, nearly half of the occupants indicated that they always reported their interactions on phones installed close to the controls (Figure 6). In light of these outcomes, we found the OBdrive app to be a helpful tool for investigating the perceived motivations behind human–building interactions without significantly altering the behaviour of occupants.

The authors would like to stress that the results reported of in this paper are based on data collected in one eCOMBINE campaign only, implying that this study is exploratory in nature. The results will be completed and analysed in combination with physical measurements (e.g. environmental data) and data from other eCOMBINE pilot studies.

Figure 5.

Measured actions vs. self-reported actions on OBdrive.



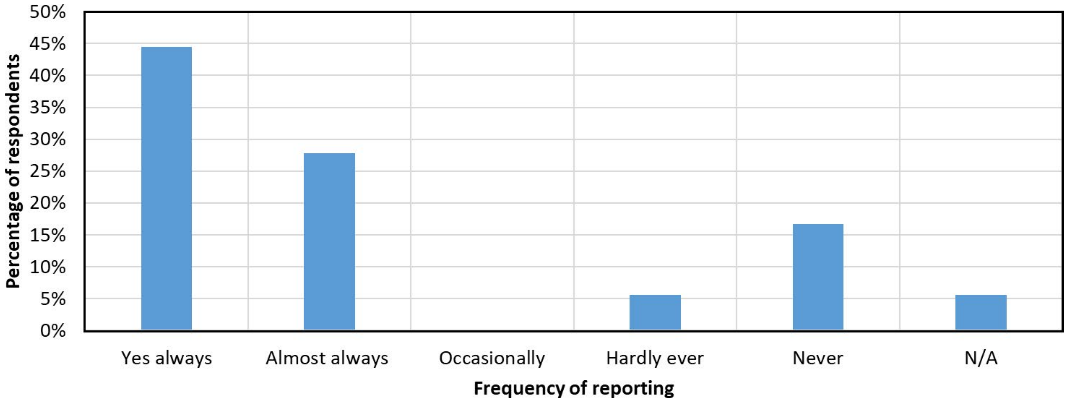


Figure 6.

Frequency of reporting. Answers to the post-campaign survey question: Over the last two weeks, how often did you report your interactions on the mobile phones installed close to windows and blinds?

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SECTION 6

BEHAVIOURAL INTERVENTIONS FOR RENEWABLE ENERGY DEVELOPMENT

6.1 Public Engagement, Social Media, and the Transition to Renewable Energy in Spain

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KEYWORDS

public engagement, renewable energy systems, scientific communication, RD&D

1. Introduction

Public engagement is critical to reducing carbon emissions and scaling smarter, more efficient and cleaner energy systems; however, for the average citizen, razor thin lines separate the latest energy app, gadget or green initiative from the cold bureaucracy of infrastructure or the hundred-plus-page policy documents, such as the EU Clean Energy Package of 2019 or Spain's 427-page Plan Nacional Integrado de Energia y Clima (PNIEC). Furthermore, surveys suggest that although most citizens across the EU want cleaner energy, the approval process and public acceptance of specific renewable projects remains challenging[1,2]. Therefore, researchers, policy-makers, clean energy producers and community energy managers must all continue to communicate, build trust and sustain dialogue. In short, they need to practice multilevel and multimodal forms of public engagement. To that end, this research analyses the importance of social media in recent public engagement campaigns promoting clean energy projects in Spain. The goal is to understand the values of social media to different stakeholders, what types of format and specific messages seem to enhance public engagement positively, and what might be done to maintain or even increase local support for renewable energy, especially the newly named citizen energy communities[3] .

2. Review of Literature

Recent research on Spain's energy transition suggests the importance of early, robust and continuous public engagement. Sorman et al.[4]recently surveyed and conducted semi-structured interviews with expert stakeholders and learned that 'transparency' is the foremost concern with regard to the transition: 'right to information results vital in terms of citizens' rights for understanding and participating on energy related issues.' Similarly, Pellicer-Sifres[5] maintains that the 'transformative' transition in Spain must be aligned with the values of 'equity, sustainability, participation and diversity.' Finally, Capellán-Pérez et al.[6]argues that renewable energy cooperatives, which currently occupy a small sliver of the total production and consumption in Spain, must 'project a public image that transmits the social, economic and environmental benefits of renewable energy.' These three studies stress certain aspects of communication and public engagement; they also relate to other empirical research on renewable energy in the Iberian Peninsula[7,10] and are part of an established approach to energy transitions and public engagement[1,2,11,14]. Many researchers note the role of mass media in improving public support for renewable energy; the increasingly important role of social media deserves further attention.

For example, in one of their many influential publications in this field, Patrick Devine-Wright and Susana Batel[15] call for the better translation of generic laws and climate mandates into specific local realities. Further analysis of local realities and how representations of renewable energy projects circulate through social media need further analysis to enhance understanding of how digital campaigns might be translated into support on the ground.

3. Methodology and Findings

Building on previous research on social media and scientific communication[16,17], I collect empirical data from three areas: 1) published stories on specific local energy initiatives (e.g., co-operative blog posts, industry newsletters, national news articles, etc.); 2) internal documents provided on request by community energy stakeholders; and 3) semi-structured interviews (six completed as of October 2020, eight planned) with fourteen individuals associated with government agencies, ongoing H2020 research projects and renewable energy cooperatives in Spain. These interviews put social media communication plans (Twitter, Youtube, LinkedIn, etc.) into context and help to define 'successful' public engagement with local renewable energy infrastructure further. Together, the results show 1) how the messengers crafted multimodal texts for distribution, including posts, podcasts, longer videos and webinars; 2) specific cases in which the timing and context enhanced or limited the messaging (e.g. COP 25 in Madrid, COVID-19 lockdown, the EU Green Deal); and 3) potential correlations between social media activities and behavioural change. Interviews will be recorded, transcribed, translated (when conducted in Spanish) and entered into the qualitative data-coding software NVivo, which primary factors and subfactors, as well as comparisons across projects, to be indicated.

4. Discussion and Conclusions

The results of this enquiry will be used to generate indicators of public engagement, which in turn will offer a more holistic view of how engagement works in social media and how these tools might be leveraged to maximize Spain's contributions to the clean energy transition. A holistic understanding will reach beyond simple metrics—such as the number of comments, views, likes, or shares—to show which media and which messages might have helped achieve both intended and unintended outcomes. The indicators will be especially helpful in gauging how social media offers targeted impacts to activists and policy-makers in Spain (often in Spanish) and how energy research and renewable benchmarks are disseminated abroad (often in English). Such findings are relevant, and timely, locally owned and distributed renewable energy is a central feature of the post-COVID recovery both in Spain and across the EU.

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6.2 Social and Market Acceptance of Photovoltaic Panels and Heat Pumps in Europe: a Literature Review and a Survey

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KEYWORDS

social acceptance, market acceptance, solar thermal, heat pumps

1. Introduction

The rapid adoption of renewable energy solutions (RETs) in buildings is a key factor in achieving the European Union's climate and energy targets. The necessary technologies are available, but non-technological barriers still exist[1]. It has been suggested that social acceptance of RETs has at least three dimensions: socio-political, community and market[2]. Efforts to assess the adoption of RETs should cover more than one dimension of acceptance.

Solar photovoltaics (PVs) are one of the most popular RETs available on the market, having been available for decades and heavily studied. Most of the barriers to their diffusion identified in previous studies can be related to policy support, technical performance and finance[3]. Heat-pumps (HP) have also emerged as environmentally friendly solutions to supplying the energy demand of buildings. Nevertheless, few studies have focused on user-related aspects and public perceptions of HPs, despite the many aspects related to public perceptions that can affect the uptake of the technology in residential buildings[4].

The aim of this article is to conceptualize and assess the social and market acceptance of innovative SunHorizon technologies (PVs and HPs) in Europe, in order to identify which aspects need more focus to ensure the replicability of these key solutions to achieve a low-carbon building sector for a wider audience. The work presented in this article is part of the SunHorizon EU project[5].

2. Methodology

A review of the existing scientific literature on the social and market acceptance of similar technologies was carried out to contextualize acceptance, frame the survey questions to build on frontline knowledge, and understand what drives acceptance and adoption. A literature review of EU projects was carried out to gather knowledge about projects like SunHorizon and obtain guidelines for developing the survey.

Data on social and market acceptance among different stakeholder groups was collected at the demo sites in SunHorizon and beyond through an online survey. To reach a wide public for social and market acceptance, the EC's EU survey service was utilized. The partners responsible for each demo site were tasked with identifying local stakeholders, contacting them via e-mail and distributing digital links to them. However, some sites required survey distribution in paper form.

The survey was applied mainly to stakeholders in the countries where SunHorizon demo sites have been introduced, namely Germany, Spain, Belgium and Latvia. Stakeholders outside the project were also contacted via social media. The survey was administered to the following stakeholder groups:

- Business representatives
- Private building owners
- Public building owners
- General public, residents and end-users

For social acceptance, the data collected are used to understand how to make stakeholders more positive towards the technology and thus less likely to oppose it. As for market acceptance, the data are used to identify the barriers and motivators for different stakeholders to adopt the technology. The data obtained from the survey were analysed using multiple approaches, including multivariate data analysis with principal component analysis (PCA) and a MANOVA (multivariate ANOVA), followed by a COST (consider one separate variable at a time) analysis, using the ANOVA test.

3. Results

The results of the literature review reveal three barriers to be the most common in preventing the further adoption of renewables: the low availability of information about the technology, finance and sociodemographic factors like income levels and educational levels. Low availability of information about how the technology works, the proper way to operate it, the investment and operating costs, the government incentives available and the installation process can hinder the adoption of renewables. The financial aspects can be positive or negative for adoption: economic incentives such as tax deductions or easy access to loans have been found to foster uptake, whereas high investment costs and long payback periods count as barriers.

The results of the social acceptance part of the survey identify only one aspect where groups with very high environmental indexes were more positive towards the technology than other groups, namely when the technology has a positive effect on the landscape. The market acceptance results provide stronger support for environmental values being positively influential on the adoption of clean technologies. They also indicate that the technology will increase the value of the property, the cost-savings potential is certain, new and innovative technology is an opportunity, and the system performance is certain.

The respondents were to a large extent interested in the technology, and curiosity has been found to be an important driver, as in previous literature. The availability of information was also identified as both a barrier and a driver, like the findings in the literature and EU project reviews. The survey confirms these findings in both the social acceptance and market acceptance sections, as groups that are involved with the SunHorizon project, and therefore have more information about the technology, are found to be more positive towards how the media presents the technology. The information with the highest impact on stakeholders is the increase in social status, technical performance, the environmental aspects of the technology and the related legal framework.

4. Conclusions

Market acceptance shows significant variations among both stakeholders and countries. In all countries, the investment costs of the technologies are perceived as a barrier to adoption. In Spain legal and organizational issues are also perceived as barriers, while Latvian and Belgian respondents cited the economic and legal barriers. The German respondents only perceived the investment cost as a barrier. Economic aspects are seen as the main barriers among public building owners and the general public. It is business owners who perceive the largest number of barriers, including the economic aspects, the lack of information, trust, business models and legal issues, while private building owners perceive the least barriers, being concerned only with the economic aspects. The results of this work can be used as input for policy-makers, as they formulate strategies to foster adoption in Europe.

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6.3 DER Customer Insights: A Value-based Approach to Motivating New DER Customers

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KEYWORDS

distributed energy resources, customer centricity, values modes, motivation, Australia, trust

1. Introduction

Bloomberg New Energy Finance predicts that approximately one third of Australia's electricity capacity will be "behind the meter" by 2035[1]. These resources, including solar, batteries and demand management, are known as distributed energy resources (DER). As market forces drive Australia towards a more decentralised energy system, it is important to probe more deeply the customers that DER products and projects are seeking to serve.

To arrive at a better understanding of DER customers, the customer experience was analysed from twenty DER projects funded by the Australian Renewable Energy Agency (ARENA, Figure 1). The core research question was: How can consumer insights from ARENA-funded projects be unlocked and shared to support the continued growth of DER in Australia? In particular:

— What types of customers were targeted in the projects? How can future DER projects find the right types of customers?

— What inherently motivates customers? What engagement strategies could encourage customers to participate in future DER projects?

In the absence of any consistent framework for characterising customers and their motivations across the twenty DER projects, the research turned to a values-based framework.

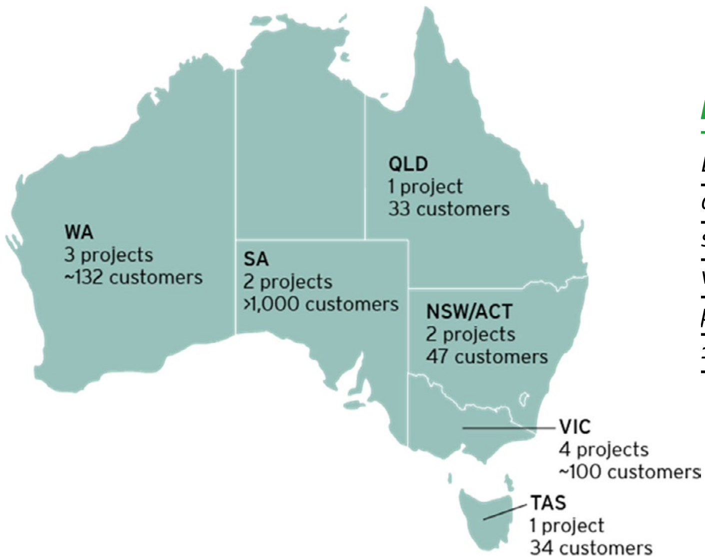

Figure 1.

DER projects across almost all Australian states and territories, with demonstration projects involving over 1,300 customers [4]

2. Background

Values are stable psychological structures that motivate behaviour and cut across demographics. Designing projects to appeal to particular values rather than specific demographic categories can be effective when projects need to appeal to the mass market.

The Values Mode framework is a proprietary motivational approach developed by a company called Cultural Dynamics Strategy and Marketing and applied by campaign strategists and market researchers, including Chris Rose, KSBR and Futerra[2]. The framework identifies three primary "values modes": "settlers", "prospectors" and "pioneers". These groups can be thought of as living in three different worlds, with fundamentally different values and motivations. Settlers are drawn to seek out safety, security, tradition, identity and belonging. Prospectors yearn for success, the esteem of others and self-esteem. Pioneers have a constant drive for new ideas, connections waiting to be made and a life based on ethics.

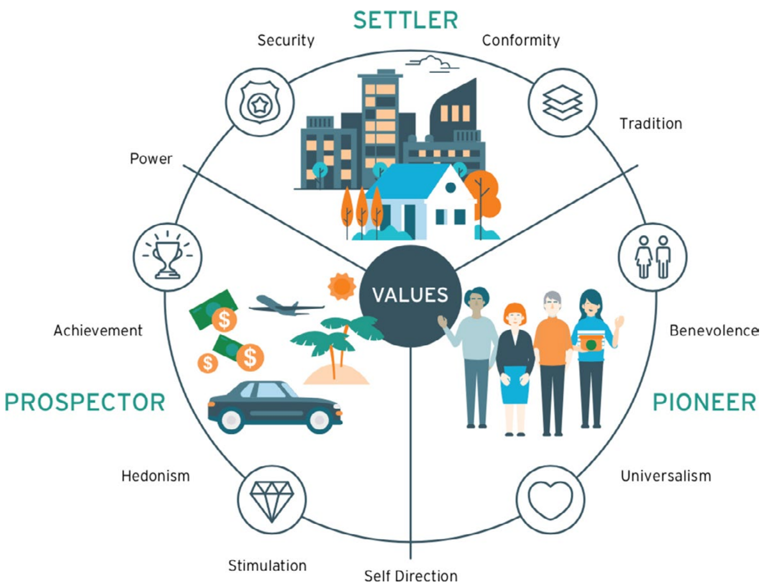

Figure 2.

The Values Modes mapped on to Schwartz' universal values [3], as visualised in the ARENA DER Customer Insights Report on Values and Motivations [4]

3. Methodology

The research followed the following process:

- Initial review of selected reports to identify high-level themes, captured as nodes in qualitative research software (Nvivo)
- Full review of a hundred reports against high-level nodes
- Granular coding of all customer insights into existing and emergent nodes
- Draft findings reviewed by twenty ARENA DER project leads

4. Results and Findings

The research found that future DER projects can benefit from better understanding of their target customer base before developing *and* communicating the product offering.

Most projects experienced delays in customer recruitment, and many did not reach their original participant targets. As many projects required customers to be able to afford (generally >$1,000) and accommodate a new battery storage unit, it was challenging to recruit the target number of customers and, in some cases, to keep them fully engaged and responsive over the life of the trial. DER products needed to be communicated more broadly and deeply than originally anticipated, for example, by holding community events and one-on-one (and sometimes face-to-face) conversations with prospective customers. This was time- and budget-intensive to an extent that is unlikely to be feasible in a commercial context.

Few (<6) projects formally segmented their customer base prior to developing the product and engaging the target market, which may have contributed to the recruitment challenges. Most trials were led by electricity distributors, who were focused on solving network constraints and needed to approach the 'mass market' but used blanket marketing strategies. They often required high levels of uptake (sometimes over 20% in a limited geographical area), which was not achieved easily. In comparison, the energy retailers used Experian's proprietary Mosaic tool[5], and several community- and developer-led projects involved customers in the design process. The deeper engagement approaches appeared to improve customer satisfaction.

Deeply understanding customer values can help reveal customers' motivations. The 'gold standard' in understanding customers is segmentation based on specific audience research, but this is costly and time consuming. A values modes method may offer an effective targeting heuristic for future projects that do not have the resources to undertake new research to formally segment their customer base. The research found nine common motivators for project participation, eight of which mapped neatly against the universal values and values modes (Table 1). Developing and communicating DER products to align with these motivations is likely to lead to better customer uptake in the future.

MOTIVATORS OF DER CUSTOMERS		UNIVERSAL VALUES	PRIMARY MODE
1	Financial security/benefits	Security, power*, universalism*	Settler
2	Security of supply	Security, power, self-direction*	
3	Maintaining the status quo	Conformity, tradition	
4	New technology	Stimulation	Prospector
5	Aesthetics/ status symbol	Achievement	
6	Energy independence	Self-direction*	Pioneer
7	Environmental benefit	Universalism	
8	Community benefit	Benevolence*	
9	Trust	N/A	N/A

Table 1.

Eight of the nine motivators of DER customers mapped against the values modes [4]

5. Discussions and Conclusions

By applying this approach to the ARENA projects, it was evident that:

— Financial benefit was a core motivator for all DER customers, cutting across values modes. However, effective ways of communicating the financial benefits vary across values modes, for instance, by highlighting cost savings for settlers, 'smart investment' for pioneers and 'fair value for money' for pioneers.

— Settlers are motivated by security, desiring reliability and 'maintaining the status quo'. Therefore, to maximise uptake by settlers, it is important that products minimise any perception of threat to a customer's security, including energy reliability and financial risk.

— Prospectors drive the first wave of mainstream DER adoption and are excited by 'getting ahead' or 'making a smart investment'. When targeting prospectors, it is important that the product is attractive financially and aesthetically.

— Pioneers desire fairness and are willing to support 'the greater good'. Ensuring social equity in design and implementation will protect a project from customer backlash.

— Trust also cuts across the values modes and is critical to achieving a customer-centred energy future. Current trust levels in the Australian energy market are low – only 32% of households believe that the market is working in their interests[6]. To build trust, projects may want to consider models such as the "Trust Equation" (credibility, reliability, intimacy, self-orientation) [7].

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6.4 DER Customer Insights: Lessons from Customer Journeys for New DER Customers

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KEYWORDS

distributed energy resources, customer centricity, customer journey, service design, Australia

1. Introduction

Australia's energy system has undergone a rapid transformation over the last ten years, from being predominantly centralised and carbon-intensive, to being more decentralised and lower carbon (AEMO, 2019). A major source of this change are distributed energy resources (DERs), such as solar photovoltaics and battery energy storage systems. One in five homes (more than two million households) are now equipped with rooftop solar installations (Clean Energy Council, 2020).

To learn from this experience and to support the continued deployment of DERs, much can be learned from the experiences of early customer groups. This includes the methods of communication preferred by customers, the importance of trust, and how to create advocates through high customer satisfaction. Utilising this knowledge can enhance value for customers and improve innovation capacity for DER vendors (Yachin, 2018).

This study explores the experiences of over a thousand participants in twenty DER projects funded by the Australian Renewable Energy Agency (ARENA) to ask what can be done to improve the customer experience for DER customers who are participating in funded technology trials. This can support the more rapid adoption of DER and thus accelerate the move towards cleaner, more affordable energy for consumers.

2. Methodology

A five-stage methodology was followed to capture insights from one hundred reports from twenty ARENA DER projects:

1. Literature review of reports from ARENA-funded DER projects
2. Deep discovery and analysis of a hundred reports against high-level nodes
3. Granular coding of all customer insights in existing and emergent nodes
4. Draft findings reviewed by ARENA DER project leads
5. Evaluation tool developed for gathering customer insights from future DER projects

3. Results and Findings

The DER customer journey was broken down into four main steps, documenting approaches, experiences, issues and key lessons. The four key steps are shown in Figure 1.

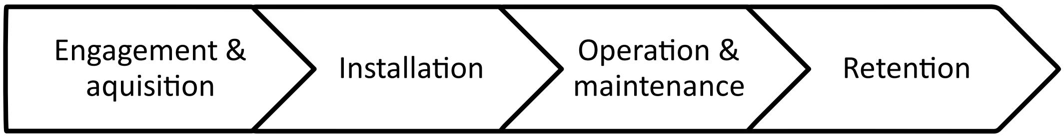

Figure 1.

Main steps in the customer journey to DER

Many of the ARENA projects emphasised the need to provide a smooth customer experience along the entire customer journey. As part of this, listening to and acting on customer feedback was seen as essential for ensuring continual improvements to the customer experience across the entire journey.

The overarching finding of the research is that funding agencies such as ARENA and the organisations it supports can both benefit from a better understanding of their target customer base before developing *and* communicating the product offering.

ARENA can maximise the impact of their funding (through increased adoption and encouraging advocacy) by supporting best practice in this regard. This would also benefit the recipients of funding (typically technology-focused start-up companies) prepare for recruiting customers who seek (and are increasingly used to) sophisticated methods of customer engagement.

4. Discussions and Conclusions

A wealth of customer insights are contained within the reports that are generated by the ARENA-funded DER projects. This can serve to help inform future projects, improve the capacity and capability of DER start-up companies, and help policy-makers make more informed decisions.

Characterisation of the DER customer journey revealed six common themes that led to increased recruitment and better customer experiences. The key findings were:

1. A deeper understanding of customers leads to increased customer acquisition and better engagement.
2. A well-articulated customer value proposition with clear benefits can improve customer acquisition rates and lead to more successful customer engagement.
3. Deploying commercially mature products minimises the risk of issues affecting operation and maintenance, and the journey's retention phases.
4. A frictionless process along the entire journey, with a key and knowledgeable point of contact when support was needed, is key.
5. This step has a lasting impact on customers. Well trained, knowledgeable installers are needed who understand them and the products.
6. Trust wasfound to be critical in public acceptance and advocacy.

Engagement and acquisition posed the biggest challenges to the ARENA funded projects, but the installation phase had a lasting impact on customers. The customer journey method is valuable because it can support agencies like ARENA, policy-makers and those in the DER supply chain to 'walk in the shoes' of the customers they want to assist and understand the barriers from the latter's perspective.

The main limitation of the study is the potential for bias in the various ARENA project reports that were researched and authored by ARENA-project participants. The public reports were a condition of ARENA's funding, meaning there is a risk that they were written with an overly optimistic outcome and did not reflect the true nature of the customers' journeys. Standardising customer interviews across ARENA DER project participants in future would help address this limitation.

Ultimately improving understanding of the customer journey will help accelerate the rate at which DER is deployed by the sector and maximise the potential benefits it can offer to customers, the environment and the energy system.

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6.5 A System Approach to Off-Grid Hydropower for Community-led Flood Resilience

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KEYWORDS

systems thinking, pico-hydropower, flood warning, community engagement, prototype development

1. Introduction

Energy availability under both normal and hazardous conditions is a key element of sustainable development[1] and resilience to natural disasters[2]. Access to off-grid renewables, such as pico-hydropower, provides multiple benefits particularly to remote communities in low- and lower middle-income countries, which often lack reliable energy and resources to support hazard planning and response.

Applying a systems approach to these issues could help humanitarian and development practitioners and community stakeholders co-develop technology-supported projects that address local needs. Systems thinking is a holistic analytic approach that focuses on how different elements of complex systems are interconnected and affect program processes and outcomes[3]. Our study investigates a community systems approach to energy generation and distribution management with reference to water-based disaster emergencies within a framework of sustainable development. This approach is being applied to localised hydropower and flood-warning systems, including a potential hybrid prototype.

2. Background, History, Review of Literature and Methodology

The foundational work for this study involved a literature review of best-practice community engagement in reducing disaster risks with a focus on technology-supported solutions. It includes information from case studies of communities with installed off-grid renewable energy generators and flood-warning systems. These highlight the critical role of 'community-centric' approaches that seek to reinforce community capabilities and their systems, rather than replacing them[4,5]. Such approaches are well suited to community-level developments, as they canvas a wide range of stakeholder views and address pragmatic issues that are likely to affect the longer-term viability of developed solutions. Within our current project, this approach supports:

1. Engagement with all relevant community stakeholders and a developed understanding of their respective needs
2. Identification of priority needs, e.g. in off-grid energy generation and distribution, and localized hazard response
3. Co-development of prototype systems
4. Solutions regarding long-term support and the further development of technology-supported interventions, i.e. how these can be sustained in low-resource environments, with histories of resource inequity and environmental injustice.

3. Results and Findings

Energy availability is a critical factor for sustainable development and hazard response. However, remote communities in low- and lower middle-income countries often lack reliable energy sources, limiting their overall capacity. While there are potential solutions, these often need to reconcile diverse needs to form jointly agreed solutions. Our study employs a systems approach to the local development of hydropower generation and flood-warnings. These applications can support communities in becoming more resilient against floods and therefore more sustainable over time. According to our research design, the approach should emphasize the following:

— Analysis of vulnerability and capability assessments, which confirm energy insufficiencies and vulnerability to flooding in riparian communities

— Community engagement for smooth collaboration between the different stakeholder groups involved

— Interdisciplinary collaboration for prototype development following systems engineering processes (i.e. SIMILAR process[6]).

4. Discussion and Conclusions

Energy availability is essential for socio-economic sustainability and resilience to disasters. Many vulnerable communities need support to developmental and hazard preparedness, of the kind afforded by reducing disaster risks and related programming, to ensure safer communities and improved livelihoods. Systems approaches can minimise factors in program failures through early hazard detection and smoother process transitions in development and implementation phases. This is therefore recommended as a framework for the effective co-development of prototypes. The combination of pico-hydropower and flood warnings can serve community needs, but developed solutions are context-specific and require effective community engagement and resource planning to achieve enduring success.

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6.6 Exploring the Role of Stakeholder Dynamics in Residential Photovoltaic Adoption Decisions: A Qualitative Survey in Germany

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KEYWORDS

social dynamics, communication activities, photovoltaic adoption, decision- making process, quantitative surveys

1. Introduction

Residential decision-making with respect to low-carbon technologies has been studied intensively. Yet, in behavioural studies to date, individuals are typically assessed in isolation from their social environments[1]. Furthermore, in existing energy-transition modelling approaches, relevant stakeholder interactions and their effects are barely accounted for[2]. The research at hand addresses this gap by investigating stakeholder dynamics in residential PV decision-making from a procedural perspective. Based on a quantitative survey, we investigate the perceived influence of various stakeholders on decision-making. Special attention is given to the relative importance of different stakeholders in the different stages of the adoption process while also considering the socio-economic characteristics of the participants. Individual credibility dimensions (hereinafter referred to as (stakeholder) attributes) are found to explain the varying influence of stakeholders along the different stages in decision-making in the PV adoption process.

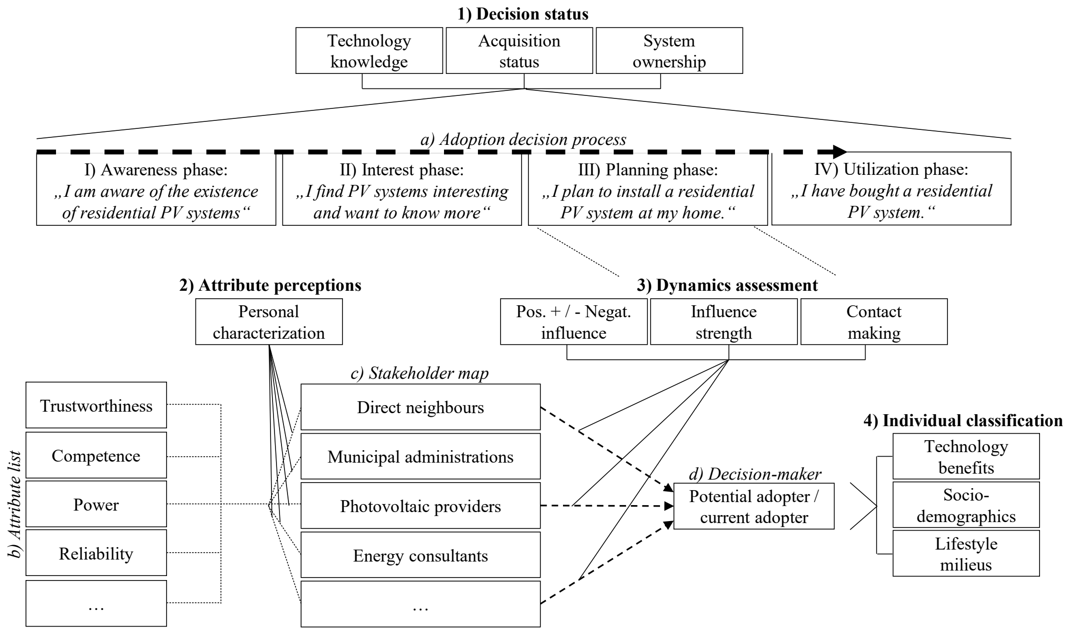

Figure 1. *Composition and structure of the computer-aided survey (1-4 set out the general structure, I-IV represent the different stages of the decision-making process, a-d are answer possibilities of the participants).*

2. Methodology

In this project, stakeholder dynamics have been explored with the help of a computer-aided survey. Survey participants were required to be house-owners with decision-making power over their rooftops and awareness of PV systems. The survey consists of 1,165 completed questionnaires. Fieldwork was completed in late 2019. The survey is divided into four main parts (1-4), as illustrated in Figure 1, to which reference will be made in the subsequent discussion.

First, adoption decision status was determined by asking respondents whether they currently own a PV system (current adopters, CAs) or alternatively, how strong on a five-point Likert scale their intentions to adopt within the next three years were (potential adopters, PAs).

The decision-making process (a) was divided into four stages. The participants were first asked to indicate their current stage in the decision-making process to adopt: i.e. the awareness stage, interest stage (II), planning stage (III), or utilization/purchase stage (IV). Participants who, after becoming aware of PV, were still in the process of developing an interest in PV or planning to adopt it were classified as potential adopters (PA), while participants who had acquired PV were classified as current adopters (CA). Participants were then asked to describe their relations with stakeholders (c) during the stages they had completed (stage I; stages I and II; or stages I, II, and III). Specifically, participants were asked which stakeholders (c) they had communicated with whether these stakeholders had influenced them positively or negatively toward PV and the strength of the stakeholders' influence. Participants were also asked to rate the credibility attributes of each stakeholder (b). Lastly, driver and barrier statements, and socio-demographic and lifestyle questions, were asked to differentiate segments of decision-makers (4).

3. Results and Findings

The survey participants are largely distributed between the sub-groups PAs with low adoption intention (n=486) vs. high adoption intention (n=285) and the CAs (n=394). High-intention PAs are defined as those participants who agree or strongly agree to adopt within the next three years. Study participants report a higher net equivalent income (2186 €/month) compared to the national mean (1959 €/month). The mean net equivalent income of CAs and high intention PAs does not significantly differ, whereas the mean income of low intention PAs is significantly lower (-247€/month, $p<0.001$).

Both CAs and PAs who indicated a high intention to adopt show a positive relationship with statements about the environmental, economic, autonomy and social benefits of adopting PV. CAs are most likely to agree, followed by high-intention PAs. This confirms the expectation that respondents who strongly believe in the benefits of adopting PV also harbour stronger intentions to adopt PV.

Furthermore, communication with various stakeholders is important in the decision to adopt. The descriptive analysis reveals that the reported contact rates with stakeholders vary during the decision stages and differ among the decision-maker sub-groups (CAs, PAs Stage III, PAs Stage II). Across all study participants, the stakeholders with whom participants are most likely to have contact at all decision-making stages consist of family and relatives, friends, acquaintances and colleagues, neighbours, manufacturers, providers and the local utility. A closer look at the sub-groups reveals that on average CAs perceive a larger number of stakeholders as exerting a positive (pro-PV) influence throughout all stages of the decision-making process than the PAs. Furthermore, PAs with a high intention to adopt perceive a larger number of stakeholders as exerting a positive influence compared to PAs with a low intention to adopt. This is supported by[3], who rate "a high level of communication" between the solar company and the adopter as important in reducing perceptions of complexity.[4] also state that "established social connections [are] more important than geographical proximity", as most active peer effects resulted from existing relationships.

To measure stakeholders' influence on decisions to adopt, PAs were also asked how likely they were to take up PV. We find that positive (pro-PV) and high-influence contacts with family, neighbours, energy consultants and PV providers have significant ($p<0.05$) and positive coefficients when regressed on the probability to adopt (R^2=0.18).

The influence strength of the stakeholders can largely be explained by their perceived attributes (R^2 between 0.4 and 0.72 for varying stakeholders and varying phases). The most important attribute in all phases for nearly all stakeholders is competence ($p<0.1$). While reliability has a stronger impact for commercial stakeholders ($p<0.1$), likability is more important for social peers ($p<0.1$).

4. Discussion and Conclusions

This exploratory assessment reveals that the influence of stakeholders is indeed dynamic: the influence of different stakeholders varies depending on their perceived attributes, as well as on the stage the decision-maker has reached in the decision-making process. The intention to adopt PV is strongly dependent on income and on the influence of stakeholders who are perceived as credible (e.g. competent, reliable, likeable, etc.). This is also correlated with the perceived non-financial benefits. This suggests three policy implications that could increase residential adoption of PV: strengthening the influence of administrative and commercial stakeholders by enhancing their reliability and competence, clarifying the non-financial benefits, and elevating financial benefits.

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6.7 A User-Centered Design Approach to Identify Behavioral Biases in the Adoption of Solar PV by Households

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KEYWORDS

diffusion, communication, design thinking, user-centred design, cognitive biases

1. Introduction

Buildings offer great potential for solar photovoltaics (PV), given that no land-use change is required, the energy is used directly where it is generated, and it activates citizens within the energy system. In contrast, households have under-invested in energy technologies for decades, resulting in policies that force innovations into the market or that rely on economic incentives[1]. Relevant behavioural research predominantly focuses on activities that use energy. However, investments in energy technology have the potential to exert much greater impact on sustainability goals[2,3]. Energy technology adoptions are typically described using Rogers' model of innovation diffusion, where information plays a prominent role in the decision-making process[4]. The timing, source and quality of information have all been identified as critical factors influencing consumer behaviour[5,7]. However, there is a lack of research into the methods of improving information delivery to consumers. Likewise, there is a lack of randomized field trials for testing energy investment behaviour at scale[8,9], which is critical for validating the impact of insights from using laboratory or qualitative methods[10].

2. Objective

This paper describes the first phase of an applied project to improve information delivery to Swedish consumers and nudge them towards adoption of PV. The objective of this study is to identify relevant behavioural techniques for randomized field trials of solar PV investment. The trials will be conducted via web-based commercial tools, their own goal being to increase lead conversion and reduce cost. Therefore, sub-objectives include:

— identifying customers' needs, barriers, motives and misconceptions about PV
— identifying promising methods of information delivery to serve the customer's needs
— mapping PV market stakeholders to ensure robust and successful experimentation.

3. Methodology

The project uses a Design Thinking approach, starting with mapping user journeys to understand behavioural insights in the decision-making process. Twenty-eight semi-structured interviews are being conducted with decision-makers in three ownership categories – villas, multi-family cooperatives and professional property owners. Existing communication channels are reviewed to describe the current state of information delivery in the market and improve the design process for experimentation in light of the required commercial features. The interviews and review combine to reveal specific decision-making contexts and behavioural techniques, which are matched with relevant theories in the scientific literature to form the basis for field trials.

4. Results and Findings

The interviews reveal a wide range of barriers, motivations, triggers, activities and behaviour that span the entire adoption process. However, the focus here is on information acquisition and presentation during the "gaining knowledge" and "forming an opinion" stages[5]. A number of barriers commonly found in the literature are present, such as long payback times, a lack of knowledge about the technology, uncertainties about the technical or economic performance, and difficulties in finding trustworthy information[6,11]. Some unexpected themes also arose, such as a desire to understand PV within the context of other energy options to make investments with the greatest impact. There are also misunderstandings, such as the expectation that PV is rapidly improving (motivating waiting) or that completely avoiding grid sales is a prerequisite for a good economy. This last point made batteries a frequent point of discussion, despite their being uneconomic, and thus leading to the conclusion that PV as a concept is also uneconomic.

PV providers and third parties are increasingly building professional-looking web-based tools that calculate the energy-generating potential of a user's roof, recommend a system, and provide a quotation with some indicators of the financial savings. On the surface, this appears to be valuable information, but many of the tools involved provide simple, limited information, overestimate energy generation and economic gains, and generally present a best-case scenario, sometimes pushing the boundaries of plausibility. There is also a lack of interactivity or transparency such that using the tools to test different options with rapid feedback is difficult, thus limiting the educational value.

The shortcomings of online tools reveal an interesting point of conflict between the motives of customers and of providers: websites can be lures to generate leads and capture customers. The goal is to generate personal consultations where the provider has the customer's full attention, builds trust and can be more personal and therefore effective in their analyses. For the customer, this system requires consulting with multiple suppliers to cross-examine their offers and analyses, though they still lack input from a neutral, trusted source. The state government's energy agency has a PV calculator aimed at educating users, but its inputs do not make it easily comparable with commercial tools, thus reducing its effectiveness as an arbiter.

5. Discussion and Conclusions

Although the Swedish PV market is small, it is growing rapidly, with a disproportionately high number of suppliers. For individual companies trying to build a brand and capture market share, word-of-mouth recommendations and personal connections are a valuable strategy[12]. From the consumers' perspective, this can create an information barrier that prevents them from reaching the implementation stage[4,5]. Several interviewees reported that their receipt of the first offer spelt the end of their investigation into solar PV. While it may not fit into the relationship strategies of individual businesses, a personalized information source focused on educating consumers can lower the barriers to information and reduce information asymmetry, which also lowers transaction costs for the PV industry as a whole[13].

These insights will be valuable in devising new communication strategies and revealing relevant behavioural techniques that may reduce the barriers to users. A fundamental need is to consider information-overload and decision-fatigue, which promote bias towards the status quo. The user's understanding of performance indicators is also important[14], which quantifies their perceived estimate of a PV system (technical, economic, environmental). The framing of PV benefits as savings versus investment is a notable test point, on that will need to consider time-inconsistent preferences such as present bias and hyperbolic discounting. A question of framing also arises where the tool can act as an authority to provide a specific recommendation, or as a dynamic educational tool that allows the user to explore options and receive feedback. Novel probability indicators inspired by finance can also be tested to reduce loss-aversion from economic uncertainties[15,16]. These key insights provide experimentation points that can design randomized field trials to be executed via web-based channels during the second phase of the project.

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6.8 Determinants of Residential Intentions to Adopt PV: A Meta-Analysis

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KEYWORDS

residential sector, rooftop photovoltaic, meta-analysis, single study issues, theory of planned behavior, reporting standards

1. Introduction

To reach the global goals to reduce carbon emissions to net zero by 2050, the decarbonization of the residential sector is of central importance[1,3]. As this process largely depends on individual decisions to adopt low-carbon energy sources, and as residential photovoltaic (PV) systems are a central component of this transition[4], the antecedents of the residential adoption of PV systems have been researched widely to help accelerate diffusion[5]. The roles of socio-demographic and general personal motivations, such as environmental concern and innovativeness, have frequently been investigated, and theories capturing beliefs about PV or the innovative and pro-environmental aspects of the product have been used as theoretical backgrounds to understanding adoption decisions. However, due to the different theoretical perspectives and explanatory variables, questions remain regarding the role of predictors in PV adoption[5]. Aggregating empirical evidence is further hampered by inconsistencies between studies concerning the use and operationalization of predictors, different sampling procedures and contexts.

To advance research from the existing body of literature body, a statistical meta-analysis is performed that aims to reveal patterns of relationships among explanatory variables and residential adoption of PV. Theoretical development is advanced by determining point estimates of the relationships between an intention to adopt and socio-demographic variables, the typical Theory of Planned Behavior (TPB) constructs, and additional variables related to environmental attitudes and innovativeness. Furthermore, following the Meta-Analytical Structural Equation Modelling (MASEM) approach as outlined by[6] and applied by[7,8], the suitability of an (extended) TPB model to replicate the extracted data is assessed. Finally, the implications for future studies of enhancing the future aggregation of scientific evidence are discussed.

2. Methodology

In order to include only the commensurable literature, peer-reviewed scientific articles written in English that had conducted a quantitative survey on residential PV adoption intentions and reported bivariate correlations were selected. A literature search with a fixed set of keywords was conducted in August 2020 using Web of Science, Scopus and PsychINFO. The search yielded 946 results, of which 653 remained after doublets were removed. The screening procedure was conducted by two independent screeners and covered title screening (205 remain), abstract screening (110 remain) and full-text screening. Of the 24 papers selected, only five report correlation tables[9,13]. We contacted the authors of the remaining articles via e-mail, and gathered three more correlation matrices[14,16].

Conceptually similar constructs among and within primary studies were grouped by two independent researchers to ensure reliability. If there were conceptually similar constructs within one study, the composite was computed. To compute the meta-analytically pooled correlation table, the meta-package in Stata was used, and a random-effect model with inverse-variance weighting deploying the REML (restricted maximum likelihood) method was applied[17]. Using the correlation table as input, four structural equation models were computed, using a maximum likelihood estimator.

3. Results

The meta-analytically pooled correlation table reveals medium to high significant correlations between environmental concern (p = .343**[1]), novelty seeking (p = .475**), perceived benefits (p = .530**), subjective norm (p = .326**) and intention to adopt a residential PV system respectively, whereas socio-demographic variables and barriers were uncorrelated with intention. Particularly large correlations were also found between environmental concern (p = .693**), novelty seeking (p = .636**), social norm (p = .491**) and benefits respectively, as well as novelty seeking and social norm (p = .504**).The four subsequently computed structural equation models were statistically significant and could explain around 30% of the variation in intention, with benefits being the strongest predictor of intention. Benefits in turn can be explained by the decision-makers' environmental concerns, novelty seeking and perceived subjective norms, leading to a coefficient of determination of around 70%.

4. Discussion and Conclusions

In this study, we attempted to make sense of the vast amount of data that is already available on the residential adoption of PV. However, the empirical evidence is in large parts far from being similar enough to meaningfully combine results, and a lack of reporting standards further aggravates the problem. Therefore, only eight studies could be included in the final meta-analysis, which limits its informative value. Only small portions of the heterogeneity among effect-size estimates in single studies could be explained by sampling error, typically around 8%. The results of the MASEM analysis support the findings of[5,18] that socio-demographic variables are not good predictors of adoption decisions. The most important predictor for adoption intentions is the decision-making unit's perception of the personal and environmental benefits of PV systems. The results are also in line with the idea that general dispositions, such

1 *Significance levels: * p<.1; ** p<.05*

as environmental concern and novelty seeking, determine how a product is perceived in the first place, rather than determining adoption intentions directly[11,19]. Consequently, we propose to use a slightly modified version of the TPB in future studies, in which attitudes are explained with reference to environmental concerns, novelty seeking and social norms. To enhance future aggregations of scientific evidence, we furthermore recommend the use of consistent predictors and measures for adoption, the systematic collection of contextual variables and compliance with reporting standards.

Overall, our results imply that policy measures should focus on enhancing the perception of benefits instead of the reduction of perceived barriers. Measures aimed at increasing the financial benefits of PV installations could include options to reduce the initial costs. Promotional strategies for these measures could focus on the environmental benefits or innovativeness of PV systems, with the latter playing a particularly large role in regions with low diffusion stages. As the perception and importance of the personal and environmental benefits depend on the characteristics of the decision-maker, promotional strategies could also be tailored to consumer segments representing groups of like-minded people rather than socio-demographic groups so as to account for the interchangeable or complementary effects of psychographic determinants.

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SECTION 7

ENERGY COMMUNITIES

7.1 Understanding Preferences for Characteristics of Renewable Energy Communities

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KEYWORDS

Renewable energy community, choice-based conjoint experiment, renewable energy ownership, positive energy districts

1. Introduction and Background

Building energy self-sufficiency, reducing energy costs, and meeting lower emissions targets through renewable energy technology (RET) has become a central focus of many community and private sector energy projects. The spread of renewable energy technology has been facilitated by lower installation costs, increased reliability of the technology, and supporting policy and investment[1]. Additionally, the expansion of RET has opened the discussion around how energy systems of the future will be configured. As the decentralization of energy production and management becomes a real possibility, with citizens taking on greater responsibility within the system, rethinking future communities becomes more important. New opportunities and shifting responsibilities will create new roles for involved stakeholders, including the private sector and citizens.

While ample literature focuses on the acceptance of single RET in specific sites, it is important to recognize that RET operates within a system of multiple processes and actors that interact at numerous levels[2]. This embeddedness makes it essential to understand configurations of renewable energy projects that would appeal to citizens beyond acceptance of single RET on single sites. Examples of community renewable energy projects, such as the Hunziker Areal in Zurich, Switzerland and Vauban in Freiburg, Germany, have shown that the appeal of living in such communities goes beyond reliance on RET and includes benefits such as green mobility options and shared community spaces. The aforementioned projects fit into the EU's plans to develop 100 Positive Energy Districts (PEDs) – places that couple "built environment, sustainable production and consumption, and mobility to reduce energy use and greenhouse gas emission and to create added value and incentives for the consumer" – by 2025[3]. Despite numerous such projects in development across the EU, no academic attention has been given to exploring the appeal of the multiplicity of benefits offered by PEDs or PED-like projects.

This research aims to address this gap by understanding the appeal of different configurations of PEDs. Creating suitable renewable energy community configurations for individuals can increase their likelihood of engaging in their community and becoming energy citizens. Greater citizen engagement within renewable energy communities is important because it can mean more rewarding, emissions-cutting outcomes from the use of RET and related technologies (e.g. smart meters). In this study, configurations of PEDs and PED-like communities are studied because of their salience to the EU's energy transition agenda and their ability to offer a variety of valuable services that result from community-private sector partnerships.

This research explores the appeal of three attributes that characterize renewable energy communities: RET ownership and engagement from the citizen, availability of mobility options, and availability of communal spaces. These attributes align with characteristics seen in PEDs, as well as established drivers of RET acceptance found in the literature. Ownership of RET has been found to be important in a community's acceptance of a renewable energy project[4], and may predict a citizen's involvement with RET. Citizen engagement and acceptance of renewable energy structures has been found to be higher when the project is citizen-driven and locally-owned[5,7]. An analysis of several case studies in Germany found that community ownership of wind turbines led to wider acceptance of their installation compared to wind farms owned by a commercial company[6]. Renewable energy cooperatives have also been found to attract individuals that are favourable towards renewable energies[4] and motivated to participate in local energy policy decisions, though once having joined, individuals often prefer delegating issues of cooperative development to an executive[8].

Ownership and technology has also been studied in the context of access-based car sharing[9]. The research showed that lack of ownership was a driver behind lack of engagement for the brand and care for the cars. In this context, the preferred type of ownership structure may predict an individual's intended engagement within the PED.

Further, understanding the configuration of mobility aspects within a PED is important as mobility is often a central focus in renewable energy communities. Mobility options describing restrictions around private cars and allowance of electric vehicles are explored. Finally, the availability of communal spaces, such as community gyms and workspaces, is tested in order to explore the appeal of including human-centric aspects to potential residents.

2. Methodology

We ran a choice-based conjoint experiment, a common method used in market research[10,11], to test preferences for PEDs. The experiment was integrated into the Swiss Household Energy Demand Survey (SHEDS), which collects data from a sample representative of the Swiss population (excluding Ticino). The experiment sample consisted of a random SHEDS subsample of 1500 respondents.

During the experiment, respondents were shown six choice sets consisting of two PED options each. Different levels of the aforementioned attributes describe each PED option: ownership and citizen engagement (e.g. you own the PV and are an active trader; a cooperative owns the PV), mobility (e.g. public transportation replaces private cars; only a shared fleet of electric vehicles exists), communal spaces (e.g. a PED might include a shared gym, workspace, or guest rooms for a small monthly fee).

The latent class analysis will be applied to the data to segment respondents into groups that share similar preferences in their choices. Additionally, Hierarchical Bayes (HB) estimation may be used to understand the importance of each attribute level. This analysis can indicate which characteristics of renewable energy communities are important in an individual's choice and what segments of consumers could exist. Such information around consumer desires can be critical to the acceptance of RET projects.

3. Research Aims

The results of the research will indicate the importance of various attributes in renewable energy communities, highlighting which benefits hold the most potential for citizen engagement. Ultimately, the intention is to provide policy-makers and entrepreneurs involved in the development of renewable energy communities with more information on segments of potential residents and their preferences. Creating configurations of renewable energy communities that entice citizens to interact with RET and others in their community puts them closer on the path of becoming human-centric, energy-positive communities.

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7.2 Energy communities in Italy: Analysis of the Internal Gap between North and South

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KEYWORDS

energy communities, barriers, enablers, southern Italy, northern Italy

1. Introduction and BackgrounD

Technologies for distributed energy generation have reached a level of maturity that will favour the creation and diffusion of local energy systems. Nevertheless, technology is only part of the energy debate. The progressive involvement of local communities in the ownership, decision-making and organization of energy production plants is leading to the birth of a new socio-energy system based on distributed generation from renewables. In this context, energy communities will play a crucial role in reviving discussion of the entire infrastructural system and the energy market. In this paper, we describe our study, through a comparative analysis, of the socio-economic, cultural and historical factors that characterize energy communities in the two macro-areas of northern and southern Italy and that determine their level of diffusion.

Within Europe, the evolution of energy legislation is increasingly aimed at promoting new ways of developing and using renewables efficiently. For this reason, particular attention is directed at increasing local production and consumption initiatives. On the one hand, the European Commission, within its Clean Energy Package, has set out the guidelines and requirements in respect of the amount of renewable energy to be achieved by each state by 2030. On the other hand, it has introduced, through two directives – EU 2018 / 2001 (Renewable Energy Directive II, or REDII) and UE 2019/944 (the Internal Electricity Market Directive, or IEMD) – two new figures: the Renewable Energy Community or REC), and the Citizen Energy Community or CEC. In both cases, the goal is to allow the open, voluntary and autonomous participation of individual citizens, businesses and local authorities in energy generation, distribution, supply, storage and consumption initiatives. With this package, therefore, the European Commission aims to offer consumers not only tools that guarantee them more information on energy services and products or more freedom when they want to change energy suppliers, but also opportunities to aggregate their energy demand or offer or to become prosumers, single or associated. Nationally, EU countries are enacting legislation to adopt these directives. In Italy, for example, on 28 February 2020 Parliament approved Law no. 8, which entered into force on the first of March. This law, pending the complete adjustments to Directive (EU) 2018/2001, allows the activation of collective self-consumption from renewable sources or the creation of renewable energy communities. From a social and territorial point of view, energy communities can create development and consolidation, especially locally, as well as playing an important role as diffusers of structured practices in the shared management of energy resources. The introduction of new and different forms of organization in the energy sector simultaneously entails a complex of social, cultural and technological innovations, which require a complex set of conditions to develop fully. Indeed, these processes are not implemented in the same way and with the same degree of difficulty, despite the unique national legislation. Italy reveals a clear internal difference between north and south, although an initial analysis of the initiatives planned and/or already launched shows how widespread these are throughout Italy's national territory.

2. Methodology

We will analyse the differences between north and south Italia by carrying out a comparative analysis. We have selected these two large areas of the country because they traditionally present an internal gap with respect to the socio-economic conditions of their inhabitants and the levels of industrial development and productivity.

North Italy is the most economically developed area of the entire country. The south (Mezzogiorno), by contrast, is still a depressed area from the point of view of employment levels and the internal economic structure, being characterized by a weak industrial and productive fabric, by predominantly public employment and a resumption of emigration. Based on these structural differences, energy communities are also expected to assume different characteristics, which will be tested using a series of indicators: number of initiatives and projects in each area, dimensions, typologies of the actors involved and typologies of energy communities.

3. Results and Findings

The difference between the two main areas of the country is significant both quantitatively and qualitatively. On a strictly numerical level, a greater concentration of energy communities in the regions of northern Italy is evident, where these initiatives have features that partly differ from those emerging in the southern regions of the country. In fact, in the former, the funding is mixed between public and private, while in the south the investments of the larger energy communities in planning come from public sources. In both areas of the country, energy community projects take the form of place-based initiatives and are the result of an action promoted by intermediaries (local administrations and/or energy companies) who act as the aggregators of the citizens of a specific territory. Moreover, in most cases sophisticated technological innovations can be seen being deployed to obtain maximum efficiency and safety.

4. Discussions and Conclusions

The differences, and even the gap, between north and south Italy in the diffusion and characteristics of their respective energy communities can be understood by presenting some hypotheses concerning the socio-economic, cultural and historical factors involved.

1. The different economic structures of the two areas is one of these basic factors. It is also the product of economic policies that have been perpetuated over decades. On the one hand, therefore, the income structure and the presence of a more solid entrepreneurial fabric in the north areas can be hypothesized as an enabler for a wider diffusion of community-type energy experiences. On the other hand, the economy of the south is more dependent on public transfers and is distinguished by a more fragile and fragmented productive fabric. All this appears as a barrier.
2. Another difference relates to cooperative and collaborative practices, which could affect the cultural and trust dimension on which community dynamics are based. This dimension seems to have established itself more extensively over time in northern society, as the feeling of trust in community institutions and practices appears less strong in the south, at least in the lower and middle social strata.
3. Finally, according to what has been argued, it is possible to detect not so much a different sensitivity towards energy saving and environmental issues in the south than in the North, but rather less willingness to build shared paths for the achievement of objectives related to the energy transition.

These results suggest that further research should focus on analysing the success and duration of these initiatives in relation to each area and the different conditions it presents. Furthermore, it should be established which actors are able to involve citizens in a more participatory and active way, and in accordance with which social, cultural and economic mechanisms.

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7.3 Energy Communities and Energy Conservation

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KEYWORDS

energy conservation, social identity, social influence, real-time feedback, energy communities, field experiment

1. Introduction

This paper aims to investigate the effect of a newly created social identity on energy conservation by studying individuals who become members of a clean energy community. Clean energy communities are characterised by their promotion of renewable energy and energy efficiency (Gui and MacGill, 2018; Mlinarič et al., 2019). Energy communities are social networks and in many cases involve interaction between community members, which may be conducive to creating a new social identity for them. Multiple authors (e.g. Bomberg and McEwen, 2012; Rogers et al., 2008; Seyfang, Park, & Smith, 2013) have stressed the importance of a shared identity for achieving progress and success in the field of renewable energy projects. Initial qualitative evidence suggests that involvement in energy communities may indeed encourage sustainable energy behaviour (Biddau, Armenti, & Cottone, 2016; Middlemiss, 2011). Sloot et al. (2018) observe, based on survey data, that being part of an energy community potentially enhances community members' motivation to engage in energy conservation. However, none of these studies accounted for the self-selection of individuals as members of energy communities.

Furthermore, an extensive literature has considered the effect of behavioural interventions on stimulating electricity conservation (e.g. Alcott, 2011; Brandon et al., 2019; Tiefenbeck et al., 2019; Andor and Fels, 2018; Buckley, 2020). While these interventions usually focus on the regular customers of energy suppliers, to the best of our knowledge they have not yet been applied in the context of clean energy communities. However, energy communities have distinct features that make the application of behavioural interventions to stimulate conservation behaviour very promising. Energy communities allow combinations of new technologies with interventions that harness the new social network's potential to be tested. An example of such a technology is a smart shower meter that provides real-time feedback during showering; this is used in the current study.

This paper aims to investigate to what extent membership in an energy community induces electricity conservation and enhances the effect of real-time feedback on water and electricity consumption. This is the first study to explore this relationship in a field experiment, in which a random assignment of participants to treatment groups allows the causal effects to be estimated. The results are important for the effective design and support of energy communities and behavioural interventions to induce household electricity conservation.

2. Methodology

Three hundred households are participating in the field experiment, which is being implemented in collaboration with GEN-I, an energy utility in Slovenia. At the start of the study, a virtual energy community is established. Approximately 150 households are randomly assigned as members of this community. Over a period of five months, the community receives monthly newsletters with energy-saving tips, testimonials and comparison reports of electricity use within and outside the community, and members have access to an interactive virtual portal. Half the members and half the non-members also receive real-time feedback on resource consumption while showering. This allows us to disentangle the effects of real-time feedback on electricity and water conservation by community and non-community members alike.

We have access to daily smart-meter and showerhead data from all households for their daily electricity use, as well as their water consumption and shower behaviour. The experimental data is complemented by pre- and post-intervention survey data, including information on the sociodemographic characteristics of the participants (e.g. age, gender, education, household income, employment status), as well as information on household size, household characteristics, house characteristics, energy sources used, number and type of electric appliances used, age of electric appliances used, energy literacy and personal attitudes. In the post-treatment questionnaire, data are collected on energy literacy, personal attitudes and sense of social and environmental identity.

3. Hypotheses and expected results

This paper aims to investigate whether, by establishing a new social identity that is associated with greater awareness of resource use and a stronger motivation to engage in energy conservation behaviour, membership of an energy community can significantly decrease the household electricity consumption of members.

Further, previous research e.g. by Tiefenbeck et al. (2018; 2019) has shown that real-time feedback while showering reduces resource consumption by 22%. Providing such feedback has the potential to significantly reduce the electricity needed to heat the water for showering. While the above hypothesis has been evaluated in previous research, this study aims to evaluate the extent to which membership in an energy community can enhance the effect of real-time feedback on energy consumption from showering.

In addition, we aim to test whether the households in energy communities experience a sense of social identity through their community membership, and whether they become more aware of their electricity consumption than the households in the control group.

Finally, real-time shower feedback might trigger a moral licensing effect. Tiefenbeck et al. (2013) show that residents who received weekly feedback on their water consumption lowered their water use, but at the same time increased their electricity consumption compared with the control group. While there is a precedent for this moral licensing effect in the literature, it is also reasonable to expect that there is no moral licensing effect on electricity consumption in our study. This is because the participants can view a visualisation of their electricity consumption over time on the virtual portal. This draws attention to electricity consumption and leaves less room for subconscious behavioural adjustments, especially as the participants can directly detect when their electricity consumption patterns are increasing.

The results of this project will provide information about the potential of clean energy communities to stimulate energy conservation behaviour.

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7.4 Actions to Boost Energy Efficiency and Indoor Air Quality: Case Studies in Italian Schools

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KEYWORDS

indoor air quality, energy efficiency, behaviour, comfort

1. Introduction

Indoor air quality in schools has always been receiving particular attention.[1] This is not only due to the health emergency ongoing all over the world. In fact, the last EU directive on energy performance of buildings[2] has recognized the relevance of the matter. In 2009 the World Health Organization guidelines highlighted that better performing buildings should provide higher comfort levels and wellbeing for their occupants in addition to improve health. However, also the behaviour of buildings' occupants is crucial. From this perspective, ENEA, *Italian National Agency for new Technologies, Energy and Economic Sustainable Development*, has been carried out a series of actions in order to promote both energy savings and the need and usefulness of achieving ever higher levels of air quality in shared environments. The experimental awareness campaign we present was carried on in several schools. It focused on an active involvement of students, especially in terms of direct and collective processing and interpreting the results (data) recorded through the aid of an ad hoc instrumentation provided, thus allowing the participants to visualize the outputs of their behaviour. Starting from the idea of a *practical* sharing of these actions[3], hopefully new habits and robust pro-environmental knowledge will be acquired, replicated and disseminated over time even outside school; thus establishing a sort of *virality*, a beneficial "wildfire" contagion of the project experience towards other contexts and subjects.[4] The possibility by the students to become a sort of "multiplier subjects", is therefore, in this case as in other Behaviour Change projects, one of the aims of the implemented initiative.

2. Background, History, Review-of Literature, or Methodology

In the framework of EFFEDIL project[5], ENEA decided to evaluate a monitoring strategy of the indoor air quality in a low secondary school in the South of Italy, where an energy retrofitting programme was undertaken. The indoor air pollution in schools is a combined effect due to both indoor and outdoor physical, chemical and biological factors, and it also depends on environmental ventilation level. By monitoring public infrastructures, the so-called "sick building syndrome" has been shown to be responsible for diseases, such as allergies and headaches[6,7,8]. ENEA set up a methodology for continuous and real time monitoring in order to evaluate comfort and indoor air quality, in collaboration with the ISS – *Istituto Superiore di Sanità*, which developed the guidelines concerning the passive air quality[9]. Then, an experimental campaign *in situ* was conducted, by means of a sensor network specifically designed for the measurement of temperature, humidity, CO_2, NOx, CO, VOCs. The basic idea aimed at involving students, after a training period and an awareness campaign on energy efficiency aspects.

3. Results and Findings

Micro-climatic parameters were monitored, together with temperature, humidity and CO_2, which are often in the cause of decreasing attention and learning in classroom. Through the training path on specific topics and by compiling daily tracking records, the reported information were used to synchronize all the data recorded through the sensor network. The initial evaluations show, for instance, how the CO_2 values are strongly linked to some specific activities in the classroom and dependent on correct or wrong air exchanges. The study has shown that an aware management of the ventilation, during all the seasons, can maintain the CO_2 values below 1000ppm, and thanks to other microclimatic factors, such as temperature and humidity, an adequate comfort level can be guaranteed. Other indicators of the indoor air quality were also monitored, such as CO, NOx and VOCs

4. Discussions and Conclusion

From a perspective focused on the achievement of a behavioural change by the subjects involved in the project (students), a goal that seems to have been essentially reached thanks to the estimates of the air quality made over time (pre-post intervention measurement), the *feedback* played by these estimates proved crucial. In literature, the *feedback* tool (in its various and different application forms) is recognized as one of the most effective strategic levers (*drivers*) for achieving and consolidating new behavioural habits experienced during the project phase. It is also desirable, as a phase to be planned in subsequent moments, the opportunity to implement a *feedback* system for a more or less long post-intervention period. Moreover, this time frame would allow to build more rigorous measurements from a scientific point of view to test the validity of the strategy used, organizing comparisons between experimental and control groups through *randomized control trials* (RCT)[11] .

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7.5 Understanding Preferences for Characteristics of Renewable Energy Communities

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KEYWORDS

Renewable energy community, choice-based conjoint experiment, renewable energy ownership, positive energy districts

1. Introduction and Background

Building energy self-sufficiency, reducing energy costs, and meeting lower emissions targets through renewable energy technology (RET) has become a central focus of many community and private sector energy projects. The spread of renewable energy technology has been facilitated by lower installation costs, increased reliability of the technology, and supporting policy and investment[1]. Additionally, the expansion of RET has opened the discussion around how energy systems of the future will be configured. As the decentralization of energy production and management becomes a real possibility, with citizens taking on greater responsibility within the system, rethinking future communities becomes more important. New opportunities and shifting responsibilities will create new roles for involved stakeholders, including the private sector and citizens.

While ample literature focuses on the acceptance of single RET in specific sites, it is important to recognize that RET operates within a system of multiple processes and actors that interact at numerous levels[2]. This embeddedness makes it essential to understand configurations of renewable energy projects that would appeal to citizens beyond acceptance of single RET on single sites. Examples of community renewable energy projects, such as the Hunziker Areal in Zurich, Switzerland and Vauban in Freiburg, Germany, have shown that the appeal of living in such communities goes beyond reliance on RET and includes benefits such as green mobility options and shared community spaces. The aforementioned projects fit into the EU's plans to develop 100 Positive Energy Districts (PEDs) – places that couple "built environment, sustainable production and consumption, and mobility to reduce energy use and greenhouse gas emission and to create added value and incentives for the consumer" – by 2025[3]. Despite numerous such projects in development across the EU, no academic attention has been given to exploring the appeal of the multiplicity of benefits offered by PEDs or PED-like projects.

This research aims to address this gap by understanding the appeal of different configurations of PEDs. Creating suitable renewable energy community configurations for individuals can increase their likelihood of engaging in their community and becoming energy citizens. Greater citizen engagement within renewable energy communities is important because it can mean more rewarding, emissions-cutting outcomes from the use of RET and related technologies (e.g. smart meters). In this study, configurations of PEDs and PED-like communities are studied because of their salience to the EU's energy transition agenda and their ability to offer a variety of valuable services that result from community-private sector partnerships.

This research explores the appeal of three attributes that characterize renewable energy communities: RET ownership and engagement from the citizen, availability of mobility options, and availability of communal spaces. These attributes align with characteristics seen in PEDs, as well as established drivers of RET acceptance found in the literature. Ownership of RET has been found to be important in a community's acceptance of a renewable energy project[4], and may predict a citizen's involvement with RET. Citizen engagement and acceptance of renewable energy structures has been found to be higher when the project is citizen-driven and locally-owned[5,7]. An analysis of several case studies in Germany found that community ownership of wind turbines led to wider acceptance of their installation compared to wind farms owned by a commercial company[6]. Renewable energy cooperatives have also been found to attract individuals that are favourable towards renewable energies[4] and motivated to participate in local energy policy decisions, though once having joined, individuals often prefer delegating issues of cooperative development to an executive[8].

Ownership and technology has also been studied in the context of access-based car sharing[9]. The research showed that lack of ownership was a driver behind lack of engagement for the brand and care for the cars. In this context, the preferred type of ownership structure may predict an individual's intended engagement within the PED.

Further, understanding the configuration of mobility aspects within a PED is important as mobility is often a central focus in renewable energy communities. Mobility options describing restrictions around private cars and allowance of electric vehicles are explored. Finally, the availability of communal spaces, such as community gyms and workspaces, is tested in order to explore the appeal of including human-centric aspects to potential residents.

2. Methodology

We ran a choice-based conjoint experiment, a common method used in market research[10,11], to test preferences for PEDs. The experiment was integrated into the Swiss Household Energy Demand Survey (SHEDS), which collects data from a sample representative of the Swiss population (excluding Ticino). The experiment sample consisted of a random SHEDS subsample of 1500 respondents.

During the experiment, respondents were shown six choice sets consisting of two PED options each. Different levels of the aforementioned attributes describe each PED option: ownership and citizen engagement (e.g. you own the PV and are an active trader; a cooperative owns the PV), mobility (e.g. public transportation replaces private cars; only a shared fleet of electric vehicles exists), communal spaces (e.g. a PED might include a shared gym, workspace, or guest rooms for a small monthly fee).

The latent class analysis will be applied to the data to segment respondents into groups that share similar preferences in their choices. Additionally, Hierarchical Bayes (HB) estimation may be used to understand the importance of each attribute level. This analysis can indicate which characteristics of renewable energy communities are important in an individual's choice and what segments of consumers could exist. Such information around consumer desires can be critical to the acceptance of RET projects.

3. Research Aims

The results of the research will indicate the importance of various attributes in renewable energy communities, highlighting which benefits hold the most potential for citizen engagement. Ultimately, the intention is to provide policy-makers and entrepreneurs involved in the development of renewable energy communities with more information on segments of potential residents and their preferences. Creating configurations of renewable energy communities that entice citizens to interact with RET and others in their community puts them closer on the path of becoming human-centric, energy-positive communities.

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SECTION 8

HOUSEHOLDS

8.1 Role of Online Information Sources in Energy Efficient Renovations: Perspectives of House Owners in Finland and Sweden

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KEYWORDS

energy efficiency, communication, households, decision-makers

1. Introduction

Collecting information is an important stage in end-users' purchasing decisions. Depending on the type of purchase requirement, the search for information could be either internal or external[1]. Internal searches involve using one's memory to find a solution for one's requirements, whereas in an external search one will look for outside sources of information, such as market-based information, expert opinions and personal contacts. Typically, purchasing decisions involving large investments entail external searches. Energy renovations in buildings are high-involvement purchasing decisions, and homeowners may engage in extended information collecting. The difficulties in finding reliable information are recognized as a major barrier to homeowners' decisions to invest in improving the energy performance of their houses[2]. From the policy-makers' perspective, effectively communicating information to homeowners to increase their awareness of the advantages of energy-efficiency measures could be one strategy to facilitate their adoption.

Mass-media communications like advertisements on televisions or in the newspaper are more likely to influence innovators and early adopters[3]. Interpersonal sources such as neighbours, friends, relatives and colleagues are often important sources of influence in the adoption decision[3]. In respect of investment-oriented measures, externals actors close to the end-users' supply chain, such as installers and sellers, may have significant influence in adoption decisions[4]. In the last two decades, the internet has become an integral part of peoples' lives. It is widely used for searching for

information and is considered an important source of information in making purchasing decisions. In this study the role and expectation of online information as perceived by homeowners in the Baltic Sea region of Finland and Sweden is presented and discussed.

2. Methodology

This study is based on a questionnaire survey sent to three thousand single-family house-owners randomly selected from seven municipalities in Västerbotten and Norrbotten counties in Sweden and twelve municipalities in Ostrobothnia in Finland during spring and summer 2017. The questionnaire was divided into four sections: demographic background, house attributes, knowledge and attitudes towards energy renovation, and relevance of online information sources for energy renovation. The response rate for the survey after one reminder was approximately 30% in Sweden and 26% in Finland.

3. Results

Craftsmen were reported as an important source of information by the majority of the respondents in both Sweden (72%) and Finland (81%). Personal networks were considered important by 63% and 58% of respondents in Sweden and Finland respectively. In Sweden, a significant percentage of respondents (55%) considered online sources (for example, websites) are important for information on house renovation, but in Finland relatively fewer respondents (38%) thought that online information was important. Television, newspapers and direct advertisements were thought to be important by the least number of respondents in both the countries.

The "ownership" of online sources may influence individuals' attitudes towards using information from such sources. In Sweden and Finland, a large number of respondents prefer online sources of information to be managed by a research institute and/or a government organization. An online information source managed by the product sellers is least preferred in both countries. One reason for this may be the possibility that such information sources would promote specific products and not necessarily address homeowners' concerns regarding renovation. Homeowners do not like commercial advertisements on a website on renovation.

Most homeowners in Sweden (58%) and Finland (46%) would like online sources to have an easy-to-use calculation tool to investigate the cost-effectiveness of renovation measures (Figure 4). Also, more than 50% of respondents in both countries would like to have the contact information of relevant companies in any

online source of information on renovation.

4. Conclusions

Effectively communicating information about the benefits of energy-efficiency measures may facilitate the adoption of such measures through increased awareness and knowledge. Homeowners who are end-users may be influenced by various sources, depending on the specific purchasing decision. For renovation, craftsmen were considered an important source of information by most homeowners in northern Sweden and Finland. Online information was considered important by a large number of homeowners. Younger (18-45 years) people with higher (i.e. university) education were more likely to use online information. Currently, the perceived expertise and trustworthiness of online information sources on renovation are low as compared to other available sources. Hence, if an online source of information on renovation is going to make an impact, then it should present an image of expertise and trustworthiness to its potential users. In an online information source, potential users would also like to have an easy-to-use tool to help them calculate the cost-effectiveness of measures, as well as contact information for suitable companies. Homeowners would be more interested in using an online source if it were updated regularly. Also, they would like an online source which is easy to navigate to obtain the information they are searching for.

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8.2 The Impact of COVID-19 Lockdown Restrictions on Domestic Energy Consumption Great Britain

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KEYWORDS

COVID-19, lockdown, energy demand, energy behaviour, building, behaviour change, smart meters, carbon emissions, homes

1. Introduction

Reducing building energy demand is key to achieving the UK's net zero emissions target. Buildings like homes, schools, offices, shops, etc. currently account for 29% of carbon emissions. This is one of the most challenging sectors, as it drives peak energy demand in the UK and is an area in which the government is planning to invest billions of pounds to reduce its emissions. One of the key building blocks in the plan to reach 'net zero' emissions is to have a good understanding of where and how we use energy, the main source of carbon emissions.

COVID-19 is impacting, and will continue to impact, on building energy demand in both the short and long terms. In the short term, lockdown restrictions around the world are causing huge changes in daily routines, such as the near 24/7 occupancy of homes and the closure of schools and businesses. This has resulted in very significant changes in energy use[1], changes that have come at the cost of massive social and economic impact and that are unsustainable in the long term. Post-COVID-19, a 'new normal' in energy use will result. Carbon reduction plans will need to be rapidly changed to take account of this 'new normal' following the initial outbreak of this global disease. This paper aims to understand the changes in domestic energy consumption patterns in GB during the first few months of the lockdown. In doing so we consider how these changes may persist beyond the end of COVID-19 lockdown restrictions.

The research presented here uses half-hourly electricity and gas data for around 1700 households in England and Wales from before, during and after the core lockdown period in GB. These are used in combination with survey data from September 2019 for each household and dwelling, a survey from May 2020 about changes to the household and its activities during the lockdown period, and contextual data such as local weather data and energy performance certificates (EPCs) where available[2].

2. Background and Methodology

The Smart Energy Research Lab (SERL)[3] was established to provide university researchers with access to residential half-hourly gas and electricity smart-meter data from randomly selected consenting households in Great Britain (GB). The first wave of approximately 1700 participants was recruited in September 2019. All participants provided consent for SERL to access their smart-meter data for research in the public interest, and most completed a survey of approximately forty questions about their households and dwellings. SERL has permission to link these data with contextual data on, for example, local weather data and EPCs. In May 2020 these participants were invited to complete a second survey specifically on the impact of the COVID-19 lockdown restrictions on their household's circumstances and behaviours.

The combination of the longitudinal smart-meter data and the contextual data provided by the surveys, weather reports and EPCs allows us to analyse how energy consumption patterns changed for the ~1700 households in the study and to attempt to explain these changes. We are able to determine how the lockdown affected different types of household and offer potential explanations. For example, households with children, elderly couples and those living in flats or detached houses may have different energy needs. Many households gained or lost members during the lockdown period. Many people started working from home, while many key workers continued to work outside the home. By capturing this type of information, we gain unique insights into how changes or a lack of change in respondents' circumstances translate into changes or a lack of change in energy use.

3. Results and Findings

1711 households signed up for smart-meter data-collection in September 2019, of whom 1673 completed or partially completed the survey at the time, and 1084 completed our survey in May 2020 on the impacts of COVID-19. Our analysis compares energy consumption during the first lockdown (23rd March to 10th May 2020) with a period of similar degree days (8th September to 27th October 2019). Preliminary results indicate that consumption of gas increased significantly ($p < 0.05$) by 38% during the lockdown compared to the corresponding earlier period ($N = 993$ households). Electricity consumption was 12% higher during the lockdown, increasing on average from 8.3 kWh/day to 9.3 kWh/day ($N = 1107$ households, statistically significant for $p < 0.05$). These results are preliminary and analysis is ongoing; more detailed, rigorously checked results building on these initial findings will be presented at the conference.

4. Discussion and Conclusions

Other studies have shown significant changes in energy use in the UK during the lockdown period, but lack the contextual data to explain their drivers or how different groups of the population are affected. With longitudinal data from before, during and after the core lockdown period in GB, we have the potential to understand how energy use may continue to change going forward beyond the peak of COVID-19. Preliminary results show that energy use rose significantly during the first national lockdown in the UK. Further analysis will build on these results for presentation at the conference.

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8.3 A Micro-scale Analysis of Attitudes and Behaviours Regarding Sustainability and Domestic Energy Saving in Italy

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KEYWORDS

domestic energy saving, sustainability, cultural approach, attitudes, behaviour

1. Introduction

The international literature on energy consumption and sustainability covers a vast array of approaches, from technological issues favouring virtuous behaviour (e.g. tools, design, infrastructures, policies and laws) to the human factors that can actualize that behaviour (e.g. culture, values and norms, civic and political aspects)[1,3]. Although such approaches also exist in Italy, top-down approaches developed in engineering or economics have been privileged, often partly integrated with contributions from behavioural sciences focusing mainly on the individual level[4]. The purpose of this paper is to establish the basis for taking a cultural approach to sustainable energy consumption in Italy. The first step is a review of the current Italian psycho-social scenario in the literature, to be conceived as a data baseline to enable future innovative policies on energy sustainability through communication, education and social commitment[5]. The second step is an exploratory study of the connection between attitudes towards sustainability and domestic energy consumption in Italy, aimed at producing context-sensible policy suggestions.

This paper is the result of the collaboration between ENEA (*Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Energy Efficiency Department*) and the Università degli Studi di Milano (*Department of Cultural Heritage and Environment – Social Psychology Research Group*). It is the starting point of a path aimed at stimulating the energy transition by studying the psycho-social factors that are capable of triggering virtuous individual behaviour on a domestic micro-scale. The collaboration was launched under the framework of "*Italy in Class A*", a national campaign for energy efficiency promoted by the Ministry for Economic Development.

2. Literature Review and methodology

2.1 Attitudes and behaviour regarding sustainability in contemporary Italy

According to the psycho-social literature, Italy presents a contradictory picture[6]. The main, general factor is the dissonance between on the one hand high awareness of sustainability and energy issues, including consistent demands by citizens on the political-legislative system (e.g. to establish more restrictive laws) and on the other hand the will of citizens to change their daily behaviour. Italian citizens indeed appear to be aligned with the other Europeans regarding the degree of importance they attribute to sustainability and climate change, but at the same time they evince in this regard low perceptions of individual responsibility and moderate perceptions of self-efficacy and proactivity[7]. Moreover, the spread of sustainable behaviour in Italy, including energy saving, is lower than the EU average, despite the greater awareness of the impact of environmental problems[8]. Within this general framework, two additional issues characterize the Italian scenario. Firstly, social representation of sustainability issues revolves around two main elements: economic savings and preservation of health. Secondly, energy usage is strongly heterogeneous, due to climatic, residential, socio-economic and gender variables.

2.2 The exploratory study: aims and methodology

In line with the analysis described above, an exploratory project on the situation in Italy was developed. Its goals are to deepen the social representation of sustainability and energy saving, and to improve understanding of the relationship between sustainable and energy-saving attitudes and behaviour on the domestic micro-scale. The micro-scale allows us to investigate the existing differences between various socio-economic and housing groups. The study involved 155 participants (59 families) living in the Lombardy region. The procedure involved the design and administration of two surveys, respectively addressed to individuals and families, through which domestic attitudes and behaviour were detected.

3. Results and Findings

The data analysis shows that the social representation of sustainability in Italy has three key elements: environmental protection, energy savings and sustainable mobility. In more detail, the first two are found to be the strongest factors and show the most intense correlations between them. Regarding domestic energy savings, a substantial difference among diferente generations is noticed, due to the coexistence of two different general attitudes. On the one hand, particularly among the young, saving energy is found to be closely connected with the ideological dimension of environmental protection. On the other hand, and more prosaically, it is linked to economic savings, mostly among older people. This result highlights the presence of different energy subcultures in term of both attitudes and behavior. Although limited to a specific geographical area, in fact the sample is heterogenous for gender, age, commitment and type of dwelling. Regarding gender, the data show that the greater intensity of sustainable attitudes and behavior in females is not due to a greater strength and rootedness of general beliefs about sustainability, but to a more intense perception of individual agency, which in turn triggers specific daily practices. Another significant factor of difference within families is the commitment to sustainability issues. "High sustainability" families have significantly fewer numbers of household electronic devices (on average 16.38% less than other families). This highlights the close connection between attitudes and purchasing choices in Italian families. Even a condo, if compared with detached houses, can be described as a supportive environment in promoting a lower average presence of household devices and more innovation-oriented consumer choices. It is notable that no significant differences were found on the basis of annual income, except for families that reporte annual incomes of less than 15,000 euros and being in a condition of energy poverty. Finally, a generally positive correlation is found between sustainability and energy-saving attitudes and behavior, with some significant variations. For instance, the use of fully loaded washing machines and dishwashers appears to be connected with positive attitudes towards energy saving, the subjective perception of agency and the possibility of representing an example for others, not with considerations of environmental sustainability in general.

4. Discussion and Conclusions

The collected data suggest that certain innovative policies should be adopted for use in Italy. First, they highlight the need for a fine-tuning of communication and educational campaigns, taking into account the attitudinal differences that are due to gender, age and dwelling. Second, they indicate that a focus is needed not only on energy outputs, thereby encouraging energy saving in domestic consumption, but also on inputs, thus guiding consumer choices within the family. Moreover, they identify specific social groups (women, highly sustainable families) that can act as micro-scale (condominium, neighborhood) gatekeepers to favor the ecological transition of the rest of the local community. Further research will be developed to apply these general guidelines to processes of social transformation.

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8.4 Identification of Everyday Food-related Behavior Patterns with High Potential for Direct and Indirect energy savings: KTH Live-in-Lab Exploratory Case Study

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KEYWORDS

food-related behaviour, food-related choices, electricity consumption, living lab

1. Introduction

Nowadays, electricity consumption associated with everyday food-related behavior is increasing significantly due to the situation with the COVID-19 pandemic, which is causing people to cook mostly at home. If estimates of energy usage associated with cooking were previously in the region of 2-7% of the total electricity consumption demanded by households, then today this figure has grown up to 15-20%. This means that we need to find more energy-efficient ways of everyday residential cooking.

It is clear that different customer segments have different food-related behavior patterns. For our research, we have chosen the category of young single students living alone. Moreover, each chosen student represents one of the four personas profiles. The experimental study was designed to examine in detail the behavior of four students at a living laboratory (KTH Live-in-Lab) over a month to identify specific patterns of food-related behaviour with low, medium and high levels of energy use. Behavioral insights were recorded through the collection of large amounts of data from home appliances, everyday surveys, receipts from the grocery store, wearable devices and home IoT sensors. Despite the small size of the study group, we tried to focus specifically on identifying behavioural patterns associated with the individual choices of a particular persona profile and its impact on energy consumption. Such patterns can be identified and tracked at the individual level, and only then proceed to a larger-scale experiment. Another reason in favour of using a small group is the need to collect a very large amount of data about the rather active involvement of each individual from the study group through in-depth interviews, everyday surveys, feedback sessions, etc.. This is easier to control with a smaller group, where research of the appropriate quality can be done.

During the pre-test experimental part, when we tried to investigate how the participants prepare food in as much detail as possible, it immediately became clear that it was also necessary to observe what the participants were preparing. If the data on how food is prepared gave us an objective understanding of the direct energy consumption of the activity, then the data on what they eat allowed us to make a preliminary classification of the indirect energy consumption.

This experiment made it possible not only to identify behaviour patterns with high energy usage, but also to analyse which strategy for behavioural change fits a particular persona. In other words, we have developed personalized strategies for behavioural changes.

2. Background, History, Review of Literature and Methodology

The United Nations Intergovernmental Panel on Climate Change (UNIPCC) makes it clear that climate change is due to human activities, and it recognizes buildings as a distinct sector among the seven to be analysed in its 2007 Fourth Assessment Report[1,2]. Though technological advances and strict regulations are important in promoting energy conservation and improving energy efficiency[3], it has been increasingly recognized that behavioural factors are of great significance in achieving energy conservation[4,7]. Also, the main objective of many energy and environmental policies is to achieve energy conservation by households by changing their energy use behaviour[8]. It has been suggested that behavioural changes can be just as effective as technological changes[9].

Historically, energy-saving programs and policies have relied largely on technological or economic interventions. By combining technological interventions with behaviourally informed design principles, the motivation to undertake pro-environmental behaviour can be increased and the CO_2 emission produced by buildings reduced[9,10].

One of the everyday activities for which electricity consumption has mostly grown in recent years and that the greatest level of dependence on tenant behaviour is cooking. Food is the single strongest lever for optimizing human health and environmental sustainability on earth[11]. The food sector is responsible for a substantial share of the greenhouse gas emissions that are producing climate change[12], and people are starting to realize the importance of their own everyday habits in this regard[13]. For individuals there are several ways to minimize personal carbon footprints, one being to change eating habits, e.g. what kind of food to consume, how to cook it, and where the food has been imported from. The scientific literature on cooking energy efficiency mainly deals with the efficiency of cooking appliances, while few studies focus on the influence of cooking behaviour. Furthermore, a study of users' influence on electricity consumption from cooking[14] states that up to 25% of the electricity used can be reduced by changing specific habits.

The methodology in this study was based on four stages:

Stage 1: *Personal profile design (personas)*

During this initial stage, we analysed several personal profiles of KTH Live-in-Lab students and identified four types of personas for a more angular experiment involving a detailed study of food-related behaviour data for a representative of each persona.

Stage 2: *Data-collection*

During this stage, we organized data collection in accordance with ethical approval and GDPR. The main focus was to identify electricity usage patterns in food-related everyday behaviour to calculate direct energy and an analysis of additional data on the ingredients and products for evaluation of indirect energy (transportation index, packaging index, processing index). An additional objective in this stage was to identify data-related issues and obstacles by keeping a data-quality journal.

Stage 3: *Strategies for potential energy savings*

All data from the second stage became a foundation for creating strategies for potential energy savings. At this stage, we followed a mostly analytical process, during which we tried to build different behavioural models and scenarios for each individual.

Stage 4: *Feedback sessions and process evaluation*

At the end of the experiment, we organized a series of individual feedback sessions, as well as a larger group survey with several representatives of each type of persona.

The residential food system analysed in this project has several different aspects; the physical infrastructure (kitchen), end-user activities (grocery shopping, cooking, recycling), resource flows (food, water, energy, waste) and the end-users emotions (personal feelings, perceived influence on decision-making, health). As a consequence, the residential food system is divided into the following four subsystems. System 1 (S1) is the system that represents the individual him- or herself, which in this case is the single tenant, the student. The single tenant will interact with system 2 (S2), being the kitchen. What enters the kitchen comes from the grocery store, being system three (S3). The grocery store inflow mainly comes from suppliers and distribution centres, which will be defined as 'the world', i.e. system four (S4). S4 also consists of trends affecting decisions made by the individual. In terms of project delimitations, the project will mainly focus on S1 and S2, while S3 and S4 will be treated as in- and outflows.

3. Results and Findings

This explorative case study has enabled us to develop several strategies for direct and indirect energy savings in food-related everyday behaviour using realistic data. The process of data collection was quite well received by the participants, showing the potential to use such a methodology to build a self-monitoring tool or to conduct further scientific research on the consumer food system. Each strategy was discussed both with the experiment participants themselves and with a larger group. The resulting strategies should be tested with a larger group of participants in the future, but they can already be recommended for use and testing in other buildings with a similar type of tenant, and also be used in digital services aimed at reducing the electricity usage of everyday food-related activities. The next step would be to simplify data collection and analysis to scale up this process of evaluation.

The main structure of indicators and the dataset can be used for a variety of applications, with some adaptations to different purposes. Knowledge of food habits gathered through this process could also be valuable to public authorities in adapting the food environment in cities or to architects in designing apartments and kitchens. One could also think of a system showing the consumer a reduced number of indexes at every trip to buy food and even creating personal accounts to see the evolution of one's consumption. However, to attain greater effectiveness, sustainability assessments could be mixed with other actions targeting other drivers of the food system all along the supply chain because they influence consumer behaviour.

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8.5 The Spectrum of Residential Cooling Demand: Modeled Demand Versus Occupants' Real-life Needs

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KEYWORDS

cooling energy demand, indoor thermal comfort, occupant behaviour, mixed- methods approach, simulation, energy sufficiency

1. Introduction

The heat waves of the past two decades have pushed climate adaptation and the mitigation of heat stress in the building sector up the political and public agenda even in regions with temperate climates, like Western Europe. The average number of cooling degree days (CDD) in temperate regions like Germany have doubled within the last fifty years[1], and demand for energy for cooling is predicted to multiply. Building standards define certain temperature thresholds above which a building is considered 'overheated' and needs cooling. The residential cooling energy demand is thus directly related to the number of hours in which indoor temperatures exceed this critical numerical threshold. What this understanding of 'cooling demand' does not consider, however, is the actual need for active cooling to be experienced by the occupants themselves. Thermal comfort models of building occupants exist, but the majority of them consider neither occupants' activity patterns, nor sociodemographic and psychological factors[2].

We suppose there is a substantial difference between the predicted cooling demand and the cooling demand perceived by actual users due to the following two crucial factors. First, there is huge intra- and inter-individual variation regarding thermal perceptions and thermal preferences[3,4]. Secondly, people are not passive recipients of thermal stimuli, as chamber experiments often suggest: quite the contrary, they can react with a variety of adaptive actions, such as modifying clothing levels, adjusting blinds, or even adapting their expectations of comfort[5].

Considering these aspects, the actual demand for active cooling from the residents' perspective may well be much lower or higher than the calculated cooling demand. Depending on individual thermal preferences, occupancy schedules and people's everyday practices (i.e. adaptive behaviour, but also practices that increase the internal heat gains), we argue that a substantial energy-saving potential could be exploited while maintaining thermal comfort. In this interdisciplinary

mixed-methods study, we seek to quantify this potential by comparing the predicted cooling demand based on thermal comfort simulations of residential buildings in Munich, Germany, with the perceived cooling demand based on the residents' thermal comfort levels as stated in our survey.

2. Methodology

Energy consumption in buildings can be investigated in a top-down or bottom-up approach[6]. While the top-down approach focuses on macroeconomic factors, the bottom-up approach depends on socio-demographic, household and energy behaviour characteristics and data[6]. In order to devise policies on a district level with the focus on the occupant, the bottom-up approach should be implemented[7]. The present study introduces a bottom-up methodology and combines household survey and thermal building simulation results in order to identify possible strategies to improve thermal comfort while at the same time reducing or even avoiding the energy demand for active cooling (see Figure 1).

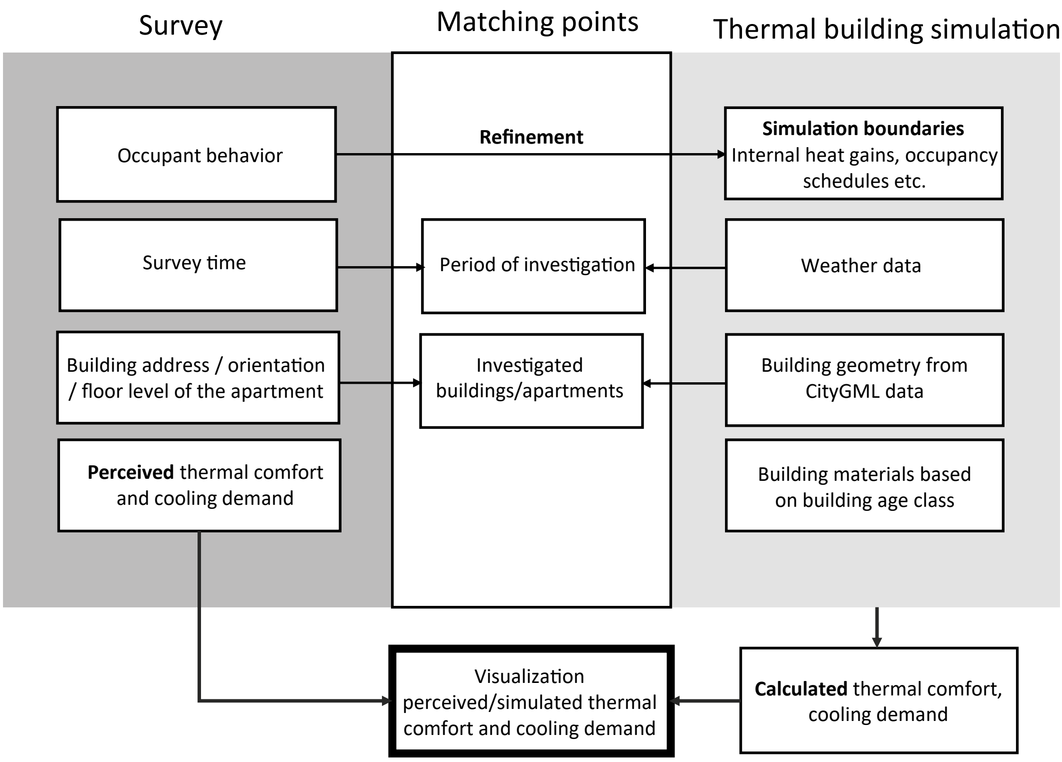

***Figure 1.** Mixed methods approach merging household survey data (resident's thermal comfort and cooling demand) with simulation results (calculated thermal comfort and cooling demand).*

We have selected three areas in the city of Munich, Germany, as study sites which cover the most typical kinds of city neighbourhoods in Germany and many other European cities to ensure transferability. These are usually characterized as follows:

1. Mainly older buildings in the city centre with high urban densities and few green spaces
2. Mainly residential buildings from the 1960s-1970s on the city outskirts of medium density due to compact or high-rise building structures and large public green spaces
3. Mainly detached houses or small multi-family apartment buildings on the city outskirts with low density and a large share of private green space

The urban energy simulation will be carried out with an *urban modelling interface* (umi)[8]. The simulation model will be extracted out of the CityGML data, and boundary conditions will be assigned according to building age classes. The boundary conditions will be refined based on the survey outcomes. The survey, to be carried out in June/July 2020, will assess the perceived cooling demand, indoor thermal comfort, user behaviour, characteristics of the apartment, the individual person and the neighbourhood.

3. Results

At the moment of submitting this abstract, the research is still ongoing. Key highlights will include visualization of the results, which can be used by planners and policy-makers as a decision-making tool (see Figure 2). The visualization uncovers the difference between predicted and perceived thermal comfort, thus making visible the saving potential in the demand for cooling.

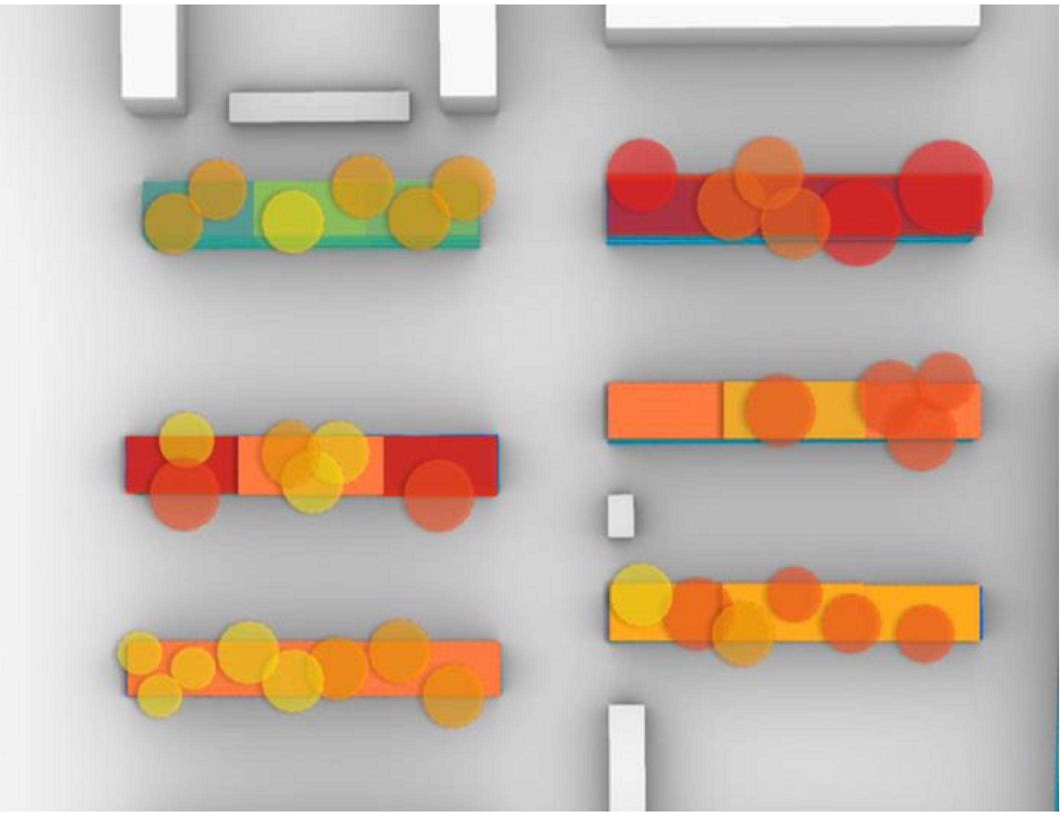

Figure 2.

An example of a visualization with umi rendered in Rhinoceros.

The colours of the buildings show the simulated degree of overheating (cooling demand) based on DIN4108-2 building standards. The colours of the circles show the degree of overheating (cooling demand) perceived by the residents.

Additionally, the survey data will allow us to specify what it is that mainly causes this saving potential by examining how building physics, behaviour and individual thermal perceptions contribute to reducing or enhancing indoor heat stress, thus influencing the perceived need for active cooling.

4. Conclusion

Our research can show how, in Germany, occupants are able to avoid active cooling and save energy while still experiencing thermal comfort. It is thus of great importance to support and enhance the range of energy-sufficient behaviour and attitudes in residents in order to prevent the spread of mechanical cooling as a new building standard. This visualization tool contributes to this goal by quantifying the energy-saving potential and uncovering possible levers to provide energy-sufficient thermal comfort through architecture and urban planning. This will involve consideration of the behavioural, psychological and social aspects.

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SECTION 9

HARD-TO-REACH ENERGY USERS

9.1 An In-depth Review of the Literature on 'Hard-to-reach' Energy Users

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KEYWORDS

energy efficiency, behaviour, hard-to-reach, underserved, vulnerable, low income, high income, renters, landlords, split incentives, small business/enterprises, policy

1. Introduction

Despite decades of efforts, we still face what is called the "energy efficiency gap". This is partly because our main focus has been on improving technologies or infrastructure while ignoring the human actors and the decisions that are needed for change. So-called "behaviour changers" (those in government, industry or research tasked with changing user behaviours[1]) call those audiences that fail to participate in their efforts 'hard to reach' (HTR) or 'underserved',[1] Criticism has deservedly been levelled at these terms, as they seem to imply that the onus is on the non-participating individuals, not the behaviour changers designing such interventions. In order to ensure that everyone benefits equitably from energy-efficiency policies and programmes, we need to change how we target these users. This is even more urgent in light of the COVID-19 pandemic and its impact on the most vulnerable (and newly vulnerable) members of our society.

Energy efficiency and HTR researchers, practitioners and policy-makers from six countries have embarked on a three-year research collaboration to address these global issues[2]. The purpose of this effort is to describe the diverse user segments commonly referred to as HTR and to uncover the barriers and behavioural opportunities for engaging more effectively with these audiences. This paper aims to provide an overview of the findings to date, particularly an in-depth review of the HTR literature.

1 See VEIC (2019) for the definition of 'underserved' used here.

2. Methodology

Our primary method in conducting this research was a full, integrative, narrative literature review. As a starting point, we conducted an external literature search for primary and secondary literature from the last fifteen years focusing on HTR audiences and using three methods:

1. *Outreach to our professional networks*. HTR experts kindly provided us with key literature on specific audiences (e.g. SMEs, young adults, fuel poverty).
2. *Keyword search*. Online search in SCOPUS, Academia and Google Scholar, using relevant keywords. Over 350 publications were marked as either highly relevant or relevant.
3. *Backward and forward reference searches of key literature*.

We analysed and synthesised publications offering definitions of HTR, as well as other energy-user audience characteristics and specific energy-using behaviour that was targeted. We also provided an overview of estimates of audience size, where possible, identified clear gaps and made some preliminary recommendations.

This literature review focused specifically on:

— *Vulnerable households* (including low-income and fuel-poor)

— *High-income* energy users in the residential sector

— *Renters and landlords* in both the residential and commercial sectors

— *Small to medium enterprises* (SMEs).

These audience segments were selected based on surveys and interviews with HTR experts[3], as well as the most commonly mentioned HTR audiences in the literature. We have not yet focused on specific case studies showing various engagement strategies and behavioural interventions, as this will form part of a Case Study Analysis in Year 2.

3. Findings

3.1 HTR Definitions

Our in-depth review of the HTR literature identified many sectors that aim to reach those HTRs, particularly in the literature on social services, education and health (see Table 1 in[4]). Many valid criticisms were raised regarding the HTR terminology, and we uncovered a range of other terms used in describing this audience:

— Underserved

— Socially disadvantaged

— Hard to help

— Hidden populations / hard to hear

— Illegalised, criminalised and stigmatised

— Under-represented / invisible

— Unchangeable

— Hard-to-count

— Hard-to-engage / motivate

— Understudied / under-explored

— Hard-to-treat

— Hard-to-heat / cool

There are problems with all of these terms. They depend on who is doing the defining and/or on what their exact focus is. Some terms seem to put the onus on the audience, rather than the behaviour changers who are trying to engage them (e.g. 'service-resistant', 'hard to motivate'). Some seem to put more onus on to the behaviour changers to do more to identify, find and engage such energy users (e.g. the 'underserved', 'overlooked', 'understudied'). And at least two terms, 'hard to treat' and 'hard to heat/cool', refer to homes rather than their residents.

3.2 HTR Audiences and gap analysis

The HTR audiences most frequently mentioned in the literature included residential low income, otherwise vulnerable, renters with split incentives, and SMEs. We found a lot more literature focusing on the residential than on the commercial sector, and the complexities in that sector were largely ignored[4]. Multiple or non-energy benefits (NEBs) and costs were mentioned, yet remain under-explored. There was more information on the demographics (though limited regarding age, gender and particularly race) than the psychographics of target audiences. Equity considerations, although mentioned as important motivators, are mostly understudied in the clean energy sector[5].

3.3 Barriers and Needs

The literature identified a group of key barriers common to a variety of HTR audiences:

— Competing life priorities
— Financial considerations
— (Mis)trust
— Market failures such as split incentives
— Informational barriers.

A lot more focus in the literature was spent on describing barriers to engagement than the actual needs of HTR energy users. Very few papers actively undertook needs assessments with HTR audiences or their representatives.

3.3 Target behaviour

There was also a rather limited focus on defining specific ESBs for HTR audiences, especially from the perspective of greatest user need or the potential to help overcome barriers. Most "behaviours" actually focused on the technologies (e.g. lighting, HVAC, appliances) rather than the underlying services or actual behaviour (investment, maintenance, curtailment etc., see[6]) that merited specific interventions to change them. This lack of a clear definition of types of target behaviour is a matter of concern, as it dilutes focus and clarity when designing interventions.

3.4 Estimated HTR audience size

The potential size of the HTR energy users' group is vast, estimated by some publications to be >50% ([7], especially once one looks beyond just the residential sector to include, for example, commercial tenants[8]). This number is expected to rise due to COVID-19. It will be more important than ever for policy-makers and programme managers to identify, define and engage this large user group in order to help countries' recovery efforts.

4. Preliminary Conclusions

Defining who is 'hard to reach' is difficult, and there are many different terminologies and approaches, some more problematic than others. HTR audiences are diverse, respond to different (country) contexts and have different barriers and needs. Unlike specific market barriers or failures, behavioural factors seem to be understood and utilised less by behaviour changers. We argue that clear audience definitions and in-depth examinations of their barriers and needs, as well as clearly defining target behaviour, are essential steps to designing better interventions for this audience.

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9.2 A Collaborative International Approach to Characteristizing "Hard-to-Reach" Energy users

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KEYWORDS

energy efficiency, utilities, hard-to-reach, underserved, vulnerable, low income

1. Introduction

Energy users who often do not participate in efficiency and conservation programs are referred to as "Hard to Reach" (HTR), yet their participation is key to ensuring equitable access to the benefits of energy efficiency. To this end, HTR researchers, practitioners and policy makers from New Zealand, Sweden, the United States and Canada (represented by the Consortium for Energy Efficiency [CEE]) and the United Kingdom embarked on a three-year research project in 2019, in partnership with the User-Centred Energy Systems Technology Collaboration Programme (Users TCP) of the International Energy Agency (IEA)[1]. One objective of this initiative is to characterise the diverse segments commonly referred to as HTR energy users and uncover barriers and opportunities to more effectively engaging them. This paper presents our preliminary findings with a focus on HTR audiences, barriers and considerations for cross-country transferability of findings. While the term "HTR" may implicitly put the onus for changing behaviour on energy users, this project focuses instead on the so-called "behaviour changers" (see Rotmann, 2016) and their ability or otherwise to reach HTR audiences more satisfactorily.

2. Background

In the U.S. and Canada, programme administrators focus on HTR audiences to ensure that all customers have equitable access to the benefits of energy efficiency. Additionally, many utilities have mandates that are specific to serving income-eligible customers. In New Zealand and the UK, the main motivations for engaging with HTR are equity and improved health, particularly for vulnerable populations. In Sweden, interest in more effectively engaging HTR is based on growing energy use disparities within countries and the need to address mobility as an energy service, due to increased rates of travel and the resulting negative externalities.

3. Methodology

The data sources used to characterise the various HTR audiences and barriers described in this paper included:

— A **Survey** of international HTR collaborators (N=122 from 21 countries).

— **Stakeholder interviews** (N=49) with HTR experts from the U.S./CAN (n=18), SWE (n=11), NZ/Australia (n=13) and UK (n=7).

— Input from **HTR Workshop** held in 2019 (twenty attendees from five countries).

— Input from **CEE member organizations** via various meetings (May 2019–June 2020).

— **Review of international HTR literature**[2].

The data were combined across all these sources and analysed by country, common themes being identified. The frequency with which a given HTR audience or barrier was mentioned in the data was used as a proxy for its respective priority level – an admittedly limited approximation. These data were provided voluntarily by HTR researchers, practitioners and policy-makers, primarily from the participating countries, and thus do not represent all the HTR efforts that may be underway worldwide.

4. Results and Findings

4.1 Audiences[2]

Figure 1 below illustrates the frequency of mention of HTR audience by country for each audience that was mentioned by at least three countries. The HTR characterisation[3] provides definitions of many of these HTR audiences. The HTR literature review analyses different HTR terminologies and their critiques; the literature on audience definitions and characterisations; and HTR demographics, psychographics, barriers and needs; and it provides estimates of audience size[4].

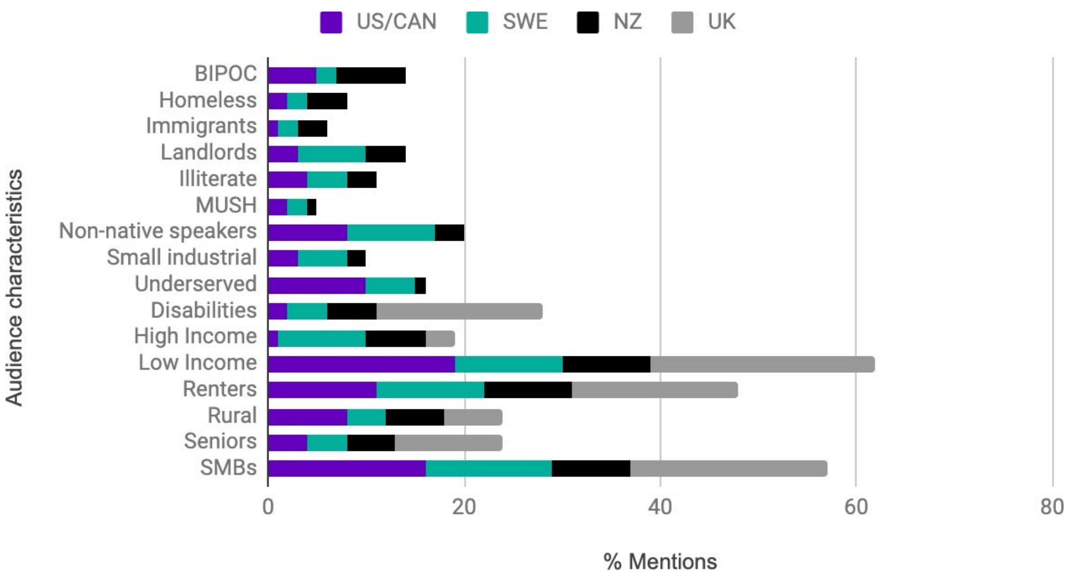


Fig 1.

% Mentions of HTR audience characteristics by country

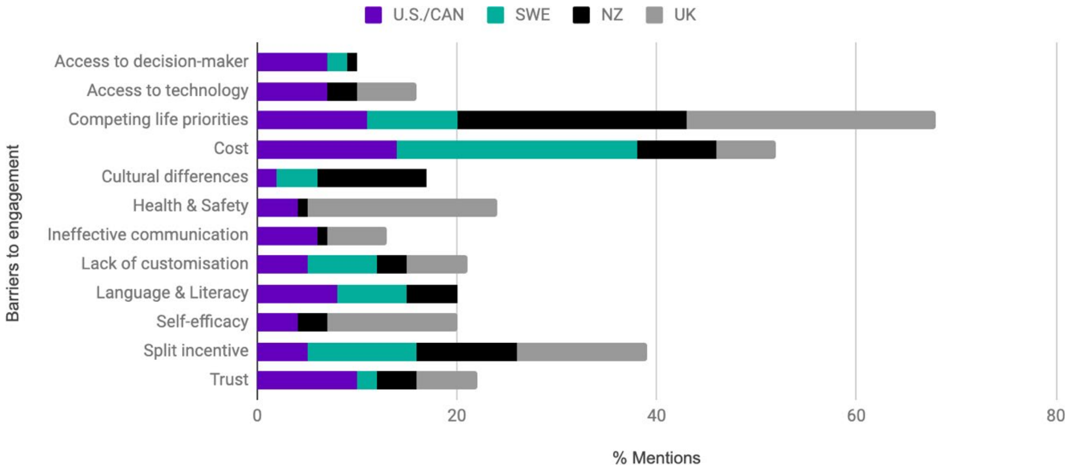
2 *BIPOC refers to Black, Indigenous, and People of Colour, whereas MUSH refers to Municipalities, Universities, Schools, and Hospitals.*

4.2 Frequency of Barriers by Country

Given the diversity of HTR audiences, we hypothesised a similar diversity of barriers to participation (Figure 2 below). However, in all four countries, just three barriers accounted for between a third and half of all barrier mentions. The barriers listed here are barriers faced by HTR audiences from the perspective of the "behaviour changers" who are aiming to engage them better in programmes. Overall, it is noteworthy that this diversity of audiences appears to experience only a handful of barriers with great frequency.

Fig 2.

% Mention of Barriers by different countries



5. Metrics for Cross-Country Transferability

Many factors could impact on the transferability of lessons learned from international HTR across countries. We have identified several preliminary metrics for assessing cross-country comparability:

— programme goals

— technology access

— energy market and climatic conditions

— socio-demographics

— entity that implements programmes in the given country (including associated implications for authority and value placed on non-energy impacts)

— policy environment

There is substantial overlap across countries in the goals and desired outcomes, the degree of technology access (except for smart meters) and socio-demographics. However, the entity charged with designing and implementing energy programmes varies a great deal across countries, and sometimes even within them.

6. Conclusions

Although the participating countries are geographically distant from one another, they are all grappling with ensuring that *small businesses*, *renters*, and *non-native speakers* of the country's main language have the chance to benefit from efficiency efforts. Despite the diversity of HTR audiences, surprisingly only a handful of barriers appear to impede programme participation for many. It is important not to discount policy, market and cultural differences between North America, European peers and New Zealand. Yet similarities in the goals and desired outcomes of energy programmes invite optimism for the potential transferability of at least some international lessons. Looking ahead, further investigation is needed to understand which approaches have or have not been successful in engaging specific HTR audiences in different countries, and which aspects of these stories may be most ripe for leverage through this international collaboration.

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9.3 Stimulating Homeowners' Energy-Saving Behaviour Through Local Authorities' Actions

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KEYWORDS

home renovation, energy efficiency, homeowner behaviour, local authority actions, policy instrument

1. Introduction

In Europe, 50% of dwellings are owner-occupied single-family houses (EUROSTAT, 2020). Houses of this type that were built before the 1970s were poorly insulated, and many of them need an energy renovation. This presents particular challenges to local authorities (BPIE, 2020), such as rebuilding existing houses as highly energy-efficient buildings with healthy indoor climates, increasing the renovation rate to 3%, and promoting equal access to financial aid while ensuring affordability. At the same time, homeowners need to be stimulated to adopt low-carbon technologies with an appropriate set of actions and policy instruments. Local authorities can be a trusted mediating and quality-assuring advisor for homeowners, but they are also limited in their role and in the way they can change homeowners' willingness to adopt low-carbon technologies.

Local authorities (LAs) have a role to play in facilitating independent energy consultancy and tailored advice in their territories. However, the traditional approach often involves central organization and top-down paternalism: energy performance certificates, financial incentives, subsidies, tax credits, etc. (Wilson et al., 2015). The involvement of third parties is often limited to public procurement, with little or no cooperation. In contrast, many studies have emphasised the new role or the varying degrees of engagement of local authorities in energy-efficiency measures (Hannon and Bolton, 2015; Morrow, 2008). Shaw (2012) found that a key feature of innovative local authority actions is to collaborate with other communities and to apply a partnership approach.

This paper introduces and evaluates innovative local policy instruments to spur the adoption of renovation measures by homeowners. The paper investigates how seven local authorities in the UK, Belgium, France and the Netherlands have dealt with the development of both virtual (online web modules) and physical consultancy (pop-ups) in target areas. The evaluation results recommend how local authorities can develop a strategic approach to civic engagement.

2. Methodology

This study used a participatory approach to study local authority (LA) engagement to create awareness and easy access to low-carbon technologies for homeowners. Seven LAs from four countries have developed and run pop-up consultancy centres and modular web-portals by implementing civic engagement, co-creation and a strategic management plan. The LAs, as trusted advisors, interact not only with homeowners actively but also with different stakeholders for purposes of co-creation. It is hypothesized that such LAs' pop-up consultancy and web portal actions will stimulate the adoption of home renovation measures. A homeowner renovation journey model is being applied to help the LAs understand homeowners' search for virtual and physical advice regarding home renovation measures. At the same time, the LAs have tested various advice strategies in temporary physical (pop-up) consultancy centres, strategically placed near the target segments of homeowners, where the LAs gave renovation advice and promoted low-carbon measures. In addition to following the process, stakeholders' views regarding the approach taken to the development of pop-up centres and modular web portals were collected through workshops and roadshows to evaluate the proposed approach.

3. Findings

The LAs' engagement was analysed using qualitative data collected from reports of workshops, project meetings, interviews and roadshows. Based on the participatory case studies conducted by the seven Las over two years, a homeowner renovation journey model was modified from an innovation-decision process model developed by Rogers (2010). Figure 1 shows the resulting homeowner renovation journey for determining LAs' actions in a structured way. Instead of a linear journey, "closing" the decision loop is important in emphasizing the need for civic engagement.

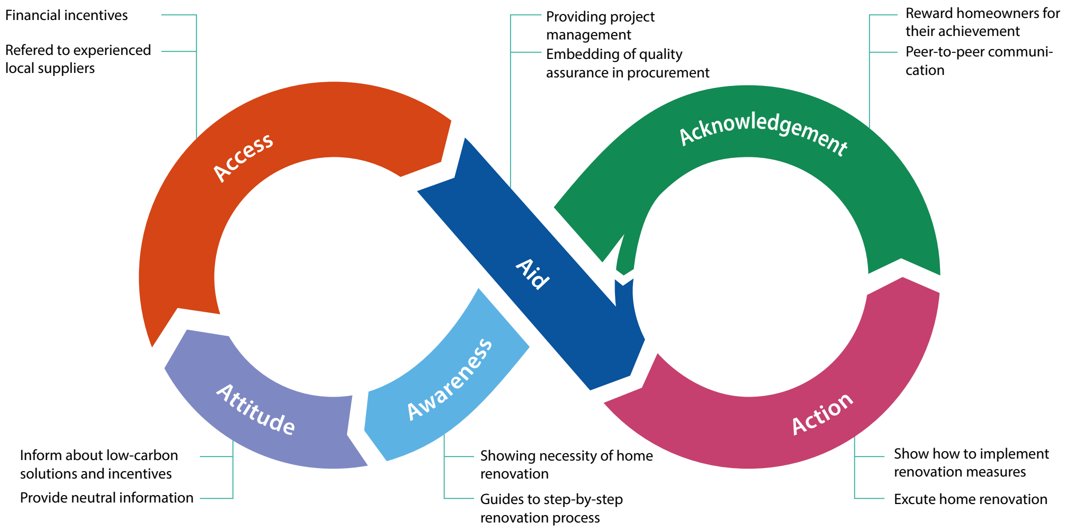

Figure 1.

Homeowner renovation journey model for the inventory of supporting local authority actions

The model emphasises the connected actions of LAs to support homeowners, such as providing energy-coaching services, offering a platform for successful renovation stories (civic engagement), providing thermographic photos of the roofs in a region, referring to local suppliers, demonstrating cases of renovation in target areas, strategically promoting pop-up consultancy centres, organising events/workshops, and so on.

The research finds that, in order to perform and provide interrelated services, there are four main factors that contextualise LAs' changing roles and attitudes in promoting home renovation measures.

Engagement of local authorities

— Co-creation and collaboration. LAs need to collaborate with different levels of stakeholders. For example, the research identified collaboration and knowledge exchange with other local, regional and national authorities, homeowners' associations, confederations of contractors and SMEs, local and policy actors, and knowledge institutions.

— Personalised services for energy-saving measures. It is important to identify homeowner segments in order to approach homeowners in more personal ways and with targeted information regarding their building type and housing situation (e.g., thermographic roof photo of their home and continued relationship with management after first contact)

— Communication and organization. LAs need to think beyond regulation and incentives to promote low-carbon and home-renovation measures through both virtual and physical events, including citizen ambassadors or schools.

— Sustainability. LAs need to monitor and regularly evaluate their actions to sustain them.

4. Discussion and conclusions

Firstly, the participatory research showed that cooperation with citizens' organisations, other local authorities and umbrella organisations during development produces better targeting of audiences. Secondly, collaboration with the supply side and intermediaries increases engagement. Thirdly, combining virtual consultancy with physical consultancy increases the interest of homeowners in home renovation, while personal contact increases the quality of the engagement. Lastly, keep the homeowner renovation journey in mind, and link with relevant stages of this journey.

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9.4 Are Tenants Willing to Pay for Energy Efficiency? Evidence from a Small-scale Spatial Analysis in Germany

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KEYWORDS

energy efficiency, willingness to pay (WTP), hedonic regression, spatial regression, rental markets, split incentive

1. Introduction and Research Question

The buildings sector accounts for 36% of final energy use and 39% of CO_2 emissions globally[1], thus making the sector's decarbonisation indispensable to meeting international climate goals and limiting the rise in global temperatures. Germany is no exception to this, but the current energy-efficient refurbishment rate (1% p.a.) remains below the country's official political target of 2% p.a.[2].

The rate and depth of energy refurbishments both differ between owner-occupiers and rental properties, with private landlords and homeowner associations having comparatively the largest refurbishment backlog[3]. One explanation for this is the split incentives that exist in rental markets, where most of the unlocked co-benefits of energy-efficient retrofits ultimately benefit the tenant and not the landlord. Due to this so-called 'landlord-tenant dilemma'[4,5], energy-efficient retrofitting in rental properties tends to be most attractive to landlords when it also leads to long-term economic benefits.

Numerous studies have thus examined and quantifies the "willingness to pay" (WTP) a premium for energy efficiency in the residential sector[6,8]. Findings to date generally identify larger energy efficiency premiums in the sales than in the rental market[7,9,10]. However, such premiums are not ubiquitous[11,12], and many conventional hedonic modelling approaches do not account for spatial dependence, omission of which can produced biased and exaggerated results[13]. Indeed, spatial analyses have found price premiums to vary significantly across different geographical locations[14], and even within a single city[15].

Given the variability of the results, small-scale spatial analyses are needed to provide concrete recommendations for local and national governments and administrations. We aim to address this research gap by focusing on the city of Wuppertal, Germany, and examining the impact of a property's energy performance on rental prices across different residential areas.

2. Data and Methods

2.1 Data

We used data from the internet platform *Immoscout24.de* (IS24) to illustrate the energy efficiency performance and hedonic characteristics of rental properties. IS24 is Germany's largest real-estate platform, with a market share of about 63%[16]. The dataset contains all advertisements for Wuppertal that were published from 2012 to 2019. We combined the georeferenced dataset with building block-level data on socio-economic statistics and built environment characteristics provided by the City of Wuppertal. In total, our dataset contains 12,232 entries.

2.2 Methods

Both a hedonic ordinary least squares (OLS) semi-log regression model and a spatial error model (SEM) were applied to the data, with the listed price per square meter for apartment rents as the dependent variable. The latter is expressed by the following equation:

$$\ln(price_i) = \alpha + \beta EE_i + \gamma H_i + \delta N_i + \mu T_i + u_i$$

with

$$u_i = \lambda w_i * u_j + \varepsilon_i$$

where EE represents the energy efficiency performance of the apartment based on the EPC (energy performance certificate, measured in kWh/sqm*a), H represents the apartment's characteristics (e.g. fitted kitchen, age of building, living area), N represents the neighbourhood characteristics (e.g. population density, unemployment rate) and T represents a series of dummy variables to control for time-fixed effects. ε represents the error term; u_i and u_j are the error terms at locations i and j, respectively, w_i being a vector that expresses the spatial relationship (weights matrix), while λ is the coefficient of spatial component errors.

In a second analysis, we subset the data set based on four residential areas to assess small-scale spatial differences between tenants' WTP.

Results and Findings

We identify spatial autocorrelation in the dependent variable (Moran's I=.493, z-value=121.23, p<.001) and spatial dependency in the residuals of the OLS model (Moran's $I_{Residuals}$=.32, p<.001). As also supported by the lower Akaike information criterion (AIC) value and the overall higher fit of the model, we therefore focus on the results of the SEM model.

The model was found to explain a significant amount of the variation in rental prices (LR=3,263.20, p<.001), with a Nagelkerke Pseudo R^2 of 0.61, indicating a reasonable goodness of fit. In line with other studies, the model provides evidence of a price premium for energy efficiency. The effect is statistically significant ($b_{Energy\ Performance}$=-0.00017, p<.001), but the effect size is small and can be interpreted as follows: willingness to pay increases by 0.017% for each improvement in energy efficiency of 1 kWh/sqm*a. Comparing the relative influence of other apartment features on rental prices shows that they lead to larger relative increases in rental prices (e.g. 3.7% for a fitted kitchen).

The second analysis shows that improvements in energy efficiency lead to increasingly high rental prices in average and good residential areas respectively, but not in simple residential areas, where energy efficiency in fact penalised with a discount (bEnergy Performance=0.00014, $p<.05$).

3. Discussion and Conclusions

Our results confirm the existence of a premium for energy efficiency in the rental market in Wuppertal. However, the premium is small, both compared to other apartment features and in absolute terms, so that investments in energy efficiency are hardly economically viable for landlords. While actual renovation costs depend very much on the building in question, sample calculations based on our dataset suggest long payback periods; no evidence of easier re-letting or reduced vacant periods of a property was found. WTP is thus currently not sufficient to refinance the energy-related renovation costs through the market within a reasonable time frame. In light of existing opportunity costs, the incentive for landlords to invest in visible apartment features or ecological heating systems is higher.

Our analysis thus provides not only an explanation for the backlog in low-demand rental housing markets, it also produces concrete recommendations for overcoming this market failure. First, other refinancing models are needed, and regulatory instruments such as an obligation to refurbish or mandatory standards for energy efficiency should be considered. The varied results obtained across the four residential areas further demand a spatial differentiation within the funding framework.

Secondly, stronger incentives are needed for tenants to make energy efficiency a relevant rental criterion and to demand it on the market (e.g. via campaigns, a higher CO_2 price, rising energy prices). Given tenants' significantly higher WTP for renewable heating technologies, the relative roles of energy efficiency and renewable energies in achieving climate-neutral building stock may need to shift.

Finally, investments in energy efficiency and the associated cost allocations are in danger of furthering existing tendencies towards social segregation in rental markets and should therefore be considered against the backdrop of social and urban development policy objectives.

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9.5 To what Extent has Covid-19 Impacted Hard-to-reach Energy Audiences?

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KEYWORDS

Energy Use, Behaviour, Hard-to-Reach, Underserved, COVID-19

1. Introduction

Energy users who haven't yet participated in efficiency and conservation programmes despite ongoing outreach are often referred to as 'Hard-to-Reach' (HTR) or 'underserved'. These individuals or organizations can include, e.g., low income or otherwise vulnerable households; and small businesses or commercial building operators. More effectively engaging underserved and HTR audiences is key to ensuring everyone benefits equitably from energy efficiency (EE) policies and programmes. This is, even more, the case in light of the COVID-19 pandemic and the ongoing implications for energy use and affordability for the most vulnerable (and newly vulnerable) members of our society.

We focus on HTR audiences from the residential and non-residential sectors in this paper and have undertaken a broad stakeholder analysis (Ashby et al., 2020) and a critical in-depth literature review (Rotmann et al., forthcoming). In these works, we have characterized HTR audiences - segmented into vulnerable and high-income households; renters and landlords; commercial sector; and SME audiences - as well as energy services (e.g. mobility) and their energy-saving behaviours (ESB) and barriers to their engagement. Building on this, we have also looked at the impacts of COVID-19 on these specific audiences, including their added vulnerabilities and whether the pandemic has exacerbated or decreased HTR audience size estimates.

2. Methodology

Our primary method for this work was a comprehensive, critical literature review (see [1] and [2]) and a compilation of recent statistics. In addition, we collected survey, interview and focus group data during the 2020 COVID-19 pandemic in the US, UK, New Zealand (NZ) and Sweden. Data from NZ consisted of an online survey (with 330 respondents), and follow-up interviews with 25 householders to explore changes in home energy use in the four months following the initial COVID-19 (lockdown) restrictions in April and May.

3. Findings

3.1 Literature review

Depending on the definitions and metrics, the potential size of the HTR energy users group is vast; estimated by some authors to exceed 50% of the population [3]. This is especially the case when looking beyond the residential sector. The rental sector alone, with its split incentive issues, makes up more than ▯ of commercial and residential properties in most countries. SMEs make up almost 99% of all businesses and create over half of commercial and industrial greenhouse gas emissions [4]. They are also regarded as one of the hardest-to-reach segments.

The number of low income and vulnerable households and small businesses is expected to rise due to COVID-19, and the huge number of people who are newly unemployed, furloughed or who have lost their businesses because of the economic fallout following extended lockdowns. This suggests that it will be more important than ever for policymakers and programme managers to identify, define and engage this large user group as part of COVID-19 recovery efforts, particularly in countries where vulnerable households (will) face excess utility bills by being forced to stay and work (and school their children) from home.

For example, new research [5] shows that children from low-income families will be hit the hardest by those policy interventions, with the energy use of some households with children rising by 75% [6]. Sovacool et al. [7] summarise some of the worrisome public health and economic predictions, including that 300 million people worldwide are likely to lose their jobs. At the end of April 2020, more than half (54%) of the entire global population was under some kind of lockdown, with the share of energy use exposed to containment measures reaching 50% [7]. We also know that certain behavioural changes, like working from home, differed between different energy users (e.g. the most vulnerable, low-income households who often included essential workers, were also the ones least likely to be able to work from home).

3.2 Empirical insights

- Unlike most countries, Sweden has taken a different approach to managing COVID-19. When it comes to mobility, declines in demand (~30%) has shown relatively similar patterns found in countries with stricter measures. Mobility has become more "reachable" due to the pandemic but variations do exist: whereas air traffic has experienced strong low demand levels (~55-70%), road traffic has returned to near-normal levels [8].
- In the UK, fuel debt is growing due to higher domestic consumption arising from lockdown measures and the reduced income of many households due to unemployment, shielding and furlough. By May 2020, 4% of all energy consumers had already fallen behind on energy bills, with a further 7% expected to fall behind in the future [9].
- In the United States, a survey of 1,000 energy customers [10] found that many are using more energy and monitoring their energy use less; 15% reported postponing a utility bill. COVID-19 impacts have varied by customer: some are postponing planned upgrades while others are making new plans to improve the comfort and style of their homes.

We will discuss these empirical findings (including those from NZ) in more detail, following further analysis, at the BEHAVE conference.

4. Conclusions and recommendations

Although the COVID-19 pandemic may eventually abate, its significant economic (e.g. widespread unemployment, whole job sectors disappearing), health (e.g. chronic illness and disabilities, susceptibility to other respiratory diseases) and social consequences (e.g. high level of evictions and homelessness, compounded structural inequalities) will likely persist [11]. Positive trends are also possible to observe (e.g. declines in household mobility and commercial sector electricity demand). An important challenge is how (behaviourally-informed) policy interventions can help sustain positive changes among certain HTR segments in the long term. Still, the number of people who will fall into the various HTR audiences described here is likely to increase due to COVID-19. Vulnerable households and businesses will likely suffer disproportionately from additional global challenges, such as the climate crisis, economic recession, inequality, etc. This pandemic has certainly helped to highlight the need for deep, structural changes in our societies and foster research on (newly) vulnerable populations who are in dire need of support and who are often also hard-to-reach for energy Behaviour Changers.

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SECTION 10

POLICIES AND PROGRAMMES

10.1 Overcoming Defaults: Cognitive Biases and Consumer Engagement with Local Energy in a Multiple-supplier Model

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KEYWORDS

Local energy, behavioural economics, cognitive biases, future energy markets, survey experiment, multiple supplier models, default effects

1. Introduction and background

Local energy is increasingly referenced in UK government strategy documents as having a key role to play in the energy transition (BEIS and Ofgem, 2017). As well as supporting the integration of renewable generation assets, under certain conditions local energy systems have the potential to reduce constraints on the grid at peak times and help achieve social policy objectives, such as alleviating fuel poverty, strengthening community ties and empowering consumers. The rise of local energy is creating challenges for energy market regulation: under the 'supplier-hub' principle, consumers have a relationship with a single energy supplier. Increasingly, the option for consumers to take on contracts with multiple suppliers is viewed as having the potential to support energy-market innovation (Spence 2018). However, making changes to the supplier-hub model would necessitate understanding how consumers might react to more complex alternatives, such as multiple supplier models (MSMs).

This study takes a behavioural economic approach and views consumers' tendency to remain with incumbent suppliers through the theory of 'default effects'. Three behavioural mechanisms have been proposed to explain why individuals tend to stick with defaults that are assigned to them: cognitive effort, implied endorsement and loss aversion (Jachimowicz et al., 2019). Cognitive effort suggests that people stick with defaults because of the mental effort required to process alternatives and form preferences (Tversky and Kahneman, 1974). Implied endorsement suggests that individuals perceive defaults as recommended to them by the default-setter (McKenzie et al., 2006). Loss aversion claims individuals compare with the status quo and emphasise potential losses over gains when making decisions (Tversky and Kahneman, 1991). As the evidence suggests these mechanisms already affect tariff switching (Ofgem, 2011), they may also impact on switching to local suppliers. However, it is unclear how an MSM might affect this. This study fills a gap in the behavioural economic literature, as well as providing empirical evidence on the social acceptability of MSMs in Britain, with insights into how the growth of local energy could be supported.

2. Methods

Two nationally representative online survey experiments were conducted in July 2019. The first experiment (n=1200) was designed to test first, the social acceptability of MSMs, and secondly, for those sticking with defaults, the relative importance of cognitive effort, implied endorsement and loss aversion. Participants were asked to imagine having received a letter from their current energy supplier offering them an opportunity to 'add on' a local supplier to their current tariff. They were randomly assigned to one of three conditions. In the 'multiple-supplier default' condition, participants were told that they had been automatically enrolled on to the MSM. In the 'single supplier default' condition, participants had to take action if they wanted to switch to the new MSM. In the 'active choice' condition, participants were asked to choose between a single supplier and a multiple-supplier option.

The second experiment (n=800) was designed to test two things, first, whether an MSM could mitigate loss aversion associated with supplier switching; and secondly, whether participants would be more willing to switch to a local supplier under the current supplier- hub model or an MSM. Participants were asked to imagine having received a letter from a local energy supplier. They were randomly assigned to one of two conditions. In the 'single supplier condition', participants were asked if they would like to switch entirely to the new local supplier. In the 'multiple-supplier condition', participants were invited to add the local supplier's services on to their current tariff in an MSM, with their current supplier meeting any extra demand.

Behavioural mechanisms were measured through survey questions. Data were analysed using logistic regression models.

3. Results

In the first experiment, in the 'multiple-supplier default' condition, only 16% chose to take action to switch back to their current single supplier tariff. In the 'active choice' condition 78% chose the MSM, indicating a strong preference for this model. Strikingly, in the 'single supplier default' condition, consumers' preference for adding a local supplier under a multiple supplier model was so strong that it overcame default effects, with 58% choosing to actively switch to the MSM.

The perception that the supplier has been recommended (i.e. implied endorsement) was the most robust mechanism associated with remaining with default suppliers. There was no robust association between loss aversion or cognitive effort and remaining with a default.

In the second experiment, the majority of participants stayed with their default supplier model in both conditions. However, participants were significantly more likely to engage with local energy in an MSM than under the current supplier hub model: 43% of participants chose to add on the local energy company's services in an MSM compared to

35% who switched in the single supplier condition. There was no evidence that loss aversion could explain the higher willingness to switch in an MSM.

4. Discussion and Conclusions

Participants showed a high level of interest in MSMs, depending on how they were approached. Given the difference in willingness to switch when participants were hypothetically contacted by their current supplier rather than a local supplier, the cooperation and support of existing suppliers is likely to be important. The importance of implied endorsement suggests that explicit recommendations from trusted actors may also help to drive supplier switching and engagement with innovative offers in the energy market. Previous research on loss aversion could not be replicated in this work. This suggests that loss aversion may be overcome in certain circumstances.

These findings suggest that MSMs are likely to be a promising avenue for supporting the growth of local energy and creating opportunities for innovation in the British energy market. In addition to these empirical findings, this conference paper will present ongoing research into the potential configurations of future supplier models and discuss how these might be approached from a behavioural perspective.

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10.2 Investigation of the Impact of Occupants' Behaviour on Residentail Electricity Consumption

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residential electricity consumption, occupant behaviour, electricity-saving education, ANFIS.

1. Introduction

Consumption of electricity has dramatically increased by 29% globally in the last decade[1,3], and the proportion of residential electricity consumption in total electricity consumption has now reached 20%[2]. In the last decade in Turkey, total electricity consumption has increased at an average annual rate of 59%, while residential electricity consumption has grown by 27%[4,5] to reach 19%[6]. One attempt being made to slow down this increase is to introduce energy efficiency measures, and another oneis to implement energy conservation behaviour measures to reduce household electricity consumption. Intervention strategies such as providing information are among of the measures being used in attempting to change the energy consumption behaviour of households[3]. This study is examining the effect of energy conservation education on households' electricity consumption behaviour. These analyses have been conducted using a modeling approach called the Adaptive Neuro-Fuzzy Inference System (ANFIS), which has not been applied before in studies of electricity consumption behaviour.

2. Background Information and Previous Studies

The importance of behavioural impacts on residential electricity consumption had been studied since 1977. Statistical methods[7], engineering models[8], hybrid approaches[9] and fuzzy logic approaches[10] have been used to determine the effects of behaviour on residential electricity consumption. Studies of the effect of behaviour parameters on residential electricity consumption worldwide mainly use fuzzy logic approaches. One of these is ANFIS, developed by Jang[11] in 1993 and used in modelling nonlinear functions. This model approach has been used in several studies on, for example, energy management[12], medicine[13], hydraulics[14], agriculture[15] and solar energy[16]. However, to the authors' knowledge, it has not been applied to the study of electricity consumption behaviour.

There are intervention strategies such as commitment, goal-setting, providing information on energy conservation, rewards and supplying feedback information on energy consumption patterns. These intervention strategies are used to make changes in the households' energy consumption behaviour[3]. Some studies state that the effect of behavioural changes on residential electricity-saving potential is around 10-40% on average[17,8,18].

3. Methodology of the Study

In this study, surveys are being conducted of a hundred households in Yalova. These surveys are designed to gather detailed information on electricity consumption behaviour, household economic and demographic data, and the appliance characteristics. These household's monthly electricity consumption data were obtained from the relevant utility company. In this study, the intervention strategy[3] we have chosen to follow is face-to-face education on energy conservation. In addition, a brochure on electricity conservation measures that can easily be introduced in homes has been prepared and provided to the households. The intervention program is being applied to fifty homes whose electricity consumption is relatively higher than the othe households in the survey. The electricity consumption data of these homes for the months after the education initiative was introduced are compared with the same months of the previous year when no intervention was applied to these homes.

An ANFIS model, using one of the leading artificial intelligence techniques, is a fuzzy logic system adapted to artificial neural networks. Using this hybrid learning algorithm, ANFIS applies the if-then rules of fuzzy logic and the input-output structure that reflects human knowledge. In this study, the dataset consisting of 100*24 matrices was processed at the ANFIS model developed at MATLAB. 75% of 100 variables have been processed as the training data, the remaining 25% as test data[14,16]. A total of 23 parameters are being processed as input data developed from the responses of the surveys. Monthly electricity consumption is taken as the output data.

4. Results and Findings

The statistical analyses of monthly electricity consumption in the homes that received face-to-face education on energy conservation show that there is a significant decrease in electricity consumption in these homes. These results indicate that significant electricity savings can be achieved in household electricity consumption through education.

The training dataset for the developed ANFIS model, Root Mean Square Error (RMSE), is calculated as 0.038, and testing dataset Mean Absolute Percentage Error (MAPE) as 22%. This situation shows that the developed model is well trained and that its prediction performance is acceptable[19]. Thus, the model results reveal important information on the effect of occupant behaviour on residential electricity consumption. It can be concluded that the ANFIS model is suitable for use in determining the effects of behaviour on residential electricity consumption. This modelling approach offers various advantages, such as providing a practical solution with a few input variables and creating the rules set by the system based on the available dataset without the need for expert opinion.

5. Discussion and Conclusions

In this study, an intervention method in the form of face-to-face education in energy conservation is being applied to fifty homes. The analyses show that a significant decrease in total electricity consumption of the homes that received such education is being achieved. The effect of changing electricity consumption behaviour is modelled using a new modelling approach called ANFIS. The predicted performance of the ANFIS model is found to be satisfactory. To the authors' knowledge, this is the first comprehensive study of the electricity consumption behaviour of households and also the first study to use ANFIS to model the electricity consumption behaviour of households. This study can contribute to changing state policies in the residential sector, by encouraging the state to raise awareness about electricity consumption through various educational programs and incentives. Some efforts to improve occupant behaviour should be considered to achieve residential electricity savings.

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10.3 Process Perspective on Home Retrofitting Decisions: A Qualitative Metasynthesis

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KEYWORDS

retrofit, energy efficiency, homeowners, process, qualitative metasynthesis

1. Introduction

The promotion of low-carbon home retrofitting among homeowners is widely recognised as an important strategy to reduce operational energy use in dwellings and mitigate climate change. Building research and policy have traditionally treated the decisions that homeowners make with regard to low-carbon retrofit as isolated events[1]. Nevertheless, research on domestic retrofit shows that retrofit decisions are often spread over lengthy periods of time[2]. Driven by evidence on the temporal nature of retrofit decisions, this study adopts a process research strategy[3] to review and produce a metasynthesis of evidence for homeowner retrofitting decisions available in the literature.

2. Methodology and Sample

A qualitative metasynthesis approach is used to assemble a process research view on retrofitting decisions[4]. The approach involves more than just summarizing findings, as it offers novel interpretations of findings, plus the ability to construct narratives larger than those in any individual report we have reviewed.

Potentially relevant articles were identified through searches with no time-related restrictions in the Web of Science, Scopus and International Bibliography of the Social Sciences (IBSS) databases. Five search terms were used: *low-carbon*, *home*, *retrofit*, *homeowner* and *qualitative research*. These were combined with synonyms of each term via appropriate operators, i.e. Boolean, together creating 62 search concepts. Qualitative studies eligible for inclusion were all those with a rich description of retrofitting processes that resulted in improved energy efficiency in owner-occupied dwellings. No geographical constraints were imposed. ‘Qualitative research’ was liberally defined as empirical research with human participants that used what are commonly viewed as qualitative techniques for sampling, data collection, data analysis and interpretation. Research conducted in any paradigm and guided by any theoretical framework was eligible for inclusion. Studies had to be written in English, and only peer-reviewed original journal articles were included. The search recall yielded 445 items, whose titles and abstracts were checked for relevance.

Only ten articles were considered eligible for inclusion in the metasynthesis, which reflects the scarcity of case-study research on dwelling retrofitting[5]. These ten articles are listed in references[6,15]. The content of every article was analysed with a reading guide, adapted from the original appraisal guide developed by Sandelowski and Barroso[4]. The analysis reports were coded to identify processes leading respectively towards or away from post-retrofitting reduction in energy use.

Overall, the ten reports used in the synthesis constitute a combined sample of nineteen retrofit cases, visible in the reports. All case-study households consisted of at least two members. The dwellings were varied in construction type and fell within an age range from the nineteenth century to the mid-1960s. Sustainability-related retrofitting activities ranged from fabric insulation only to in-depth retrofitting to Passivhaus standard. In seventeen cases, the unit of analysis was the household and their experience; in the other two cases, the unit of analysis was a specific geographical area.

3. Results

The analysis highlighted the importance of three processes necessary to reduce domestic energy use through retrofit. First, the review highlighted the importance of aligning the various goals of the different actors involved in the retrofitting. Homeowners' retrofitting activities or their absence are often used as an indicator of homeowner retrofit goals and motivations or a lack of them. However, the attribution of retrofit outcomes to homeowner intentions only is a simplification of reality: homeowner retrofit decisions are shaped by various actors, such as contractors, advisors, planners and conservation officers[7,15]. Each actor can be expected to have different understandings, motivations and expectations of the retrofitting process[7], which, combined, can steer the retrofitting decision closer to or further away from a low-carbon solution.

Second, the review highlighted the need to create an overarching vision of how to transform a house into a technological system of a low-carbon dwelling through retrofitting. Low-carbon retrofitting projects typically require the installation of a collection of energy-saving measures and appliances, and often the installation of energy-generating technologies such as photovoltaics. A simple amalgamation of individual measures and appliances is unlikely to result in the desired energy savings[16]. Instead, a building should be considered a system, as optimising the operational energy use of a whole system might be more efficient than optimising its individual components[17]. An understanding of the building as a system is also necessary to minimise the risk of unintended consequences associated with low-carbon retrofitting, such as reduced ventilation rates and poor indoor air quality[18,19].

Third, the review highlighted the need to change every-day domestic practices after the retrofitting to accommodate and maintain lower energy use. It should be noted that energy efficiency retrofitting is not an ultimate goal in and of itself, but rather a necessary step in reducing operational energy use. The goal of such a retrofitting is to reduce energy use, not to support wasteful behaviour through the increased efficiency of building components. An effective low-carbon retrofitting should ideally facilitate a transition to more sustainable energy consumption practices. Instead, the review showed that pre-retrofitting energy-related practices, such as cooling and heating, tend to continue after low-carbon retrofitting, even if they are less than optimal from an energy perspective in the house's new technical configuration[14]. Moreover, the owners tend to carry out retrofitting activities to accommodate current and often unsustainable everyday practices[8].

4. Discussion and Conclusions

This metasynthesis focused on the temporal sequences of retrofitting decisions by drawing on analyses conducted through process research, which revealed new areas that current policies should focus their efforts upon to enhance impact. The findings presented in this abstract show that homeowners' retrofitting decisions, or their absence, are better understood in relation to the actions of other relevant actors. The metasynthesis highlighted three processes necessary to achieve and sustain low energy use post-retrofitting: (i) alignment of the retrofitting goals of the actors involved; (ii) the integration of the retrofitting solutions into a technological system; and (iii) the transition to more sustainable energy-consumption practices post-retrofitting. All these processes are inherently social and are shaped in the process of homeowner interactions with various other actors. Further research is needed to investigate how the dynamics of such interactions and processes can lead either towards or away from reduced energy consumption post-retrofitting.

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10.4 Integrating Discrete Choice Experiments and Bottom-up Energy Demand Models to Investigate the Long-term Adoption of Electrical Appliances in Response to Energy Efficiency Policies

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energy efficiency policies, household appliances, discrete choice experiments, bottom-up modelling, energy demand

1. Introduction

Energy-efficiency policies in the European Union (EU) are subject to ongoing critical assessments with regard to their energy-saving and distributional effects and cost-effectiveness. Ex-ante evaluations of such policies are typically performed through energy-economy models[1]. However, equally typically these modelling approaches fail to account for heterogeneity in consumer preferences across technological variants (e.g. energy label classes), socioeconomic characteristics (e.g. income levels), or countries. For example, the PRIMES model used for the EU's Reference Scenario 2016 applies a single implicit discount rate to simulate households' decisions to invest in electrical appliances across all member states and consumer types[2].

Addressing this research gap, this study integrates empirical findings on individual behaviour in adopting appliances into a bottom-up energy demand model to simulate the long-term effects of major EU energy-efficiency policies on the adoption of energy-efficient technologies. More specifically, by employing representative surveys across ca. 4,500 households in eight EU countries in combination with the bottom-up energy demand model FORECAST, we analyse the impact of minimum energy performance standards (MEPS), labelling and rebates on the diffusion of white appliances by class of energy label and on energy demand in the EU-28 until 2030. White appliances currently account for approximately 40 percent of the EU's residential electricity use[3].

2. Methodology

Our methodology has two major elements. First, demographically representative surveys were carried out in eight EU member states[1] to analyse empirically factors influencing individual decision-making and the response of households to different policy instruments. The survey included a stated-preference discrete choice experiment (DCE) on hypothetical technology adoption of refrigerators. In these DCEs, participants were asked to make a series of choices between different refrigerator-purchasing options differing by energy label, size (volume), length of warranty, ratings of customer reviews, purchase price and availability of rebates for top-rated refrigerators. In addition to the DCE, the survey included items on socio- economic characteristics, attitudes, and household characteristics, including income, family size and environmental preferences.

Second, the empirical findings from the DCE are implemented in the bottom-up vintage stock model FORECAST[4,5] to analyse the impact of households' decision-making criteria and of policy instruments on the long-term diffusion of white appliances and on energy demand. The results from estimating the DCE via mixed-logit models[6] are used to parameterise the utility functions in FORECAST. Since our specification of the mixed-logit models allowed respondent valuation of the technological attributes (e.g. energy labels) to vary by household characteristics (e.g. income levels) and countries, these utility functions account for substantial heterogeneity across consumers by household incomes, family size and environmental preferences. The logit specification of the latent utility function[7] is then used to calculate annual market shares (sales) per label class. To transfer the findings for refrigerators to other white appliances (e.g. washing machines), we assumed the implicit discount rates[8] to be the same across white appliances per country. Likewise, to transfer the findings to the twenty EU countries not included in our survey, we conducted a cluster analysis[9] based on countries' similarities in socio-economic terms.

Important exogenous factors affecting the outcomes of our policy simulations include techno-economic variables (e.g. characteristics of available technologies, electricity prices) and policy variables (e.g. design of minimum energy-performance standards). Our simulations compare a business-as-usual scenario (essentially comprising current Ecodesign and labelling legislation) with a new policies scenario (essentially, tightened MEPS combined with rebates for low-income households). In all scenarios, the framework conditions (population, electricity prices, etc.) are based on the EU Reference Scenario[2] and were kept the same.

3. Results and Findings

Findings from the DCE generally suggest that participants dislike higher purchase prices for refrigerators and like rebates, preferring appliances with better energy labels, larger volumes, longer warranties and higher customer ratings[10]. These evaluations are found to differ by household characteristics (income, household size, environmental preferences) and countries.

1 *The selected countries are France, Germany, Italy, Poland, Romania, Spain, Sweden and the United Kingdom, which together account for about 74% of the EU population[11]. In each country, participants were selected via quota sampling so as to be representative in terms of gender, age, income and regional population dispersal. The survey was administered in July and August 2018. The total sample size is n = 4557, with individual sample sizes ranging from 415 (Italy) to 599 (Sweden). Note that at the time the survey was implemented, the United Kingdom was still part of the European Union.*

Embedded in the FORECAST model, the DCE results provide an empirical basis for scenario-specific simulations of the diffusion of white appliances in the EU by 2030 in response to different policy instruments. Principal model outputs include yearly market share (sales) and stock dynamics disaggregated by appliance technology (refrigerators, freezers, washing machines, dryers, dishwashers), energy label (A+++, A++, etc., and consumer group (eight permutations of income level, family size and environmental preferences). Aggregated indicators include final energy demand and total cost of ownership (investment, maintenance, electricity costs). Figure 1 shows how different policies should affect the long-term stock development of all white appliances from 2015 to 2030. Compared with the business-as-usual scenario, stricter MEPS combined with rebates, disbursed to low-income households, can clearly boost the adoption of efficient household appliances. The former scenario is projected to entail a 20.4% (34.9 TWh) reduction in final energy demand by 2030 (compared to 2015 levels), while the latter scenario generates savings of 29.9% (51.0 TWh) in the same timeframe.

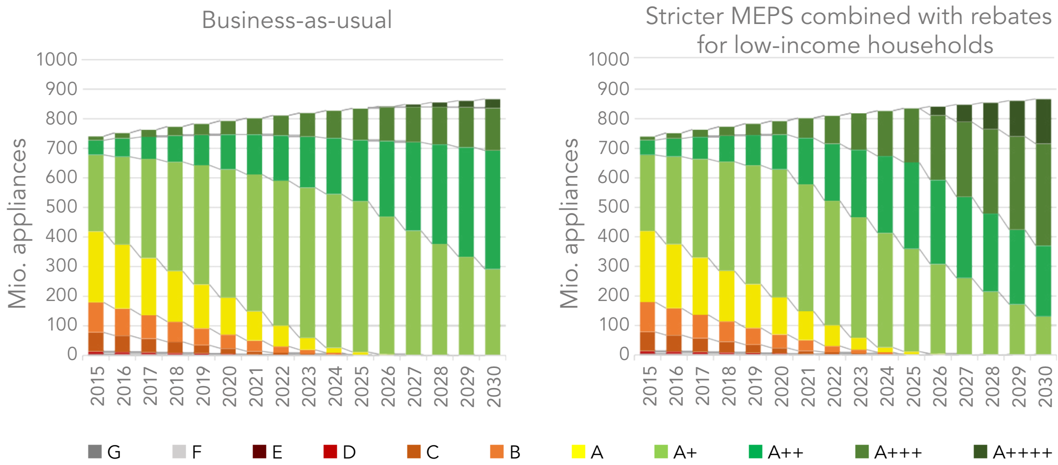

Figure 1.

Stock development of white appliances in the EU-28 by energy label, 2015–2030.

While our findings underscore the significance of the EU's Ecodesign and Labelling legislation, they also indicate unwanted distributional effects in some countries if there is stricter regulation, which should be considered when designing policy. We conclude that, by coupling empirical data on individual appliance adoption with a bottom-up energy model, our approach provides robust insights into households' responses to energy-efficiency policies and the long- term implications for energy demand.

Methodological limitations of the approach include the projection of cross-sectional survey data to future years (not accounting for prospective changes in consumer preferences), as well as the lack of consideration to direct rebound effects (i.e., consumers increasing appliance use in response to achieved cost savings). In turn, our approach illustrates the benefits of distinguishing household responses to policies (and technology features) by socio-economic group when assessing the effects of energy-efficiency policies in the residential sector. This paper can only provide a sketch of the potential applications. The empirical findings from the DCEs may also be integrated into other model types (e.g. agent-based models). Finally, future research could expand this approach to cover other end-use technologies.

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10.5 Working More, Consuming Electricity Differently? Activity Network Analysis of the 2014.2015 UK Time Use Survey

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1. Introduction

Research on energy demand tends to treat work and home separately, despite the fact that the two are interconnected. The aim of this presentation is to investigate the relationship between the duration of work and energy-related activities in the home, such as dish washing, ironing, food preparation, laundry, and watching TV, video or DVDs. It presents a network analysis of data from the 2014-2015 UK National Time Use Survey. The research questions addressed in this presentation relate to (i) how the duration of work affects the cohesion between energy-relevant activities; (ii) how the centrality parameters of energy-relevant activities change between and across work days; (iii) how changes in the timing of some energy-relevant activities may impact on how the day is configured; **and (iv) how working from home and flexible working hours can affect the timing and amount of people's energy consumption.** Findings are presented in terms of the cohesion between activities based on the duration of the work day, inter- and intra-day variations in connections between activities, energy relevant-activities with an intermediary role, and an example on the clustering of *food preparation* as an activity.

2. Design, Methodology and Approach

The analysis in this paper is based on the UK 2014-2015 Time-Use Survey[1], the most recent nationally representative time-use survey available in the UK. Data were collected between April 2014 and December 2015 using a nationally representative sample of the British population obtained through multi-stage stratified probability sampling. The sample size consisted of 9,388 individuals in 4,238 households who completed 16,550 diaries and 3,523 week-long work schedules. The time-use diaries provide information about what individuals are doing on one weekday and one weekend day and when during 24-hour periods. In addition to the time-use diary, 3,523 respondents provided seven-day information about how many hours of work they had done and precisely at which hours in the day or week. For this paper, the work diaries were used to calculate the total number of hours worked per week and to identify the total number of work days per week. First, based on the self-reported daily work hours, we divided the sample into two groups: individuals who reported working fewer and more than 35 hours per week respectively. The decision to split the sample based on the total number of hours followed UK government guidance. Second, each group was further divided based on their numbers of days worked during the week. To obtain a clear picture of the association between work days and the timing of activities, we decided to focus only on time-use diaries that were filled in on a work day. The final step was to divide the matched dairies into five daily temporal periods of equal length with the aim of capturing work days from morning to evening peaks: 4am-7:50am; 8am-11:50am; 12am-3:50pm; 4pm-7:50pm; 8pm-11:50pm; and 12am-3:50am[2]. In order to determine if there is significant difference between work days, a non-parametric Kruskal-Wallis test was applied. **We also provide estimates for the timing of energy-relevant activities and the electricity consumption of different appliances before and after work.**

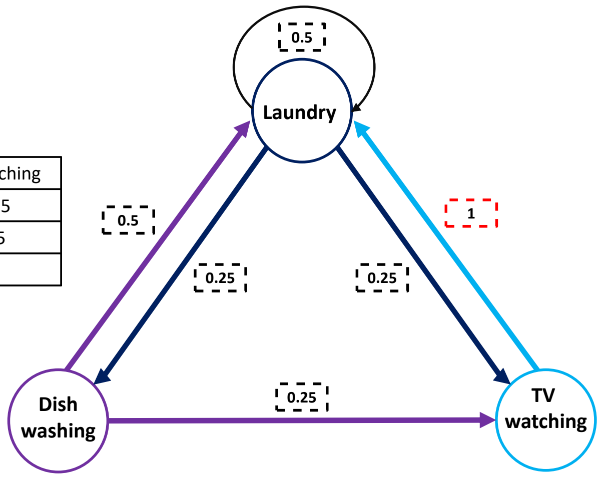
2.1. Activity-Network description

We constructed the activity networks based on the time-use diaries[3]. In this presentation, the nodes of the graphs represent the time-use survey activities reported by individuals at a time *t*. The connections between the activities are measured by the proportion of individuals switching from one activity at time *t* to another at time *t+1*. The absence of a connection means that no switch between activities was made. The arcs of the edges denote the direction of the connections between the different nodes. Activities have self-loops indicating that some activities repeat themselves from one time period to the next. Figure 1 provides an example of a graph with three activities and six edges. The figure suggests that there is a 50% of chance that *dish-washing* follows *unspecified TV, video or DVD watching.*

Figure 1.

An example of a transition matrix and its corresponding network graph

Activities	Laundry	Dish washing	TV watching
Laundry	0.5	0.25	0.25
Dish washing	0.5	0	0.5
TV watching	1	0	0



The structural characteristics of the network were assessed using network density metrics. The weighted degree metrics were used to assess the popularity of an activity. Node-clustering is based on triplets, triangles and community detection. We used R packages 'sna', 'igraph' and Gephi to describe and visualise our data.

3. Practical Implications

Recent developments in relation to the COVID-19 crisis show the importance of understanding how developments in work arrangements underpin everyday life, including activities networks and the timing of domestic energy demand. Even without large disruptions to normality, non-energy policies, such as the establishment of a shorter working week, are likely to change the timing of energy-related activities significantly. Changes in the structure of working activities and shorter working weeks combined with changes in storage and electric-vehicle provision, may have implications for future flexibility in electricity demand. There are multiple implications to this work, three of which are listed here. First, we present one way of conducting empirical studies which overcomes treating time-use activities in isolation. An excessive focus on what happens in the home can generate far too static representations of everyday life in which arrangements such as work are neglected and yet play a vital role. Second, knowing about the stability of practices throughout the day increases knowledge about daily routines in the homes. The presentation focuses on key metrics to identify which aspects of everyday life are central to how people live in their homes through the lenses of work arrangements. Third, this presentation can be seen as providing methodological tools to analyse how changes in different temporal domains, including in the structure of work and the re-organisation of activities, may affect consumption in the home and beyond.

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10.6 Promoting Energy Efficiency through Competitive Tenders: Comparing Auction Schemes and End-user Activation in Germany, Portugal, Switzerland and Taiwan

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energy efficiency promotion, electricity efficiency, tendering, auctioning, cost of avoided kWh

1. Introduction

Governments are increasingly using competitive tenders, or in other words auctioning, to promote renewable sources of energy and energy efficiency. The main rationale for governments to do this is to lower the costs of subsidy schemes. Most prominently, auctioning is used to provide financial incentives for wind or solar energy and has increasingly replaced other schemes such as feed-in tariffs. In the EU, this has been fostered especially by the European Commission's state aid guidelines, as auctioning is a competition-oriented approach. However, the competition often favours the larger plants and bidders, which, due to their size, have lower and thus more competitive production costs and better access to capital, as well as a greater capacity to take risks. As a result, auctioning renewable energy is mainly driven and used by the larger energy utilities and – at least in some cases, as Leiren and Reimer[1] argue – it might even save traditional energy utilities from insolvency. Unlike renewables, auctioning is not so often used for promoting and supporting energy-efficiency measures[2]. This paper explores how competitive tendering is currently being used to incentivize end-user energy efficiency in Germany, Portugal, Switzerland and Taiwan. It also analyses what target groups are most likely to respond to competitive tenders and what approaches may help to mitigate the over-representation of large enterprises and thus stimulate the participation of SMEs and households.

2. Background and Methodology

Auctioning is a process of buying and selling goods and services where an auctioneer launches an open call for bids and chooses the buyer or seller that submits the best bid. The economic literature on auctions claims that in general auctions are a very efficient market-oriented procedure, even when they are repeated over time. However, auction processes impose significant upfront costs on the applicant, and therefore cost-effectiveness can only be achieved for larger volumes. The auction literature (among others[2],[3] and[4]) also indicates that the auction should be carefully designed so as order to reflect its possible effects on expected revenues and entry costs. The most important elements of auction design can be derived from this literature and be used in order to compare them with the existing energy-efficiency auctions. In addition, some elements specific to energy efficiency will be added.

— The auctioned good: e.g. kWh energy savings or avoided CO_2 emissions. With kWh in particular, whether these savings are delivered or not should be verified, e.g. through measurement. It is also possible that there is more than one attribute defining the price ("single" vs. "multiple" attributes).

— The focus could be on electricity savings (Switzerland and Portugal) and / or fuel savings (Germany).

— Scope of sellers: which groups or individual actors do governments, as the "buyers" of energy efficiency, target as potential sellers of energy efficiency?

— Properties of auctioned good: are multiple units auctioned at the same time or only one unit at a time? Is a uniform price paid for all multiple units or a discriminatory price, i.e. a different price for each unit? What are the criteria for the buyer of the savings accepting a bid?

— Price development: how is the bidding process organised? Is the seller entitled to offer one bid only (single shot), or can he change the offer in an auction round over time after feedback? Are the sellers' bids visible to other sellers or not (thus, "blind" or "sealed")?

— Setting a price range: does the buyer accept bids regardless of the costs ("no reserve auction") or does he impose a limit ("reserve auction")? Is there a "buyout option", that is, a minimal price at which the sellers always have their bid accepted?

— Winner selection: what are the criteria for the buyer accepting bids (e.g. up to the available funds)?

3. Results and Findings

Experiences from the different case studies will be further explored and presented at the conference. The main features of the tendering schemes are described, among others, in different papers and presentations for Germany[6], Portugal[7], Switzerland[8] and Taiwan[9] respectively.

4. Discussion and Conclusions

Energy-efficiency auctions in different countries are proved to deliver energy savings at low cost. The tendering scheme can be repeated over time and remains a competition-oriented approach. The tendering schemes in all four places are multi-unit, first-price, sealed-bid auctions. The seller receives the price he offered (discriminatory price). All cases use a reserve auction with a fixed and published maximum price. Selection of the winner is based on funds at disposal. Most places do not use a buyout option, but it is also notable that such a "walking pass" or "flat rate" is used in one of the subject countries, Taiwan. The auctioned good might consist of kWh electricity savings only (Switzerland) or in some instances a number of different criteria as well (Portugal, Taiwan). The energy savings are mostly calculated (Switzerland), obtained by a mixture of measurements and calculations (Germany, Portugal), or are explicitly designed to be measured by energy-management systems (Taiwan).

Among the end-users that participate in competitive tenders, large enterprises are over-represented. In one case, the auction is explicitely designed to cover the large-scale measures of companies only (Germany). SMEs are to some degree better covered if project bundles (Switzerland) or soft measures like information and education (Portugal) are included. In order to promote measures in households, a separate tender with an inferior level of cost-effectiveness was realized (Switzerland). It is also possible to focus on specific groups like energy service companies (ESCOs), as in Taiwan. Overall, tendering offers a lot of scope for incentivising energy-efficiency measures. However, it is necessary to take specific precautionary measures if competitive tenders are not to be aimed primarily at efficiency measures in larger enterprises.

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10.5 An Agent-based Model of Retrofit Diffusion

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1. Background

In 2017, building stock was responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the European Union (Commission, 2010), which spurred the EU to increase its energy-efficiency target to 32.5% in 2030 (EU, 2018, 2013). In particular, the residential sector is the sector with the highest available energy-saving potential, as it accounts for the greatest share (i.e. 27%) of energy consumption (Commission, 2017). To this purpose, the European Commission has launched a new strategy to double the annual energy renovation rate by paying major attention to retrofitting the existing building stock (Commission, 2020). However, the related policy measures have proved somewhat unsatisfactory. The latest assessment on the progress made by member states towards the energy-efficiency targets shows that the EU 2020 target is unlikely to be met, a trend that makes the EU 2030 target even more difficult to achieve (Commission, 2019). In the face of this evidence, a better understanding of the factors that shape households' decisions to invest in energy-efficient technologies seems central to providing a solid foundation for policy-makers and, consequently, to achieve the EU's energy-efficiency target (Mundaca et al., 2010).

The literature on this topic is varied. In addition to the issue of the financial constraints versus savings (Michelsen and Madlener, 2013), recent studies have highlighted the role of behavioral attitudes (Frederiks et al., 2015; Wilson et al., 2015; Friege and Chappin, 2014) and inter-personal influence (Rogers, 2010; Valente, 1996; Young, 2009) on adoption decisions. In particular, households' level of environmental concern have been proved to influence the adoption of energy-efficient technologies

(Kahn, 2007; Prete et al., 2017; Abu-Elsamen et al., 2019; Bashiri and Alizadeh, 2018; Bergek and Mignon, 2017). This is defined in the behavioral literature (i.e.(Whitmarsh and O'Neill, 2010)) as the way individuals internalize the benefits to the environment associated to their adoption decisions (Achtnicht, 2011).

2. Aims

While building renovation covers a variety technologies, such as insulation, heating and cooling systems, and lighting, in what follows we focus on thermal re-insulation as a proxy for retrofitting. In the present study, we develop an agent-based model simulating the decision-making process behind retrofit adoption by a heterogeneous population of agents interacting in a network-based structure. The ability to represent network structures that affect the time path of the diffusion rate (Rogers, 2010; Valente, 1996) and the capacity to represent micro-level behavior as prescribed by behavioral theory (Rai and Henry, 2016) are the main strengths of this methodology, enabling us to simulate the process behind the take-up of energy retrofits.

3. Method

In our model, the decision-making process replicates the B′enabou and Tirole (2011) structure, where the adoption process is influenced by economic, non-economic and social factors. This agent-based structure is similar to the model of Chersoni et al. (2020), which we use to simulate retrofit adoption at the household level so we can study the joint and separate effects of the three factors on the choice to re-insulate. We calibrate the model with cross-sectional data on 29,119 European households drawn from the Second Electricity Market Study (DG Consumer and Transport, 2015), which investigated the functioning of the electricity market for EU consumers.

First, we collect information on household financial situations, a categorical variable divided into four categories that is also a proxy for income used to account for the up-front costs that negatively affect the likelihood to invest (Schleich et al., 2016), especially for low-income households (Mani et al., 2013; DellaValle, 2019). Second, we gather data on households' environmental concerns using a Likert-scale variable ranging from 0 (strongly disagree) to 1 (strongly agree) to model the less material interests that drive retrofit adoption, in particular the importance that each householdgives to energy savings for environmental reasons. Finally, we impose different inter-personal networks in order to simulate the process of mouth-to-mouth transmission of information about re-insulation and the drive to imitate.

4. Preliminary results

We first conduct a robustness check. Our model reproduces the expected patterns: the typical S-shaped curve is obtained when the adoption is driven only by social influence (Rogers, 2010). The distribution of the net perceived intrinsic benefit of acquiring the innovation (i.e. trade-offs between the economic and non-economic drivers) confirms that the model correctly reproduces the decision rule adopted.

Second, starting from the observed retrofit adoption rate of 34%, we conduct a validation exercise to find the parameter values that maximize the fit between simulation and the observed data.1 The results show that in small-world networks with high-clustering coefficients, the marginal position of the first adopter and the absolute difference between diffusion-level observation and model results are minimized.

Finally, in order to draw some policy conclusions, we aim to simulate different types of policies to assess their effect on the adoption rate in order to meet the EU 2030 energy-efficiency target. In par ticular, two types of policy based on 'awareness raising' (i.e. increasing the level of environmental concern) will be simulated.

5. Conclusions

Energy-efficiency investments should in principle result in long-term cost savings, but there are still untapped opportunities to reduce energy costs through increased energy efficiency (e.g. the energy efficiency gap (Jaffe and Stavins, 1994)). While remaining unsolved in neoclassical economics (Pollitt and Shaorshadze, 2013), households' under-investment in energy-efficiency measures has been extensively tackled within the field of behavioral economics. In this regard, the energy-efficiency gap can be explained by looking at individuals' differences in the degree of their investment inefficiencies.

Even if the model is capable of reproducing the pattern observed, it does not explain the mechanism behind it. there might be other mechanisms that lead to the same outcome (Vu et al., 2020) and their internalization of externalities (Allcott and Greenstone, 2012; Schleich et al., 2016; Fischbacher et al., 2015). Furthermore, it is widely acknowledged that social influence reinforces the adoption of technology and that potential adopters in sparse clusters or located in marginal areas of their social networks might not be affected by peer pressure (Valente, 1996). From a policy perspective, a review of policy efforts (see (Mundaca et al., 2019)) to address the low take-up of low-carbon energy technologies shows a clear orientation towards technology market development (mostly subsidies) and market failures (particularly, information asymmetries), while efforts to address behavioural anomalies are the exception. In this study we introduced an agent-based model of innovation-diffusion grounded in a behavioural economic theory that enables us to simulate how innovation diffuses and collective behaviour emerges. In particular, by accounting for the economic, behavioural and social factors, it is possible to derive interesting findings to establish under which scenarios policy interventions might effectively shape agents' decisions to retrofit in order to achieve the EU 2030 energy efficiency target.

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10.8 The Effect of Information Nudges on Energy Savings: Observation from a Randomized Filed Experiment in Finland

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1. Introduction

Electricity remains a relatively poorly understood area of spending by households[1], which are likely to miss out on potential energy savings as a result. This is where information-related behavioural interventions can have a meaningful role. Successful trials[2,3,4] have shown the potential of behavioural interventions to induce electricity savings.

Finland is different from most previously studied areas due to its northern location and its status as part of the Nordic energy market, with 100% smart meter deployment. This study evaluates the effectiveness of information nudges on residential electricity consumption among Finnish households. We conducted a randomized field experiment to study whether i) emailed energy-saving letters, ii) an online energy service platform and iii) a provision constantly updating comparative information on electricity consumption (i.e. social norms) influence households' electricity consumption.

The impacts of information treatments have been studied extensively, with estimated effect sizes varying from 2% to over 7%, and more robust results showing savings of 2-4%[5,6]. The effects are context-specific[7], and the interventions vary in their scalability. This study contributes to existing research using an experimental setting that allows the treatment effects between users and non-users of an online energy service platform to be analysed. No randomized field experiments on information nudges have yet been conducted in Finland, and generally we lack knowledge on the topic in the distinctive Nordic climate conditions, which cause high seasonal variations in energy consumption. The intervention employed emails and an online service as channels for the provision of information. These solutions are highly scalable and have not been studied as extensively[8].

2. Methodology

The experiment was conducted among customers of Porvoon Energia, a large electricity distributor in southern Finland. Participants were acquired through an online survey in which 671 households agreed to participate in the experiment through the opt-in question partly required by the GDPR. All experiment participants were given the option of signing up to access their electricity consumption data via an online energy service platform, but not everyone used this opportunity. For signed-up, i.e. registered users (R), we randomized the participant sample (N=393) into i) energy-saving tip treatment (Tip-R), ii) social norm plus reduced energy-saving tip treatment (Norm-R), and iii) control (Control-R). Those who had not registered (NR) (N=298) were randomized into i) energy-saving tip treatment (Tip-NR) and ii) control (Control-NR).

The experiment itself was conducted between November 2018 and December 2019. Information was distributed via monthly e-mail newsletters that included tailored energy-saving tips for Tip-R and Tip-NR, simplified energy-saving tips for Norm-R, reminders to check the electricity consumption from the online service platform for Tip-R and Norm-R, reminders to use the online peer comparison tool in the online service developed for Norm-R, and instructions on how to register for the online service for Tip-NR. The newsletters were sent every month except in July because of the summer holidays in Finland.

To estimate the effect of randomised nudges on household's daily electricity consumption, we use a difference-in-difference (DiD) model:

$$\ln{(kWh_{it})} = \alpha + \beta T_i P_t + \tau T_i + \gamma P_t + \mu \Omega + \varepsilon_{it}$$

where Ω refers to household characteristics such as income, household size and education, home characteristics such as floor area, house type and heating system, and weather factors like temperature and rainfall. We calculate an intent-to-treat effect since not all treatment (*Ti*) households necessarily engage with the newsletters and online peer comparison tool. The key DiD assumption of common pre-treatment trends between the treatment and control groups is valid.

3. Results and Findings

We find no statistically significant treatment effects on electricity consumption for the Tip-R, Norm-R and Tip-NR groups over the yearly treatment period. However, when the overall treatment period is divided into monthly periods capturing the seasonal changes in Finland, we observe impacts across the treated groups. The Tip-R group receiving detailed energy saving tips responded to the treatment by decreasing electricity consumption by approximately 10% in the beginning (between November 23rd and March 31st). However, in the following seven months, we observed the effect disappear. Later, in November, , the last month of the experiment, there was a statistically significant reduction of 8,.%.

The Norm-R group receiving simplified energy-saving tips and access to the peer comparison tool does not show a statistically significant response to the treatment during the experiment. Only at the end of the experiment, in November, do we observe a significant fall in electricity consumption of 7.9%. These findings could be explained by the low usage of the comparison tool and partly by the changes we made to the content of the energy-saving tips towards the end of the experiment. The newsletter was made more detailed for the Norm-R group and was compared with the previous periods. The response in the last period could indicate the necessity also to provide the detailed energy-saving tips together with the peer comparison tool to achieve any decrease in consumption. In other words, the information provided by the peer comparison tool is not enough by itself to nudge households to consume less electricity.

The Tip-NR group receiving the detailed energy-saving tips, but those who had not registered for the online energy service platform did not show any significant changes in their electricity consumption. This finding demonstrates that it may be difficult to encourage energy conservation behaviour when the target group is less interested in information about their energy usage to start with.

4. Discussion and Conclusions

This paper examines how households living in Nordic climate conditions with a high seasonal variation in temperature and energy consumption respond to energy-saving tips and peer comparisons. The results show reductions in electricity usage during the winter months for the groups of already registered users of the energy company's online service. These are also the households that expressed an interest in receiving information related to their own electricity consumption even before the experiment. Conversely, the findings also suggest there are challenges in encouraging energy-saving behaviour within the non-registered group of households, for whom energy-related issues might be of less interest. More information is required to identify the key drivers that could help activate these households.

The energy-saving tips that were provided were extensive, but the effort required to extend the nudging of information to new households, even with some personalised content, was minimal, as the cost of sending emails is low. Well-planned informational content sent digitally could be a cost-effective way of encouraging energy saving among households.

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10.9 Learning from Failure as a Support for the Energy Transition

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KEYWORDS

failure, peer learning, societal learning, energy experiments, energy transition

1. Introduction

Learning from experiments has been seen as important in developing climate and energy solutions, but less attention has been paid to learning from the inevitable failures associated with experiments. Social learning from failures is nevertheless challenging because sharing such experiences is difficult. This study examines a novel kind of intervention developed to support learning from failures related to experiments in renewable energy. A series of After Work events for pioneers of such experiments was held in different locations in Finland during 2018-2019. A total of 139 experts interested in energy experiments took part in the events. The aim of the Energy Pioneers' After Work event series was to encourage energy experimenters and other actors to openly share their failures, thus promoting the adoption of an experimental culture and the local dissemination of experimental lessons. The article explores what the events revealed about the failures and what participants learned from the discussions at them. Based on the results, we examine how sharing experiences of failure could be promoted, how the intervention itself showed aspects of failure, and what was learned from organizing this series of events.

2. Background, History, Review of Literature and Methodology

Learning from experiments is important for sociotechnical transitions (Ansell ja Bartenberger 2016). Such learning occurs when new solutions meet the requirements of their context of use. This conjuncture is successful if the solution can be adapted to the context in terms of, for example, user capabilities and expectations or permitting processes (Raven ym. 2008). In this paper, we focus on learning by doing, where learning is based on experience and reflection on that experience (Neij et al. 2017), but also on how others can learn from the experiences of others (McFadgen and Huitema 2017). Several parties can learn vicariously from experimentation if the experiences are shared. However, there are several disincentives to sharing such lessons, which are equally valuable as the lessons of successes (Catalano 2018; Seyfang and Smith 2007; Dunkley and Franklin 2017).

In order to encourage experiences of failure and collective analysis of what can be learned from these experiences to be shared, we organized a series of After Work events for pioneers engaging in energy experiments in different locations in Finland during 2018-2019. A total of 139 experts interested in energy experiments took part in the events, which were planned in such a way as to create a safe space for sharing failures, including, for example, developing a relaxing atmosphere, using humour and discussions in small groups. The results of small-group discussions were written up by a project team member, and reports of the events were shared with participants. The series of events were evaluated by collecting feedback from participants and interviewing a number of them after the event.

3. Results and Findings

The experiment contributed towards experimental, peer and social learning among participants (Edmondson 2019). The events highlighted very concrete lessons from failures, such as the need to improve flows of information, pay attention to the quality of systems' technical installations and support the fitting of new technology to the operating environment. Discussing failures also highlighted the influence of the context of the experiments (e.g. Raven et al. 2008) and the competence of the actors involved (Heiskanen et al. 2017; Seyfang and Smith 2007). The underdevelopment of the market and problems of co-development were identified as further challenges in promoting the energy transition. Vendors' promises and customer expectations may not meet, and there have been problems in communication and interaction.

4. Discussion and Conclusions

Identifying the causes of failure is key to developing new workable solutions and supporting broader learning. The experiment disproved the suspicion that people would perceive the theme of failure as negative and discouraging. On the contrary, sharing information on failures can even be empowering (cf. Edmondson 2019) if one succeeds in creating a psychologically safe state in which sharing failures is valued rather than criticized, and peer learning is multifaceted. In our experience, this new series of events makes it possible to contribute to accelerating the adaptation of new energy solutions to their operating environment, and thus to promoting energy transitions.

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10.10 Analysis of Energy Savings and Behavioral Trends from the Application of the Mandatory Energy Audit Mechanism in Italy: Focus on Energy Managements in Four Different Economic Sectors

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energy audits (eas), corporate behaviour, energy management systems

1. Introduction

The European Union Energy Efficiency Directive (EED) 2012/27 (amended by D.2018/2002) requires member states to promote the availability of high-quality energy audits to all final customers. EED also establishes that each member state ensures that non-SMEs are obliged to carry out an energy audit at least every four years unless the enterprise implements a qualified energy management system. The Italian government adopted the EED in 2014 (recently updated by D.Lgs. 73/2020), also extending the obligation to a specific group of energy-intensive enterprises (mostly SMEs), and assigning to the ENEA (Italian National Agency for New Technologies, Energy, and the Sustainable Economic Development) the management of the obligation enshrined in EED Article 8[1].

Energy audits are the first step in increasing a firm's energy efficiency. Energy-saving strategies cannot be implemented without having detailed and regular power consumption data for the facility. An energy-management system helps an enterprise devise a structured process for monitoring its energy consumption and improving its internal efficiency by means of energy performance improvement actions (EPIAs). The adoption of an energy-management system can lead to reductions in energy consumption, gains in industrial productivity and improvements in the global enterprise's performance, in addition to several other co-benefits positively affecting the company's overall competitiveness[2]. At present, empirical evidence on the effectiveness of energy audit programmes is lacking and mixed. Many studies, as analysed by Hirst and Goeltz[3], refer to the residential sector, and only few refer to enterprises. A recent study carried out by the EIB remarks that, for SMEs, the odds of investing in energy-efficiency measures are 1.5 times greater for enterprises with an energy audit than for those without one[4]. This gap appears to be even more relevant when it comes to assessing the benefits of energy-management systems in conjunction with energy audit campaigns.

The purpose of this research analysis is to collect energy audits for different economic sectors and to improve understanding of the possible links between energy-management systems and energy audits under EED Article 8. The focus is on their implementation in four different sectors in Italy and to evaluate the impact of an energy-monitoring system and an energy-management system on a company's likelihood of planning and/or implementing energy-efficiency measures.

The sectors of analysis we have identified here are two industries and two branches in the tertiary sector, in order to provide us with insights from two different perspectives.

2. Methodology

ENEA manages the energy audit programme, including the data-gathering and subsequent sectorial analysis. From the preliminary analysis of EED Article 8's implementation second obligation period (which ended in December 2019), it appears that the overall number of ISO 50001 sites amounted to 9% (about 1,050 sites) of the total number of sites implemented with an Article 8 obligation, while the overall number of sites with an installed energy-monitoring system was 70%. The ISO 50001 companies that presented energy audits numbered 358, 27% of them SMEs.

In this work we analyse the energy-efficiency measures (number of measures implemented and planned) as indicators of corporate behaviour by ISO50001 companies. Specifically, the focus is on *General EPIAs*, including capacity-building in energy management, the implementation of energy-management systems, the monitoring of energy consumption, extension and improvement of current management and/or monitoring systems, and other actions not strictly related to process or technical EE measures. The impact of the presence of an energy-monitoring system on planned and/or implemented energy-efficiency measures and on the corresponding savings is analysed. We chose to concentrate on ISO 50001 certification and energy-monitoring systems since they could be considered proxies for corporate behaviour, showing greater awareness of the relevance of energy management and monitoring.

A descriptive statistical analysis has been developed, based on both qualitative information (number and type of EPIAs) and quantitative information (energy impact of the EPIAs). The analysis covers four sectors. On the one hand there are two manufacturing sectors dominated by SMEs: ceramics (C23.3 - manufacture of clay building materials and plastic industries) and downstream plastics (C22.2 - manufacture of plastics products). On the other hand, two of the most energy-consuming consumption tertiary sectors are dominated by large companies: retail stores (super- and hyper-markets) (G47.1 - retail sale in non-specialised stores) and banks (K64.1 - financial service activities, other monetary intermediation). The database for the analysis presented here consists of all the implemented and planned EPIAs reported in the energy audits carried out in these sectors and sent to ENEA in December 2019.

3. Results and Findings

The analysis makes it possible to define and evaluate the numerous indicators that characterize the actions undertaken by companies to achieve energy efficiency. It also allows comparison of the four selected sectors, assessing the impact in terms of both energy savings and the energy efficiency of energy-monitoring systems and/or energy-management systems on those actions.

The indicators that were analysed include the average number of energy-efficiency interventions implemented and planned per production site, the average energy savings per site, the percentage of general measures planned or implemented, distinguishing between ISO 50001 certified and non-certified sites, and the number of sites with or without an energy-monitoring system. Adopting the same distinctions, we also investigated how having an ISO 50001 certification or a monitoring system affects economic indicators such as the cost-effectiveness (the ratio between investments and savings) of both implemented and planned measures and the payback time for planned measures.

The analysis includes 157 energy audits from the ceramics sector (~11% under ISO 50001, ~55% SMEs), 593 from plastics (~4% ISO50001, 82% SMEs), 559 from retail stores (~12% ISO50001) and 243 from banks (~16% ISO 50001)[5]. A preliminary analysis suggests that ISO50001certified sites would promote the implementation of EE measures. Moreover, the *General EPIAs* are mainly implemented in the tertiary sector (at least the 30% of the total EPIAs), while in the manufacturing sector the figure is lower than the 20% of the implemented measures. In particular, the percentage of implemented *General EPIA*s is relatively greater in retail stores and banks than in the ceramics and plastics sectors, and the same trend is observed relative to proposed *General EPIA*s, as shown in the table.

	Ceramics	Plastics	Retail	Banks
Implemented EPIAs	233	832	208	51
Share of General EPIAs in total Implemented EPIAs	13,3%	13,6%	33,7%	41,2%
Planned EPIAs	577	3351	1752	660
Share of General EPIAs in total Planned EPIAs	12,7%	15,3%	14,1%	16,8%

4. Discussion and Conclusions

The analysis therefore analyses the possible links between the existence of an energy-management system and the aptitude to implement energy-efficiency interventions in four different economic sectors. The analysis attempts to demonstrate the importance of companies having a suitable monitoring system in order to achieve a higher level of energy efficiency than in companies that are not equipped with monitoring systems or energy-management systems. One positive influence confirmed by empirical data is that the adoption of ISO 50001 certification and energy-monitoring systems will appear to be even more profitable for firms, allowing them to identify energy-efficiency opportunities more readily and to enjoy the multiple benefits associated with them.

Future developments will also include extending this analysis to other economic sectors on the one hand, and focusing on individual energy carriers and technologies on the other.

The adopted methodology could indeed be exploited to analyse the trend in the savings that can be achieved downstream of energy audits, both in sites equipped with an energy-management system and in sites without one. This could also be extended to other EU member states, based on the energy audits that have been conducted to comply with the EED Article 8 obligation.

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10.11 Energy Policy Mixes with Behavioural Insights into Informal Markets

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Energy transitions require policy mixes of different instruments that complement each other. The literature on sustainability transitions has argued that the consistency, coherence and comprehensiveness of instruments is key (Rogge and Reichardt 2016). Furthermore, recent advances place more emphasis on political economy questions, including the policy process (Edmondson et al. 2019; Kern and Rogge 2018), actors and power constellations (Lindberg et al 2019; Avelino et al. 2016). In spite of this recent shift from a more technical approach, the vast majority of the policy mix debate on energy transitions still focuses on the policy implementation context in industrialized countries, where implementation is usually expected to happen rather smoothly compared to in developing countries. In the latter, markets and businesses are largely informal, electricity theft may be pervasive, and demand-side management needs to be balanced with paying consideration to energy access and energy poverty. As we have argued before, developing countries also have fewer resources (financial, institutional, skills) and less experience of state-driven technology transitions (Kemp and Never 2017). These various challenges may coincide with 'the human factor in energy efficiency' (Pegels et al. 2015) in the policy process and also shape end-user behaviour and experiences, i.e. the 'actor journey' (Lambe et al. 2020).

In the past decade, behavioural insights and tools have been taken up by demand-side management and energy transitions more broadly. Several systematic reviews have made it clear that both the type of suitable intervention and their effect sizes vary according to local contexts (e.g. Buckley 2020; Andor and Fels 2018). The complexities of consumer motivations and behaviour (individual and corporate) call for policy experimentation with trials and the monitoring of different instruments across regions or states (Grubb et al. 2020). While it is still unclear how realistic such experimentation is in concrete political-economy settings that need to consider technology, end-users, policy instruments, broader developments and well-being goals (Creutzig et al. 2018), the acceptance of measures of voluntary behavioural change may be higher than strict regulations. In informal markets, where regulations are very difficult to enforce, behavioural insight programmes have the potential to be a useful complement. However, they may also fail if the specific conditions of informal markets are not taken into account by using blueprints from industrialized country programmes.

This paper critically discusses what policy mixes that include behavioural insights can look like, and what they are likely and unlikely to achieve in informal markets in developing countries. It connects the debates in the literature of sustainability transitions on policy mixes and policy experimentation with approaches to behavioural insight and demand-side management. First, the paper takes a birds' eye view of the contextual conditions of informal markets and discusses what these imply for 'real-world policy packages' (IEA 2017) and the potential of behavioural insights to achieve energy efficiency. These contextual conditions include differences in pricing and subsidies, metering and payment systems, technical and non-technical losses, the availability and reuse of technologies, and institutional and financial resources (e.g. debts, corruption, political capture). The analysis will draw on the literature and a range of own projects, mainly in Sub-Saharan Africa.

Second, the paper discusses the concrete empirical example of the Philippines' energy policy mix, particularly regarding energy efficiency and the second-hand market in appliances. It includes a discussion of creative circumventions of regulations and policy instruments by retailers and end-user behaviour in these markets. The analysis draws on semi-structured interviews conducted in December 2017 and February-/March 2020, as well as on available policy documents, to assess the present instrument mix. The consistency, coherence and comprehensiveness in planning and official implementation of policies will be compared and contrasted with de-facto implementation up to now. Current efforts and the potential of this concrete case-study to produce behavioural insights will be critically reviewed. Finally, implications will be drawn for energy programme design, including behavioural insights in informal markets.

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10.12 The Influence of Energy Policy Instruments upon the Promotion of Solar Thermal Technology in Greece

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energy policy in Greece, solar thermal technology, energy efficiency

1. Introduction

Renewable Energy Directive (EU) 2018/2001 on the 'Promotion of the use of energy from Renewable Sources' establishes a binding EU target for the share of energy from Renewables Energy Sources (RES) in the Union's gross final energy consumption for 2030 of at least 32%. In this Directive, member states are expected to develop proper support mechanisms to promote the use of solar thermal (ST) energy to achieve this target.

In Greece, ST technology is a renewable source with high potential in terms of energy savings and cost effectiveness. The total ST installed capacity in operation in 2017, for low and medium temperature applications, was 3.2 GWth, corresponding to 4,618,000 m^2 of the country's solar collective area[1]. As shown in Figure 1, Greece ranks third in the EU27 in both –respects: total ST capacity in operation in 2017 and total capacity per capita – revealing its well-established ST market. The data for the year 2017 are elaborated according to the methodology as presented by Oikonomou Th.[2]. However, the vast majority of installed systems in Greece are the simplest, yet very efficient type of technology, namely the thermosiphon system for producing domestic hot water. The effective expansion of ST technology use in more complex systems for heating and cooling, as well as for other applications such as solar heat industrial processes (SHIP) and electricity production, requires the effective implementation of proper national policy instruments.

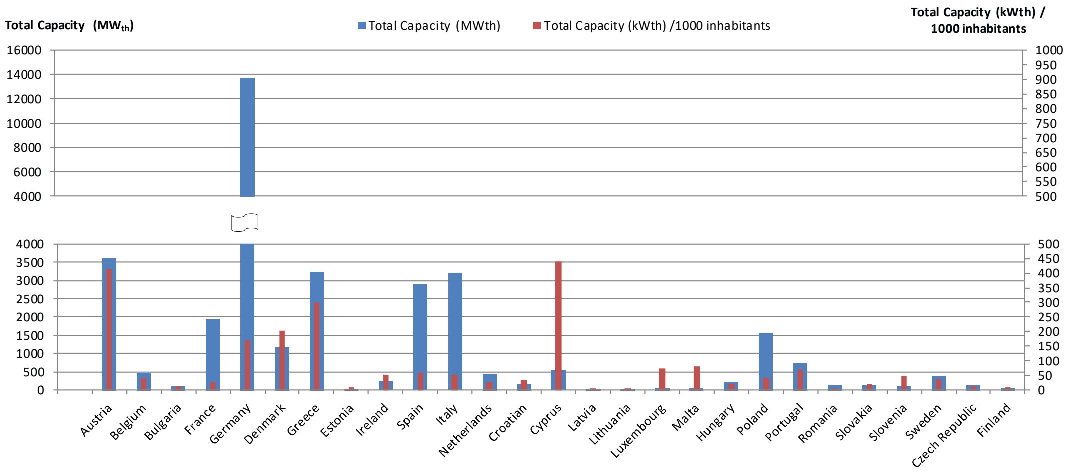

Figure 1.

Total ST capacity in operation in 2017 and total capacity per capita in EU27

2. Background

Greece's policy instruments for ST market deployment are limited and mostly addressed to RES technologies and not directly to ST systems. They include a proper regulatory framework, and incentives and funding opportunities aimed at improving energy efficiency to meet the targets set by the EU, thus promoting sustainable energy behaviour.

The regulatory framework includes measures for the mandatory installation of ST systems in new residential buildings [Law 3851/2010, Article 10] and tertiary-sector buildings [M.D. D6/B/oik.5825/09.04.2010, Article 8]. The minimum percentage of solar share on a yearly basis is set at 60%. Law 4342/2015 mandates examining the energy efficiency of buildings and includes articles providing incentives for installing ST systems. In Article 6, ST technology is included in the technologies for improving energy efficiency. Article 7 states that the 'Heads of Regions and Mayors' must introduce energy-efficiency plans for public buildings, including installation of an ST system. Article 9 establishes 'Energy Efficiency Obligation Schemes', where the required energy saving targets may be achieved by ST installations. Article 10 imposes on large enterprises the duty of performing energy audits and implementing interventions, including ST installations. Law 3855/2010 mandates the gradual installation of central ST systems or other RES technologies in existing and new central and general government buildings [Article 8]. Regarding electricity production by RES, Laws 3468/2006 and 3851/2010 lay down the necessary procedures for installing concentrating ST plants in Greece.

The Greek government also supports a more market-oriented financial support scheme, for which it has established an 'Infrastructure Fund' aimed at maximizing the use of financial instruments in the field of energy savings and promoting RES. Another indirect funding mechanism is 'Greek Development Law 4399/2016', which aims at encouraging investments, mainly in the field of manufacturing and energy, covering up to 55% of eligible costs. There are also direct funding programmes in which ST systems are applicable, such as the 'Saving – Autonomy', 'Improving the Energy Efficiency of SMS Enterprises' and 'Modern Processing' programmes.

3. Methodology

The aim of this study is to provide specific policy recommendations for how to promote ST energy in Greece. In order to achieve this objective, past and ongoing policy strategies were identified and their degree of success assessed. Moreover, this study also examined the barriers that prevent the dissemination of ST systems and provides recommendations for overcoming them.

Furthermore, best practices currently applied in other EU countries were studied, those that are most suitable for Greece being selected. The behavioural, policy and other interventions to promote ST systems in other EU countries with high levels of ST penetration, which ranked high in Figure 1, such as Germany, Austria and Cyprus, were examined for their usefulness to the needs of this study[3,4,5,6].

This work has resulted in a number of suggestions for interventions suitable for Greece, as described in the discussion section.

4. Results and Discussion

This study presents the energy policy instruments used in exploiting ST technology in Greece, with the aim of promoting sustainable energy behaviour and achieving energy efficiency. It also focuses on tracking down and collecting together the existing Greek policy instruments in the energy sector that are specifically applicable to ST technology.

In Greece, as we have seen, there are already certain policy instruments related to ST technology that are expected to contribute to the promotion of sustainable energy behaviour. However, further actions should be taken to exploit the potential of the ST sector.

The Greek ST market for low and medium temperature applications is well-established across the EU 27. This is the result of policy instruments for the development of the national ST market, established in the early 1980s, including successful marketing campaigns and fiscal incentives, such as low-interest loans and tax credits (VAT exemptions).

The Greek banking sector is cautious when it comes to approving private funding for complex ST systems such as SHIP and other energy-efficiency investments. The main reason for the is the lack of personal knowledge, resulting in considering such systems risky investments. This leads to high interest rates for business loans. To overcome this, personal knowledge should be enhanced, and interest rates could be subsidised.

In promoting ST systems in Greece, the following guidelines are suggested:

- The national energy targets, provided for in the Greek National Energy and Climate Plans, should be realized by means of specific policy measures, including ST systems. This should include implementation of competitive tendering programs, with the aim of facilitating the take-up of energy-efficient technologies, such as ST systems.
- Best ST practices in other countries should be studied and adopted in Greece. The effectiveness of ST applications should be disseminated using the appropriate tools, such as leaflets, workshops and seminars.
- More financial support programs, addressed directly to ST systems for heating and cooling, SHIP and ST electricity production, should be introduced.
- Market-oriented financial support schemes should be implemented, including subsidy measures (tax credits and exemptions, preferential interest rates, etc.) to prospective investors proving their energy-saving potential, achieved by ST installations.

- The Greek legislative framework concerning the carrying out of energy audits and mandatory energy-efficiency interventions, including ST systems, should be deployed not only to large-scale enterprises but those of all sizes.
- Policy instruments tackling energy poverty in Greece should be investigated and set up in order to achieve economic and social cohesion. The policy instruments should include measures for the deployment of the ST sector.
- Support should be given to pilot actions under a specific market strategy that would foresee and anticipate the replication of ST interventions.

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10.13 Cognition, Energy Literacy and the Class Valuation Effect for Energy Labels

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KEYWORDS

energy efficiency, energy label, household decision-making, information processing, heuristics, cognitive style, energy literacy

1. Introduction

Categorical energy labels with grade-like efficiency ratings are widely used. However, representing information on energy efficiency with limited categories has been found to induce heuristic decision-making: that is, consumers value the efficiency class *per se* while ignoring the more precise difference in energy use, which is also known as the 'class valuation effect'[1,3]. This effect has been found to be especially pronounced among those with a low level of cognitive reflection[3]. Alternatively, energy labels with continuous rating scales provide more detailed information and are more suggestive for purposes of comparison, and thus could stimulate more conscious and rational energy-related decisions[1,4]. However, the effectiveness of the continuous scale label has not yet been formally examined.

For an energy label to be effective, it is essential that consumers understand and process the information well. The continuous and categorical visualisation of the energy-efficiency rating on energy labels is intrinsically related to the concepts of holistic versus analytic cognitive style. This study therefore accounts for interpersonal and cross-country differences in holistic cognitive tendencies[5,9] when studying the processing of information on energy labels, thus adding to the understanding of the role of cognition in energy-related choices[3,10]. In addition, the effectiveness of an energy label also depends on whether individuals have the knowledge to understand

and utilise the information and whether they have values and norms in favour of saving energy[11]. Therefore, this study systematically measures and examines the influence of energy literacy on decision-making by following the concept of multifaceted energy literacy[12,13].

Overall, this study addresses the following issues: (1) whether the continuous-scale label, as opposed to the categorical label, can support rational decision-making and reduce the use of heuristics; (2) the role of cognitive styles and energy literacy in processing information on energy labels; (3) differences in the effectiveness of the labels across countries.

2. Methodology

Our analysis is based on a household survey that include a decision task with randomized information treatments (between subjects-design). In the decision task, participants were randomly assigned to either a categorical label treatment or a continuous-scale label treatment (Figure 1). Respondents were asked to identify the refrigerator that minimises lifetime costs from two otherwise identical models, based on the energy-related information communicated on the energy label and the cost information. Each participant was asked to make decisions in three different situations (Table 1). In situation B, where the energy efficiency levels of the two models were close but belonged into different classes, we expected the categorical label to trigger decision-making heuristics, whereas the continuous-scale label could support a more rational decision. The decision task was embedded in a survey questionnaire eliciting individual-level characteristics such as socio-demographic information, energy literacy (including knowledge, attitude and behaviour), holistic cognitive tendency and reasons for making the decision.

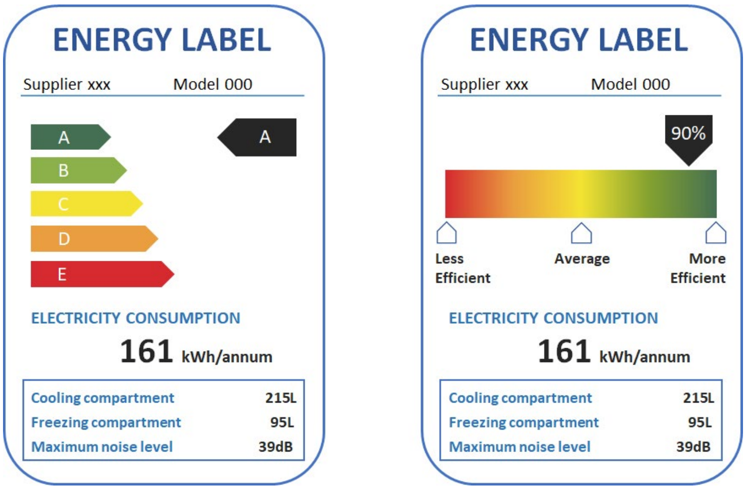


Figure 1.

Examples of categorical and continuous-scale labels

		SITUATION A		SITUATION B		SITUATION C	
	Unit	A1	A2	B1	B2	C1	C2
Annual energy consumption	kWh	160	220	205	215	155	210
Energy efficiency class (categorical label)	/	A	B	A	B	A	A
Energy efficiency level (continuous-scale label)	/	90%	79%	80%	79%	90%	80%
Purchase cost	Euro	550	400	500	400	600	500
	RMB	2,475	1,800	2,250	1,800	2,700	2,250

Table 1.

Specification of the three decision situations

Data are collected in the Netherlands and China, two countries representing respectively the analytical-focal Western and the holistic-contextual Asian cognitive styles. The survey questionnaires were administered via Qualtrics, with the sampling being done by two professional survey companies. 994 and 1041 valid questionnaires were collected from the Dutch and Chinese respondents respectively. Both samples are representative of the general urban population in terms of gender and age, but less representative with respect to education and income, where we observe a slight tendency towards higher education and higher income groups.

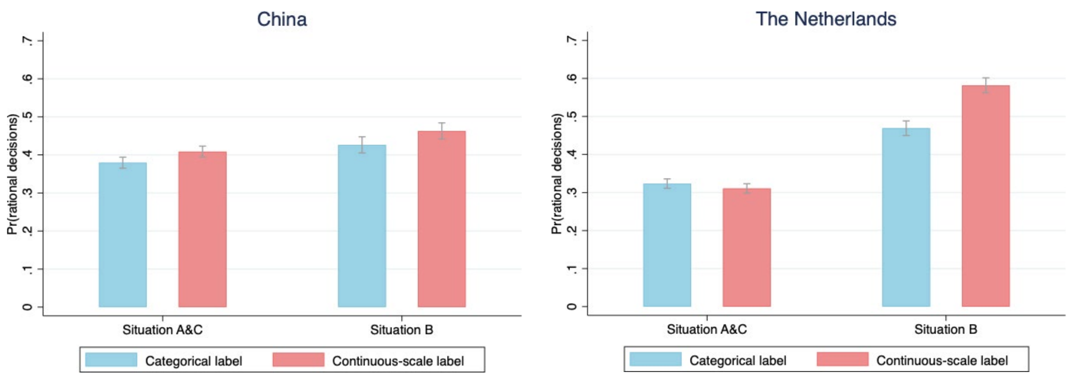
3. Results

Probit models are used to analyse the data. Below we present the average partial effects of the independent variables separately for the Chinese and Dutch samples. Overall, indicating energy efficiency with a continuous scale increases the likelihood of correct identification by 3 and 2.4 percentage points among the Chinese and the Dutch samples respectively, both significant at the 10% level. We include an interaction between continuous-scale label treatment and situation B to test whether the effectiveness of the continuous scale is dependent on the type of decision situation (Figure 2). We do not observe a significant interaction effect in the Chinese sample. However, in the Dutch sample, a continuous-scale label significantly increases the probability that the cost-minimising refrigerator will be identified by 11.3 percentage points in situation B, while not showing a significant impact in situations A and C.

Based on the theoretical distinction between the analytic and holistic cognitive styles[5,9], we expected individuals with a holistic rather than analytical cognitive style to process the information provided on a continuous-scale label more effectively. The results from the Dutch sample suggest that, as an individual's holistic cognitive tendency increases from 0.65 to 1, the continuous-scale label increases the probability of correct identification by 3.1 to 9.4 percentage points. However, in the Chinese sample, this interaction effect is only significant at the 10% level when the holistic cognitive tendency is around 0.7 (Figure 3). Moreover, possessing energy-related knowledge related to daily life increases the probability of rational decisions in both countries. However, in the Chinese sample especially, having a positive attitude to saving energy and having energy-saving devices installed at home reduces the incidence of the correct identification.

Figure 2.

Interaction effect between label treatment and situations



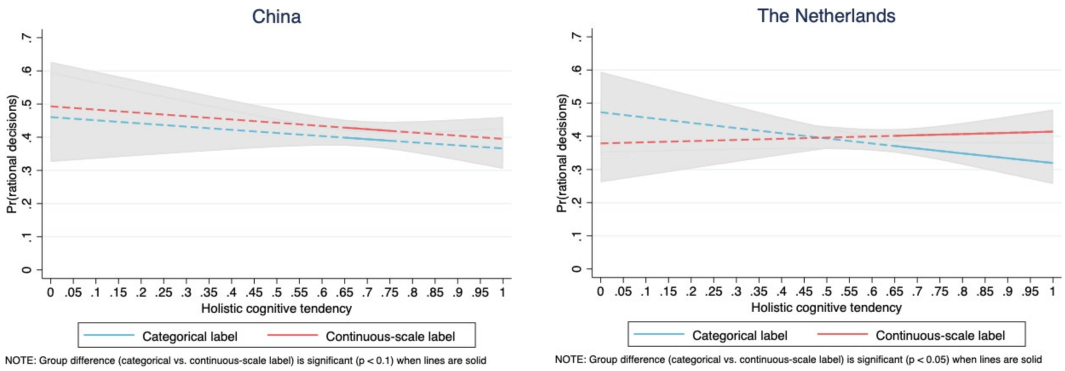


Figure 3.

Interaction effect between label treatment and holistic cognitive tendency

4. Conclusions

This study critically evaluates the use of categorical rating scales on energy labels in the Netherlands and China. Our findings suggest that energy labels placing the efficiency level of an appliance in efficiency categories tend on average to undermine rational decision-making by consumers. In certain situations, a continuous-scale label can correct for the ''class valuation effect'[2,3]. Further, our study demonstrates that a holistic cognitive style can influence the effectiveness of visual information. Thus is a valuable insight to consider in designing energy labels for countries dominated by different cognitive styles.

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SECTION 11

TRANSPORT

11.1 Sharing vehicles or sharing rides - What influences the acceptance of shared mobility services in Germany?

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KEYWORDS

Shared mobility, adoption, social acceptance, diffusion of innovation

1. Introduction

In the light of climate change and declining fossil resources, increasing energy efficiency in the transport sector is in the focus of many governments. Today, individual transport is dominated by cars - specifically the usage of private vehicles with combustion engines. Shared mobility presents one solution to break this dominating paradigm and to make transport more efficient and sustainable. Since wide adoption is crucial for shared mobility to play out its advantages, this paper focuses on psychological factors influencing its acceptance based on a survey study from Germany.

2. Background, theory and methodology

Shared mobility refers to transportation modes shared on an as-needed basis[1], e.g. carsharing, ridesharing or e-kickscootersharing. In this study, we focus on the two services of carsharing and ridesharing in order to analyse and compare psychological factors influencing the acceptance of a more established and a recently introduced sharing system. In Germany, carsharing is available in 79 out of the 80 major cities and 2.29 million individuals were members of 181 carsharing organisations[2]. The newer service, ridesharing, is provided by eight organisations in 14 major cities[3]. To compare these services, the paper is guided by the following research question: What influences the acceptance of shared mobility services and to what extent does the acceptance of the two mobility services differ?

Rogers' model on the Diffusion of Innovations (DoI)[4] outlines individual adoption decisions as influenced by the perceived attributes of the innovation (see below). The conceptual model of this study reflects the sequential relationships between the more basic dispositions (environmental identity[5] and routine seeking[6]) and the individually perceived attributes in the DoI concept, as well as general attitude and acceptance of the innovation (Figure 1).

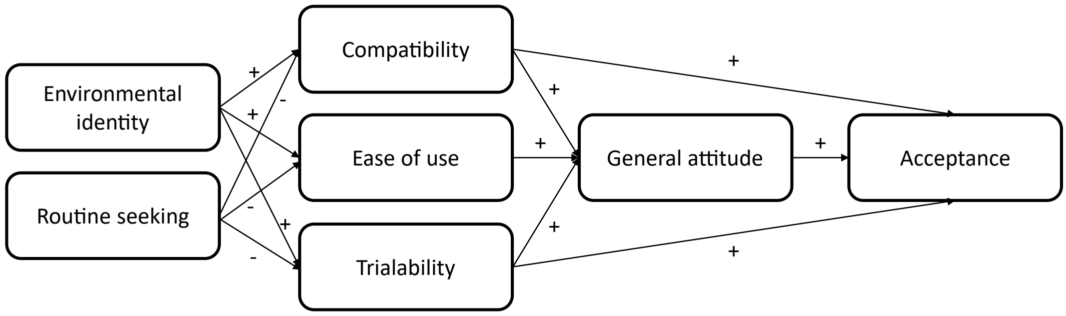

Figure 1
Conceptual model (initial model)

The data was collected in autumn 2019 via an online survey (N = 3,061) in German cities with more than 100,000 inhabitants. Participants were recruited from an online panel by a market research company and were randomly assigned to the sub-samples carsharing (CS) (n = 767), bikesharing (n = 764), e-kickscootersharing (n = 766) and ridesharing (RS) (n = 764), each receiving a different introductory paragraph. Sub-samples were quoted to be representative of the population in the selected city categories according to region, level of education and a gender-age category.

Measures for the statistical model include i) acceptance (actual and intended use of the services), ii) general attitude towards the services, iii) environmental identity, iv) routine seeking, and the DoI constructs of v) compatibility, vi) trialability, vii) complexity ("ease of use"), and viii) observability. Items on the relative advantages were not included in the questionnaire as they caused problems in an earlier study[7]. Environmental identity, routine seeking and the DoI constructs (except for trialability) were measured with items developed in studies by the authors' research team[8]. Item aggregation to scales was based on explorative factor analyses and estimations of Cronbach's α. This led to the expected one-factor solution for constructs iii-vii; two items were excluded from further analyses. As Cronbach's α was not sufficient for the scale on observability this factor was excluded.

A path analysis (PA) was used on the data with the model being identified properly and over-identified. Maximum Likelihood (ML) was selected with robust standard errors and a Satorra-Bentler scaled test statistic as the estimation method. The R package lavaan was used to test the model and to calculate the direct and indirect effects and the fit indices: Chi-Square (χ^2), Root-Mean-Square-Error of Approximation (RMSEA), Standardized Root-Mean-Residual (SRMR), Comparative Fit Index (CFI) and Tucker-Lewis-Index (TLI).

3. Results

For the variables in the path model, descriptive statistics were examined (Table 1).

Table 1.

Descriptive statistics for the PA model variables (N Carsharing=614, N Ridesharing=539)

Variables	Mean		SD		Min	Max
	CS	RS	CS	RS		
Acceptance	2.94	2.85	1.53	1.36	1	6
General attitude	4.08	3.97	1.72	1.62	1	7
Compatibility	2.67	2.64	1.55	1.50	1	6
Ease of use	4.48	4.42	1.35	1.36	1	6
Trialability	3.62	2.96	1.83	1.88	1	6
Routine Seeking	3.45	3.47	1.10	1.08	1	7
Environmental identity	5.46	5.48	1.41	1.45	1	7

The initial model was modified by removing insignificant paths and by adding regression paths as suggested by the modification indices. The final PA models for carsharing and ridesharing demonstrated a good fit and no difference between the observed and expected matrices (χ^2=7.79 resp. 1.95, p=.17 resp. p=.75). RMSEA and SRMR are less than .05 and CFI and TLI range from 0.99 to 1.01. That is, all indices show good model fit.

Table 2.

Fit indices of the carsharing and ridesharing model

Selected Fit Indices	CS	RS
χ^2	7.79	1.95
RMSEA	0.03	0.00
SRMR	0.02	0.01
CFI	0.99	1.00
TLI	0.99	1.01

The paths are significant (p<.05) and in the expected directions. In both models, the path between compatibility and the general attitude shows the largest positive standardized path coefficient (ß=.63 resp. .65), followed by the path between compatibility and acceptance (ß=.47 resp. .39). As expected, the general attitude has a positive effect on acceptance in both models. The remaining DoI variables trialability and ease of use have a positive impact on the general attitude in both models. Environmental identity has positive effects on compatibility and ease of use in the carsharing model, however, a negative impact on acceptance. In the ridesharing model environmental identitiy positively influences all DoI variables and the general attitude but not acceptance. Routine seeking negatively influences ease of use and acceptance in both models; in the ridesharing model there is also a negative influence on the general attitude. In the carsharing model, however, there is also a positive effect on compatibility (Figure 2, Figure 3).

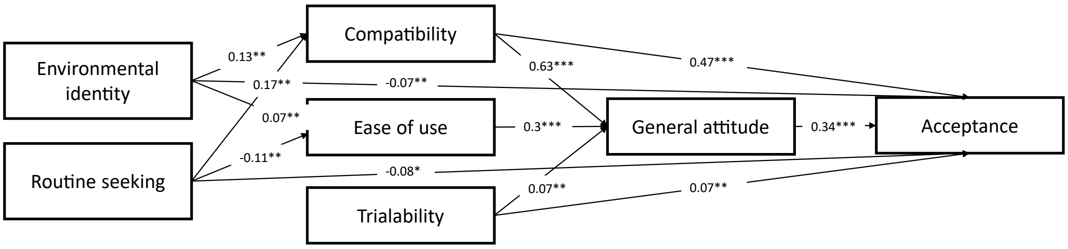

Figure 2.

Final model for carsharing with standardized path coefficients

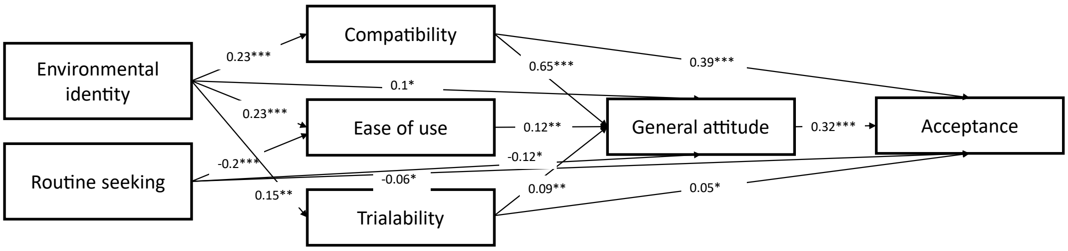

Figure 3.

Final model for ridesharing with standardized path coefficients

4. Discussions and Conclusions

The PA revealed many significant correlations in the predicted directions, thus, the psychological variables in the model can predict whether or not individuals use and intend to use carsharing or ridesharing. For practitioners and policymakers this presents an interesting finding as it provides hints towards aspects that can be influenced to change the attitudes towards the sharing services and consequently their usage. Trialability can, for example, be influenced based on the availability of the services.

The relevance of environmental identity on the acceptance is mixed: Whereas the effects in the ridesharing model are clear - higher importance of environmental issues is associated with a more positive attitude - the effects for carsharing are more complex. One possible reason could be the preference for non-motorized means of transport of respondents with higher environmental protection attitudes. Routine seeking negatively influences some DoI constructs and the attitude and acceptance in both models. For carsharing, however, routine seeking shows a positive effect on compatibility. Routine behaviour might therefore not be detrimental for carsharing usage overall and these individuals could still be reached by such a service. In future studies, it would be interesting to differentiate here between station-based and free-floating systems.

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11.2 How Choice Architecture Design Affects Preference for EV Smart Charging

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KEYWORDS

EVs, smart charging; decision-making; choice architecture; behavioural insight strategies

1. Introduction

In our contribution, we aim to estimate empirically consumers' preferences and strategies for charging their electric vehicles (EVs). Most of the previous literature on EV charging has looked at charging preferences for long distances[1], stressing that anxiety over the range of EVs is a major barrier to their adoption, charging and use[2]. However, it has also been shown that EV users usually charge their vehicles even though they have sufficient range available for their next trip[3,4]. In most European countries, individuals ride, on average, 50 km on weekdays, less than 20 km of which is for personal reasons[5]. The literature on EV driving reports that the average state of charge (SOC) when initiating an EV charging process is between 40% and 60% (≈100km), indicating that drivers usually have much more energy available in their batteries than they need[6,7]. This finding also indicates that, for the majority of drivers in everyday life, there is no reason to prefer immediate charging over smart charging (in which the charging interval is extended or postponed based on optimal grid conditions)[8]. Previous research has also observed that uncontrolled EV charging during weekdays often occurs at times of existing demand peaks[9-10]. With the increasing diffusion of EVs, therefore, uncontrolled charging can severely challenge the hosting capacity of existing distribution grids. Smart charging, conversely, can be particularly relevant in securing grid stability

and/or the use of renewable energy. Therefore, understanding the decision-making behind daily charging choices has the potential to optimize the impact of EVs on the electric system and is very important for the energy transition[11,12].

In our study, we are also interested in investigating the role of choice architecture for decision-making by drivers in the context of smart charging. The literature has recently expressed an interest in observing how changing the way information is provided can help individuals manage it and optimize their decision-making processes[13,14]. Energy-related information can be framed in various ways, for example, the charging price can be delivered in kWh or km, each of which emphasises a different facet of information. Previous research suggests that 'using translated attributes appropriately can help align a person's choices with their personal objectives' (p.

2445)[15,16]. Therefore, we aim to modulate the charging choice architecture experimentally by translating the information provided to EV users into more comprehensible and goal-directed information at the point of the decision to charge the vehicle either in a conventional (i.e., immediate) or smart (i.e., cost/energy/grid optimized) way. Here we treat immediate charging as conventional, given that for the uncontrolled charging systems, which are the most common ones nowadays, the charging starts as soon as the car is plugged in. Our results will offer insights on the most effective way of presenting charging-related information, as well as promising insights in how to increase the use of smart charging systems in the future.

2. Methodology

We will conduct an online experimental study to investigate individuals' preferences for EV charging strategies. The survey will be accessible to a broad range of current car-drivers, as smart charging systems are in the early stage of adoption, and our aim is to depict the preferences for a broad spectrum of drivers. This will also provide initial insights into the overall preferences for smart charging in the population and thus to the potential of this technology to manage the additional power demand due to EV diffusion. In the initial survey section, participants will first be asked to answer various demographic and socio-demographic questions (e.g., on values and political ideology), as well as questions related to their driving habits. They will then be provided with information on the smart charging system and its functionalities, and respondents will express their general interest in having such system for their EV. Only individuals who are interested in smart charging systems will continue to the choice-based tasks and be randomly allocated to one of our experimental attribute translation conditions. Then, with a discrete choice experiment, we will examine the importance of the main factors involved in the charging process (for examples of attributes, see Table 1). We will also test the sensitivities to these factors depending on how the information is provided.

In all experimental conditions, respondents will have to choose between conventional (i.e., immediate) and smart charging (i.e., cost/energy/grid-optimized) under various situations. Each respondent will make around thirty choices. In the control condition, the information presented to participants will be similar to that on current charging technologies (i.e., range level in percentages, costs per kWh). In the attribute translation conditions, we will translate these attributes into more accessible information to the user, for example, by personalizing the charging costs on the individual work-home trip scale, or by framing this information on a yearly basis instead of by kWh.

ATTRIBUTES:	LEVELS
Time of the day:	7-10 h
	12-16 h
	17-21 h
	22-6 h
Target battery levels:	25%
	50%
	75%
Peak demand:	(-)
	Conventional (i.e., immediate) charging coincides with peak demand
Electricity-mix of smart charging:	Electricity available
	25% RE guarantee
	50% RE guarantee
	75% RE guarantee
Price saving by smart charging:	0 (Same as conventional charging)
	-1 cents/kWh
	-5 cents/kWh
	-10 cents/kWh

Table 1. *Examples of choice-based conjoint attributes specification.*

3. Results and Findings

The scheduled time for data collection coincided with the outbreak of the COVID-19 crisis. Current literature stresses that this pandemic may have significant effects on research[17], so we decided to postpone the collection of data to June, when the strong lockdowns and restrictions on, for instance, mobility, will have been abolished in most European countries.

Regarding our experimental design, we expect that attribute translations into more personalized information will become more salient and thus easier for individuals to integrate into their decision-making process. We also expect that framing the savings on a yearly base will make them more appealing[18]. In both cases, the translated attribute should increase in importance in the decision-making process compared to the control condition.

This paper contributes to the growing body of literature on a) EV diffusion, by offering psychological insights into adoption and use differences among consumers; and b) energy transition, in particular electricity infrastructure planning, by investigating the benefits of smart charging systems. Moreover, we aim to contribute to the environmental psychology field by highlighting how choice architecture can be used to facilitate individuals' preferences for smart charging. Finally, policy-makers, grid operators and car manufacturers that are aiming to increase smart- charging processes can benefit from our insights.

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11.3 Buying Green Cars? Determinants of Intentions to Purchase Energy-efficient Cars in Switzerland

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KEYWORDS

energy-efficient cars, energy efficiency, behaviour change, social norms

1. Introduction

The transport sector plays a significant role in climate change due to both carbon emissions[1] and air pollution. Energy-efficient cars are seen as effective innovations contributing to the mitigation of these environmental problems. However, despite the environmental and economic benefits and the rapidly increasing availability of energy-efficient cars, their market penetration remains below expectation and in many countries remains stagnant at a low level of 5% to 10%[2].

In order to increase consumers' adoption levels of energy-efficient cars, it is crucial to understand the possible drivers of the relevant intentions to purchase. Understanding the underlying determinants of consumers' purchasing intentions provides a basis for the design and development of evidence-based measures to promote energy-efficient cars. The aim of this paper is therefore to investigate which factors determine the intention to purchase energy-efficient cars. Based on a survey approach, we examined consumers' attitudes to energy-efficient cars, social norms and perceived behaviour control among Swiss residents. In line with the explanation of a government program, ENERGIESCHWEIZ, energy-efficient cars are defined as those that belong to energy-efficiency categories A or B according to the Swiss energy label[1] and that produce emissions of no more than 95 grams of CO_2 per kilometre.

1 *https://www.bfe.admin.ch/bfe/de/home/effizienz/mobilitaet/personenwagen.html*

2. Literature Review and Hypothesis

A growing body of literature is investigating drivers of purchasing intentions, mainly of electric cars. Previous research has found that the following factors influence the adoption of electric cars[3]: (1) attitudes, (2) emotions, (3) perceived behavioural control, (4) social influence, (5) symbolic value and (6) environmental concerns. In detail, first, a positive attitude towards electric cars has been shown to be one of the strongest predictors of purchasing intentions. Second, emotions can be studied separately from attitudes. In this sense, positive emotions have been found to increase purchasing intentions. Third, greater perceived behavioural control has been linked to higher purchasing intentions in previous research, although less than other factors, especially compared to attitudes and emotions. Fourth, social influence is also a strong predictor of purchasing intentions. Social influence includes peer pressure, social norms, neighbour effects, collective efficacy and social culture[3]. A meta-analysis[4] testing the effects of social influence on the adoption of energy-efficient cars finds small to moderate effects on purchasing intentions. Fifth, Li et al.[3] reviewed studies of symbolic value, which includes influence of car choice on self-identity and social status. Sixth, therefore, they found that this too can influence purchasing intentions. Lastly, the effect of environmental concerns on purchasing intentions is explained. Some studies show that environmental concerns predict purchasing intentions for electric cars[5]. Many of these studies base their assumptions on an extended version of the Theory of Planned Behaviour (TPB)[5], which postulates that attitude, subject norms and perceived behavioural control determine behavioural intentions and subsequently behaviour itself.

While this previous research has focused mainly on electric cars, we propose to extend its assumptions to purchasing intentions for energy-efficient cars. As in previous research, however, we base our assumptions on an extended version of the TPB. In line with this previous research, we propose the following hypotheses:

(H1) Attitudes have a positive effect on intentions to purchase energy-efficient cars.

(H2) Emotions have a positive effect on intentions to purchase energy-efficient cars.

(H3) Perceived behavioural control has a positive effect on intentions to purchase energy-efficient cars.

(H4) Social norms have a positive effect on intentions to purchase energy-efficient cars.

(H5) The perceived social status of owning an energy-efficient car has a positive effect on intentions to purchase energy-efficient cars.

(H6) Environmental concerns have a positive effect on intentions to purchase energy-efficient cars.

3. Empirical Study

To test these hypotheses, we conducted a survey study among Swiss residents (n = 1’296). Respondents were screened to identify recent or prospective car-buyers. The questionnaire measured attitudes towards energy-efficient cars (liking, innovation, safety), social norms and perceived behaviour control (availability, practicability, reliability, price) using several items. The intention to purchase an energy-efficient car was measured using one item. Furthermore, we asked whether energy-efficient cars are perceived to be fun to drive (emotion), are a status symbol, and are good for the environment (environmental concerns).

To examine our hypotheses, we calculated a multiple regression model predicting purchasing intentions. Confirming H1 and H4, we find a positive relationship linking attitudes and social norms to purchasing intentions. There is only a small effect of perceived behavioural control on purchasing intentions. A more detailed analysis reveals that only the perception that "energy-efficient cars are easy to use" significantly influences such intentions, providing only partial support for H3. Perceptions of price, as well as the ease of purchasing an energy-efficient car, do not influence the intention to purchase. In contrast to previous research on electric cars, purchasing intentions for energy-efficient cars are not determined by positive emotions, perceived social status or environmental concerns. Based on the evidence of the present study, therefore, we reject H2, H5 and H6.

4. Discussion and Conclusions

In sum, this study adds to existing research by highlighting the importance of attitudes and especially social norms for the intention to purchase an energy-efficient car. A further contribution is that in this context, contrary to expectations, neither arguments based on classical elements of perceived behavioural control (e.g. price or availability) nor status or positive emotions seem to determine purchasing intentions. Based on this evidence, practitioners are advised to develop persuasive campaigns designed to generate a positive attitude towards energy-efficient cars. However, given the pervasive gap between attitudes and behaviour, persuasion alone is not expected to be enough to promote energy-efficient cars[6]. Therefore, decision-makers are advised to resort of measures of social influence, such as collective actions, opinion formers and the power of influencers and reference groups to promote energy-efficient cars.

Our study has limitations that are similar to those of other research. In particular, survey research may only partially predict actual behaviour. Experimental studies determining the causal effects of appropriately designed campaigns and interventions are needed to provide a further empirical basis for the impact of attitudes and social norms on the intention to purchase an energy-efficient car. Also, this investigation did not distinguish between different types of energy-efficient car. Further research is needed to shed light on factors that determine consumers' intentions to purchase, for example, hybrid cars or hydrogen vehicles.

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11.4 Determinants of Self-efficacy of Car-sharing

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KEYWORDS

user behaviour, mobility service, car sharing, self-efficacy, social psychology (Track: Users' behaviour in transport and mobility)

1. Introduction

Car-sharing has been promoted as part of a sustainable and efficient transport system that could produce reductions in the number of vehicles and driving distances[1,2]. Car-sharing has existed in Europe since the late 1940s and has gained in interest and membership in recent years. Nonetheless it is only a small part of the general population that uses these services. It is thus worth improving understanding of how well these services meet their users' needs and how they are perceived even among non-users.

In this study, we focus on the self-efficacy of stationary car-sharing in Gothenburg, the second largest city in Sweden. Self-efficacy is defined as an individual's belief in his or her ability to control and manage a specific situation[3]. It depends on four factors: (1) experiences; (2) observation of others, especially those who are perceived as similar and important; (3) persuasion by others (i.e. social persuasion), especially by persons who are considered important; and (4) emotional arousal caused by the specific situation (e.g., stress or emotional stability)[3]. The aim of the present study is to explore whether the four factors can be used to explain car-sharing self-efficacy. We define car-sharing self-efficacy as the belief in one's ability to fulfil all needs of a car through car-sharing. From this, we formulate the following four hypotheses:

1. Experiences of car-sharing influence car-sharing self-efficacy.
2. Vicarious experiences (observations of others) influence car-sharing self-efficacy.
3. Social persuasions influence car-sharing self-efficacy.
4. Emotional arousal influences car-sharing self-efficacy.

2. Methodology

A survey measuring car-sharing self-efficacy, with indicators for the four determinants (i.e., past experiences, observation of others, persuasion from others, and emotional arousal), was distributed to a sample to 1078 citizens in the city of Gothenburg, Sweden. The sample was chosen based on residence in buildings with less parking available and easier access to car-sharing at some point in time. For example, special parking spots for car-sharing were designated by the building or special membership deals. Thus, membership and experience in car-sharing was higher than among the average population. The total response rate was 25%, or 275 respondents. The study only included respondents who had driven a car during the last twelve months, or 204 respondents. Of these 204 respondents, 70 had experience of car-sharing, 129 had no experience of car-sharing, and five respondents did not answer the question. Of the 204 respondents, 91 were female and 112 were male (one respondent identified as neither male nor female). The mean age was 40.03 years. The data were gathered in October- December 2019.

Experience of car-sharing was dummy coded: past experience of car-sharing was coded as 1 and no past experience was coded as 0. Observation of others was measured through the statement 'Most of my acquaintances use car-sharing services', ranging from 1 (strongly disagree) to 7 (strongly agree). Social persuasion was measured through the statement 'Car-sharing use is perceived as something positive among my friends and acquaintances', ranging from 1 (strongly disagree) to 7 (strongly agree). Emotional arousal was measured through the statement 'I would feel stressed if I used cars from car-sharing services', ranging from 1 (strongly disagree) to 7 (strongly agree).

Self-efficacy was measured through a 100-point Visual Analogue Scale (VAS)[4] on how certain the respondents believed that car-sharing services could fulfil all the needs of car use, varying from not at all certain (0) to completely certain (100), (M = 44.55, SD = 29.85). The validity of a single-item scale has been shown to be satisfactory in relation to self-efficacy in general[5] and to self-efficacy and travel behaviour in particular[6].

3. Results

A multiple regression analysis was performed, with car-sharing self-efficacy as the dependent variable. The independent variables were past experiences, observation of others, persuasion of others and emotional arousal. Table 1 shows that persuasion by others and emotional arousal influence car-sharing self-efficacy, while experience of car-sharing and observation of others do not seem to do so.

Table 1.

Regression model of car-sharing self-efficacy

	Car-sharing self-eficacy
Experience	0.09
Observation of others	0.12
Socail persuasions	0.28***
Emotional arousal	-0.25***
R^2	0.21***

Entries for predictors are beta weight (i.e. standard regression coefficients). Car-sharing self-efficacy was measured on a 100-point Visual Analogue Scale; experience was measured on a binary question (i.e. 1= experience of car-sharing, 0 = no experience of car-sharing); observation of others, social persuasions, and emotional arousal were measured on a 7-point Likert scale. *** = $p < .001$. The table only includes respondents who answered all five questions (N=194).

4. Discussion and Conclusions

The results are supported by previous research showing that social support (e.g. social persuasion) is important for self-efficacy in transport behaviour[6]. It is somewhat surprising that the experience of car-sharing does not influence car-sharing self-efficacy. An inability to fulfil the needs of cars among pioneer users of car-sharing services might of course indicate some problems in the design and offering of car-sharing, which policy-makers and service designers need to consider if they wish to replace car-owning with car-sharing. In the present study, experience was only measured through a binary question (i.e. experience of car-sharing or otherwise). It might be interesting to investigate if and how different kind of experiences are related to car-sharing self-efficacy, such as time aspects (e.g. length of the period; past or present experience) and attitude to the experience.

It is worth noticing that overall confidence in car-sharing self-efficacy was rather low, with a mean value of 44.55 on a scale that ranges from 0 to 100. Further, the current model only explained 21 percentages of car-sharing efficacy. Future research could look more closely at what affects car-sharing self-efficacy with respect to user profiles (e.g. age, gender, personality), needs and quality of service (e.g. flexibility, costs, and sustainability). We also recommend future research to explore how car-sharing self-efficacy influences actual behaviour.

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11.5 Understanding barriers for a transformation to Electric Vehicles in India: A case study of Hyderabad

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KEYWORDS

barriers; electric vehicles; CO_2 mitigation; choice modelling

1. Introduction

Transportation is responsible for 24% of direct global CO_2 emissions from fossil-fuel combustion. According to the IEA 2-degree C pathway scenario, 15% of the global car fleet should be electric by 2030. Progress towards this goal is reflected in impressive global growth rates for electric vehicles (EVs), above 30% from 2016 to 2018, though slowing down to 6% in 2019, which saw 2.1 million electric car sales[1]. Despite these numbers, EVs accounted for only about 2.6% market share of electric cars in worldwide car sales and 1% of the global vehicle stock in 2019. To achieve a share of 15% of global sales by 2030, the transition to EVs will need to be supported by an enabling policy environment and industry engagement. It is also essential that the share of electric vehicles increases in fast-developing countries as well; for example, India has high and rapidly growing vehicle sales and represent a large and growing vehicle market. While there are encouraging signs, significant challenges related to cost, convenience and consumer awareness remain. Despite relatively strong policy support for EVs, the achievement in terms of vehicles sold and market share is very poor. The electric cars sold in India in 2019 were no more than 2100, out of a stock of about 12200[2], but no data was available on the stock of electric two-wheelers. Market share in the case of both electric cars and two-wheelers is nowhere near the 1% mark[2].

Therefore, an attempt has been made in this paper to understand and explain the reasons for the lack of enthusiasm for EVs, despite several supporting policies. This was done by conducting a stated preference survey in Hyderabad which confronted respondents with a combination scenario related to cost, convenience and policy. The choice behaviour is analysed using a discrete choice modelling framework.

2. Background, History, Review of Literature and Methodology

She et al.[3] grouped the barriers affecting EV uptake into three categories: financial barriers, vehicle performance barriers and infrastructure barriers. Other researchers have also studied these barriers. The financial barriers include the high price of EVs in the absence of subsidies, the high cost of a battery and poor understanding of the fuel and maintenance costs[4,7]. Vehicle performance barriers include safety, range, reliability, battery life and charging time[7,8], and infrastructure barriers include vehicle power and charging infrastructure[9]. Even though awareness of EVs has increased the socio-economic dimension, perceptions regarding EVs and access to recharging EVs remain the main barriers to large-scale penetration[10]. Based on the literature review, the high cost of EVs, vehicle performance, charging infrastructure and awareness were taken up for exploration in this study.

To study how prospective EV consumers react to different policy scenarios (creating consumer awareness, providing policy incentives, providing financial incentives), a survey of existing (revealed choice) and prospective users (stated choice) was conducted in Hyderabad in June to September 2017. Thus, the individuals or decision-makers in this study are residents of Hyderabad. The decision-maker chooses the EV mode (scooter or car) a function of the socio-demographics (age, gender, marital status, and vehicle ownership), revealed travel behaviour (distance travelled, no of trips per day) and sensitivities towards other factors influencing vehicle choice (environment, cost, infrastructure availability, aesthetics, driving range, charging infrastructure availability and running-operating costs). 'Probabilistic models' have been used to analyse the individual's choice of electric vehicles following McFadden[11] and Luce and Suppes[12] in this study. A convenient and common functional form for analysing the influence of potential explanatory variables on a category dependent is a binary logit model[13].

3. Results and Findings

The responses were categorised age-wise. The study finds that, in comparison to the age category 50+, it is more likely that the younger age category (18-30 years) will choose electric two-wheelers and that individuals in the age category of 30-40 will choose electric cars. However, the 18-30 and 40-50 age categories have a lower probability of choosing electric cars compared to the 50+ category. Individuals who are single are more likely to purchase electric scooters, whereas those who is married and has children is more likely to purchase electric cars. Females (with reference to the male category) are less likely to purchase electric cars. These choices, reflecting socio-demographic variables, are along expected lines in India; one expects younger individuals to use two-wheelers, while individuals who are married and have children need larger vehicles, which explains their choice of electric cars over scooters. As travel distances increase, the probability that an individual will choose an electric vehicle decreases, which explains people's anxieties about charging infrastructure and driving range. Individuals who were more aware of the availability of electric vehicles indicated that they would be willing to purchase one. This suggests that advertising would improve electric vehicle choice.

The factors that individuals rated critical in purchasing an electric vehicle are its resale value and maintenance costs, which is consistent with the cost-consciousness of Indian buyers. People also rated driving comfort and the top speed of the vehicle as critical to their decision to purchase. It was also observed that 75% of respondents would like to charge the vehicle at home or at the office. Public charging is vital for longer trips, where, due to driving range limitations, topping up the charge becomes essential.

4. Discussion and Conclusions

The study finds that there is limited awareness of the incentives provided by the government to buy electric vehicles (EVs). The stated preference experiment also shows that if awareness is improved, then there could be a significant shift of people towards electric vehicles. Additional policy incentives (e.g., for parking, charging) and financial incentives (e.g., reduced goods and service tax, concessional interest rates, etc.) will probably only marginally increase the demand for EVs.

The results generally give an idea of who market-segment electric vehicle manufacturers should concentrate on: the young and unmarried for the scooters, and those who are married with children and more middle-aged for the electric cars. Individuals in India are very sensitive to cost, and therefore factors like resale value and maintenance costs are very important to consumers considering purchasing any vehicle.

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SECTION 12

BEHAVIOUR CHANGE FOR ACHIEVING THE SDGS

12.1 How I See Me: A Meta-Analysis Investigating the Association between Identities and Pro-Environmental Behavior

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KEYWORDS

identities, pro-environmental behaviour, group identity, meta-analysis

1. Introduction

The past few years have been characterized by the climate crisis[1,2]. Extreme weather events are increasing, particularly in the Global South[2,3]. It is slowly becoming apparent that we need large-scale behavioural change to mitigate this crisis[2,4]. Fires, floods, hurricanes and climate-related health issues require as dramatic a response as we are giving to the current health crisis[2,5]. At present, however, there is a tendency not to view climate change with the same urgency as COVID-19[2,6]. In this environment, how do we persuade people to take corrective action? In this paper we explore how to encourage pro-environmental behaviour (PEB) – for example, reducing energy use in the home – using identity theory[2,7].

2. Background, History, Review of Literature and Methodology

Environmental groups like Extinction Rebellion often use campaigns to encourage PEBs to help preserve the planet and prevent further harm[2,8]. However, these campaigns may be ineffective because they do not focus on how individuals see themselves, that is, their identities and their roles in preserving the world[2,9]. In this paper, we demonstrate the power of identity when it comes to saving the planet[2,10].

2.1 Why are identities relevant for PEB research?

We are interested in encouraging PEB at any level of economy and difficulty, whether it is as easy as recycling or as difficult as installing smart meters; as cheap as turning off lights, or as expensive as purchasing an electric car[2,11]. The likelihood of an individual making any of these changes depends on psychological determinants[2,12]. We undertook this research because we wished to understand what these factors are so that we can increase the effectiveness of such campaigns[2,13]. We focus on individuals because the collective impact of many people's small actions can lead to large-scale global changes[2,14]. So how can we encourage people to make greener choices?

According to a recent systematic review, it is important to tap into one of the many 'identities' people hold[2,15]. For example, if people identify as an environmentalists, it becomes easier for them to engage in PEBs because of a need to avoid cognitive dissonance[2,16]. However, research shows that many identities affect PEBs, although no theoretically guided testing has assessed how or why[2,17]. The present paper examines an analysis of the effect of identity on PEBs within the framework of identity theory[2,7].

2.2 Methodology

To do this, we conducted a peer-reviewed pre-registered meta-analysis[17] to assess existing data on identities that are relevant for PEB using the preferred reporting items for systematic reviews and meta-analyses[18]. This approach enables us to pull the evidence together in one place and evaluate the overall impact of identities on PEBs[19,20,21].

3. Results and Findings

Our random-effects meta-analysis, consisting of 104 studies, revealed identities associated with PEB with a medium effect-size[22]. The meta-regression revealed that identity has a stronger effect on PEB when identity and behaviour are consistent with each another, thus showing the importance of identity and behavioural congruency[23]. For example, group-based identities motivated group-based PEBs best when they were not limited in this regard[24]. We define both individual- and group-focused identity and behaviour[25,26].

3.1 Category 1: Individual (Me)

— Individual (me) identity: how I see myself personally, e.g. as an environmentalist, or a researcher[10].

— Individual (me) behaviour: behaviour 'which is very largely determined by their individual characteristics and the nature of the person'[25].

3.2 Category 2: Group (We)

— Group (we) identity: how I see myself in relation to other people, e.g. as part of a group of environmentalists or researchers 15].

— Group (we) behaviour: behaviour which is 'largely determined by group memberships of the participants and very little, if at all, by their personal relations or individual characteristics'[26].

Furthermore, as expected, the PEB measure, research design and sample type we used were methodological moderators with an impact on the identity–behaviour relationship[27].

4. Discussion and Conclusions

In this paper we show how we each have multiple identities, split into two overall categories: individual[2,28] and group[2,29]. For example, you could encourage someone to look after their local environment by reinforcing the importance of the people around them, or show them how having a healthy environment benefits them personally[2,30].

4.1 What identity means for policy

This research shows that identity theory can be used by policy-makers to nurture community-focused behaviour[2,31]. We believe that we can encourage PEB by identifying key identities and framing messages and interventions to change how people see themselves in relation to the world around them[2,28]. We believe that it is possible to utilize identity to encourage PEB in three steps[2,28]:

1. Identify the relevant identity for the behaviour in question. This takes into account the fact that not all of the 100+ identities are relevant for all 600+ different types of actions studied. For example, a, identity as a cyclists was not found to be relevant for reducing car use, but it was relevant for increasing public transport use for work. Therefore, when we are interested in encouraging a particular behaviour, encouraging the appropriate identity is necessary. These levels of nuance are important for delivering effective messages[2].
2. Only choose pro-PEB identities, that is, those identities that seem positively related to the concept of PEB. For example, some identities (such as 'cyclist') relate to PEB positively because the identity is concerned with minimizing harm to the planet. However, a 'motorist' identity relates negatively to PEB because it increases harm to the planet and is therefore inappropriate[2].
3. Finally, decide whether the selected identity falls into the individual and/or the group category, and emphasise this clearly. Tailor messages to be specific and signpost that reflect individual/group identities, respectively. In other words, increasing the prominence of the relevant identity will increase the strength of the person's identity and thus increase the corresponding PEB related to it. For example, to encourage a cyclist identity (which we understand as increasing public transport use for work purposes), messages could be constructed around the following[2]:
    a. Individual (me) focused cyclist identity – 'please think about the planet when going to work – positively imagine yourself cycling'[2].
    b. Group (we) focused cyclist identity – 'please think about the planet when going to work – positively imagine yourself with others cycling, and your power as a group'[2].

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12.2 How an Ecosystem of Stories Can Play a Role in the Transition to a Low Carbon Future

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stories, narratives, visions, futures, hero story, system of stories, ecosystem

1. Introduction

Stories are considered to be one of the earliest forms of human communication. Indeed, they play an important cultural role, helping create shared beliefs, purposes and norms throughout human history[1]. Given the current challenge of climate change and broader questions of energy systems and environmental collapse, we might (re)consider what stories we hold on to, and what we believe the future will bring. Although the narrative[1] of economic growth is still alive and well, this business-as-usual perspective does not support the social changes we need. Some are calling for new stories, or for re-centring marginalised stories which promote alternative visions of the future[2,3]. This paper treats stories as an ecosystem and explores whether and how the dominant narrative might be challenged by stories and visions emerging in response to climate change and the COVID-19 pandemic.

2. Competition within an ecosystem of stories

Each story or narrative privileges a certain way of looking at the world, separating story from 'non-story', i.e. what we exclude. Narratives can be a powerful rhetorical weapon or political tool, shaping the future by presenting one vision of reality and obscuring discontinuities and contradictions which would undermine their intended meaning[4].

This is arguably the case for the dominant narrative that can be termed 'modern economic growth'. Approaches that follow this narrative often portray the only positive future as a high-tech version of the present, achieved through (green) growth and continued application of the

1 *In the full paper, we will distinguish between stories and narratives.*

current techno-economic 'hero story', in which technology acts as the hero[5]. This may suit current incumbents, who envisage a future similar to today with technology enshrining our way of life, avoiding more systemic change.

However, the dominant narrative exists within a broader context of a 'system of stories'[5]. We liken this to an ecosystem, where different stories co-exist, compete, or even consume each other. In economics, narratives compete over the framing of the relationship between growth and the environment, states and markets. Narratives in line with ecological economics stress that perpetual economic growth on a finite planet is impossible, while narratives in line with modern economic growth suggest that liberalised energy markets would improve economic efficiency, support cleaner production and internalise pollution costs. These narratives have influenced international sustainability policy and energy policy[6]. From an ecosystem perspective, we see economic growth as the 'apex predator' of modern thinking. What does this positioning mean for thinking about the future? [2]

A single unifying narrative might be insufficient for transitioning to a more sustainable world, as engaging the multiple experiences of different agents is necessary[3]. Seeing stories as part of a complex intellectual ecosystem could foster an understanding of multiple concurrent objectives, which is critical for addressing complex issues of social and climate justice, where different definitions of development are considered[7]. For example, the UN's seventeen Sustainable Development Goals provide a series of motives that together need different kinds of stories to be told. Their different focuses support a series of different visions and narratives, rather than one overarching imagined future. In fact, there are some tensions between the goals.

3. Change in reaction to shocks

Finally, we consider how external shocks such can generate windows of opportunity for new narratives and significant policy development[8]. The COVID-19 pandemic is one such game-changer: it has modified how we live and work, including accelerating the shift to online interactions and discrediting the barriers to working from home. Early in the pandemic, quiet streets and improved air quality prompted ideas of another way of life, with some calling for health and well-being to be prioritized over economic growth. Reactions to the pandemic illuminate a struggle between 'life as normal' and a desire for social change, resonating with the main narrative themes of reactions to climate change. The opportunity for change does not necessarily dictate its trajectory, and different outcomes (e.g., a better world or a worse one) could emerge from our choices about how to cope with the pandemic.

4. Conclusion

In conclusion, we recognise the need not only to change the dominant narrative, but to open ourselves up to a multiplicity of visions of the future, and consider how a whole ecosystem of stories could help us transition to a low-carbon world.

2 *In the full paper, we will define ecological terms and describe interactions in the natural world.*

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12.3 Sustainability and Coherence of Actions Aimed at Behavioural Change in Energy Consumption

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1. Introduction

Our research focuses on changes in energy practices and, more generally, on the changes in lifestyles that can be expected as part of the ecological and energy transitions by questioning the conditions for their sustainability. We consider that these changes can be difficult to measure as they are generally evaluated regarding savings (Abrahamse, Steg, Vlek & Rothengatter, 2005 ; Ehrhardt-Martinez, Donnelly et Laitner, 2010 ; Karlin, Zinger, & Ford, 2015). Based on an experiment carried out in 2013-14 on a French territory and on new experiments on a territorial scale, we proposed to explore two problematic axes. The first axis concerns the temporalities of change. We questioned the maintenance in time of the changes and adjustments that had been observed three years earlier in volunteer households to test various forms of support and information regarding energy consumption. We were also interested in the possibly delayed effects in the medium and long terms which had not been observed during the 2013-14 surveys. The second axis concerns the evaluation of the data we sent to these voluntary households and of a new sample.

2. Methodology

The research is multidisciplinary, involving psychology, sociology and engineering sciences, and closely associates with the territory, which took part in the construction of the devices and was deployed in the experimental phase and in their evaluation. The approach combines a qualitative methodology using in-depth interviews and ethnographic observations with the administration of a psychological questionnaire.

The research followed different phases:

- Recruitment of households in April 2018
- Household instrumentation in May 2018
- Interviews and questionnaires with instrumented households in June 2018
- Sending of booklets in December 2018, March 2019, June 2019 and September 2020
- Interviews and questionnaires with all households (with control) in late 2019-early 2020

The research consists of three separate samples:

- A first sample, which we call the "expert households", which includes households that participated in the previous experiment in 2013/2014 on the territory we studied.
- A second sample, which we call the "novice households", which includes households that did not participate in the previous experiment. We recruited them in several communes of the territory we studied.
- A third sample, which we call the "control" sample, which we recruited at the end of the research and with which we did not interact during the research.

The "expert household" and "novice household" samples were instrumented and received information about their energy consumption through four booklets delivered by mail.

3. Results

Data-collection instruments were deployed in 49 homes in eight communes. This represents 208 probes in total, generating approximately 30,000 data records per day. As the data collection was operational for 1.5 years, we collected more than 16 million data records. The electrical meters of all households were data collection instruments. For some, only specific electricity was measured because heating and domestic hot water (DHW) were produced from other energy sources. For others, the total electrical energy consumption of the household was measured, including heating and DHW (100% electric households). All gas-fired fireplaces were also monitored, except for one fireplace that produces its DHW using gas in a tank.

We suggested to the participating and instrumented households that they receive information on their electricity and gas consumption in the form of a booklet. We sent four, one per season, in December 2018 (based on November 2018 data), March 2019 (based on February 2019 data), June 2019 (based on May 2019 data), and September 2019 (based on August 2019 data). We therefore selected one month per season which we considered representative of that season.

The proposed data were consolidated and presented to householders in a variety of formats. The four booklets proposed a progression in the data presentation. In general, several elements of reflection determined the choices that were made to create the content of these booklets. We had decided not to vary their content too much, so as to allow us to adjust elements that might appear problematic during the intermediate interviews.

The individual houses in the project are grouped together within a radius of about 10 km of each other and have an average surface area of about 125m². Although most were less than twenty years old, they had been built between 1920 and 2013, which potentially implies a strong disparity in terms of building performance. The vast majority of households consist of two to four people. The two energy sources mainly used for heating and DHW are electricity and gas.

A global analysis of energy and comfort has enabled the homes to be characterized better and highlighted certain important elements that shed light on the cross-referencing of our analyses with those in other disciplines. This made it possible to determine the main factors influencing energy consumption and comfort, such as the intrinsic characteristics of the houses or the weather or energy mix of the dwelling. The seasonal nature of consumption and comfort was quantified. On the other hand, in order to qualify the households properly based solely on their electricity consumption (the project's starting point), it was necessary to clearly distinguish the energy mix of each household and to determine the energy sources of the two most heavily consuming items, heating and DHW.

4. Findings and Conclusions

Regarding the availability of consumption data, first of all, apart from any consideration of formatting, we observe that the data are only useful under certain conditions: a favorable context for their reception, an energy culture, even minimal awareness, a source identified as relevant, competent, impartial and legitimate, and "accessible" data. Indeed, without a favourable context, no matter how we present the data, it does not reach its target. More seriously, there is a risk of diverting information over the long term by inducing a sense of powerlessness and/or failure. In general, we observed that awareness of energy issues and curiosity motivate data being consulted, with the main objective being to respond to a normative injunction of energy sobriety.

It is therefore important to:

— Propose information related to the hypothesis of progressive learning

— Limit barriers to the reading and appropriation of data

— Capture attention and contribute to a process of reflection

— Accompany the reading without imposing a normative framework for data analysis (favour contextual reading)

— Facilitate autonomy in reading and analysing the data and ensure decision-making autonomy by contributing to an energy culture

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12.4 Bio-Ecological Education

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KEYWORDS

climate change, bio-ecological education, natural materials, physical well-being, timber, wood

1. Introduction

Understanding that climate change also depends on our daily choices is fundamental; correcting our habits, even slightly, can be decisive.

From food to construction, everything passes through industry, but even before that through market research. The market responds to our requests, not our real needs: proper bio-ecological education can contribute to reducing the impact on the environment.

In this process it is important to grasp terms such as: **sustainable development, renewable energy, biocompatible materials,** and **conscious use of resources**.

The **MaVE-Material Value Exposure** research reported on here was included in the 'CORE-WOOD' project for the competitive repositioning of the wood supply chain for purposes of wood comfort and the livability and multifunctionality of wooden structures. This project was developed in collaboration with the TESAF Department of the University of Padua, Italy. The focus was on an underestimated aspect: biophysical interactions with materials present in the built environment.

2. Background, History, Review of Literature and Methodology

The MaVE research is innovative, and the only publications are from the research team.

The emotional psychological aspects and biophysical reactions of the 'CORE-WOOD' project have been investigated, demonstrating that the materials have a real interaction with humans, and that building materials are responsible for the perceptions of comfort and well-being within built spaces.

The MaVE research protocol was developed by IRSA (Research Institute of Living Sciences) and was conducted over a decade, improving over time, on the basis of the results of experiential and information tests conducted on a sample of about a thousand subjects, and analysed at the various stages of data collection.

These tests were conducted in specially designed structures. In the last phase of the research, the

biophysical reactions of the tested subjects were monitored instrumentally in two built environments: one in masonry and the other in wood. The results, analysed on a statistical basis, have shown that building materials with natural components produce an improved biophysical responses compared to those derived from petrochemical synthesis, which increases in the case of a wooden environment.

The construction of buildings with natural raw materials would substantially reduce the production of CO_2 and would significantly enhance perceptions of well-being within built spaces, resulting in an improvement in the immune response.

This research has also served to develop an educational system, based on the experiential transmission of information: subjects become aware of their own psychological and biophysical reactions towards the environment, thus understanding the importance of their choices.

This teaching program may be provided in both schools and other locations in order to increase awareness of the use of environmentally ethical solutions in construction as well.

Our existence is necessarily expressed in an eco-systemic key, for which reason it becomes important to educate everyone involved, from young pupils to families.

A redefinition of the outdated differentiation between *private space* and *public space* is necessary because, from an anthropological perspective, we are the environment.

The didactic methodology proposed here also makes use of the traditions of the ancient workshops of the Italian Renaissance, within which the relationship was translated into an apprenticeship.

We believe that pragmatic teaching is important, connected with educational experimentation as it occurred in the workshops, that is, between teacher and pupil.

This would stimulate a new demand for the bio-ecological market, with the production of eco-sustainable materials, objects and artefacts; the greater level of supply would also lead to a relative decrease in costs.

3. Results and Findings

Climate change depends among other things on our lifestyle habits. The lockdown showed the environment having an immediate benefit because the absence of production activities, but at the same time it highlighted the serious shortcomings of most of the building stock.

Living in a wooden house from FSC (Forest Stewardship Council) or PEFC (Programme for Endorsement of Forest Certification schemes) supply chains in the absence of glues and synthetic finishes means forest maintenance and greening, greater hydrogeological stability, reduction of synthesis production processes and consequent decrease of CO_2, reduction of the production of non-environmentally friendly waste, advantage of the development of local economies, and savings of energy and health saving.

Since the Second World War market economies have developed by changing environmental scenarios, especially in agro-forestry. The progressive lack of interest in wood as a building material has led to the formation of extensive coppice woods that today appear aged. The conversion into high-trunk forests often does not allow the supply of the necessary assortments of materials for the construction of wooden buildings.

In Italy the wood technology institutes of the National Italian Council and Universities have collaborated with foreign engineering or research institutes, such as the NIED (National Research Institute for Earth Science and Disaster) in Japan, or TUDelft in the Netherlands, as part of the SOFIE project.

These collaborations have opened up new chapters dedicated to regulations; the production of bibliographies, both scientific and popular; recovery of the processing chains of construction wood; and the foundation of carpentry schools.

MaVE also led to elaboration of the EVA–Eco Valutazione Ambientale (Eco Environmental Assessment) protocol, a guideline for buildings that respect the environment and well-being. This will constitute certification of both the design and construction processes.

4. Discussion and Conclusions

Educating for awareness is the fastest way to influence climate change, and the anthropology of mind can help in this process. This discipline allows us to observe the relationship between the bio-evolutionary dimension of our species, with its universal and general characteristics, and the cultural variation that this dimension assumes in every region of the world.

One of the problems arising from globalization, especially in the new post COVID-19 era, is learning to take individual responsibility for the environment. The pragmatic teaching proposed here could be starting point for stimulating the constant and continuous assumption of ecological responsibility and improving our participation in the life of the planet.

As human beings, we are much more similar than our claim to originality suggests, and the relationship we live with the uterus that contains us, the cosmos, is seamless.

The aim of bio-ecological education is to encourage reflections on issues that are often underestimated, but which greatly affect the real sustainability of our actions.

Earth is our common home.

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12.5 Mitigation of Energy Poverty Through Consumers Behavior: Pilot Actions in Italy

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KEYWORDS

energy poverty, pilot action, consumer behaviour, energy awareness

1. Introduction

Energy poverty (EP) represents one of the greatest challenges in the European Union (EU), affecting anything from 50 to 125 million people. To tackle it, several EU and national policies and initiatives have been put in place in recent years. The problem has attracted significant funding for projects (e.g. Horizon 2020 (H2020)) related to its mitigation. ASSIST2gether, funded under Grant Agreement n. 754051, is a H2020 project with the goal of tackling energy poverty through pilot actions aimed at increasing consumers' awareness of energy efficiency and changing their consumption behaviour. After training specialized Home Energy Advisors (HEAs) from different sectors (charities, consumer associations, energy utilities, social workers, etc.), pilot actions have been implemented in all the countries involved in the project (Belgium, Finland, Italy, Poland, Spain and the UK) with the aim of optimizing the energy consumption of vulnerable users through more efficient behaviour. This paper presents the results of the pilot actions carried out in Italy.

2. HEA Training results

In order to be able to reach vulnerable consumers, HEAs have undergone a structured training, delivered in a blended mode (partly in person, partly through a dedicated online platform), on both technical topics (energy efficiency and social skills) and soft skills such as communication. The structure of the course was the same in all the participating countries, but with content tailored to specific local issues. Overall, 982 HEAs registered for the full course, and 558 completed it. In Italy, 233 people registered for the course and 122 completed it (goal: 150 registered, 75 completed). This does not take into account 1,231 high-school students that took a simplified version of the course and implemented information activities in the "Alternanza Scuola Lavoro" project.

3. Implemented pilot actions

Overall, the 122 trained HEAs in Italy delivered three main types of activity:

— Soft/engagement activities aimed at informing people about the project and giving providing generic advice about energy efficiency in forums such as energy cafés, workshops, online support helpdesks and educational activities for vulnerable consumers

— Pilot actions specifically designed to support vulnerable consumers, with analysis of energy bills and consumption habits and customized advice on energy consumption optimization, such as helpdesks at consumer associations premises and home visits by social and health workers

— Synergies, that is, activities organized in collaboration with other energy-efficiency and energy-poverty initiatives that were already in place and partly covered by ASSIST2gether scopes, such as helpdesks at charity premises and the distribution of information material during other events.

4. Discussion and Conclusions

Monitoring the results was only performed for the pilot actions. Soft or engagement activities were estimated to account generically for 2% in energy savings in the families that participated.

Pilot actions' effects were assessed by means of two questionnaires administered to HEAs: an ex-ante questionnaire to record their energy consumption habits before the action was implemented, and an ex-post questionnaire, administered after six to twelve months, to verify whether behavioural change and a reduction in consumption actually took place.

An Energy Saving Indicator (ESI) was created to take account of all the different factors that can improve vulnerable consumers' lives:

— Energy savings (% with regards to ex-ante overall consumption)

— Comfort indicator (expressed as an increase or decrease % of savings)

— Money-saving indicator (expressed as an increase or decrease % of savings).

Moreover, a qualitative index, the Vulnerable Empowerment Factor (VEF), is the awareness perceived by vulnerable consumers before and after the action.

The results were calculated directly for a control group of 172 consumers and then extended to the overall group of assisted consumers (618), with a parametrization in terms of household size, building type, heated space and type of heating system. The result was an average ESI of 5.5% and an overall VEF of 0.4.

The results were quite satisfactory, considering the difficulties that were encountered, especially:

— the low involvement of many HEAs: most of the actions were carried out by a reduced number of HEAs

— the "low consumption" starting point: many vulnerable consumers are already living in "energy saving mode", so cutting their consumption further is very difficult. The solution adopted was to try and increase their comfort or reduce their energy costs, this being the reason why the ESI was created.

An important note is that the HEAs were mostly working on a voluntary basis and came from the third sector, which in fact plays a fundamental role in the Italian society, especially in addressing all those areas in which state support is limited and/or has some deficiencies, thus improving the welfare for those at risk of being left behind.

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12.6 Energy and Behaviour: A Multi-faceted Perspective towards a Low Carbon Future

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KEYWORDS

energy and behaviour, energy efficiency, multidisciplinary approaches

1. Introduction

It is widely acknowledged that the path towards a low-carbon future includes the decarbonisation of energy supply and the promotion of energy efficiency and behavioural changes, which will require people to change their daily lives, the way they work, move, consume and interact socially[1]. However, although people are central to the energy system, the definition of "energy behaviour" is evolving and depends on who is studying it and how. Much of the current literature associates energy behaviour with individual actions in homes, leaving groups and their dynamics in businesses and industry understudied[2,3]. This work presents a multi-faceted view derived from a book we co-edited, *Energy and Behaviour: Challenges of a Low-Carbon Future*[4], to shed light on the interface between people and energy, including the main disciplinary and interdisciplinary approaches to this topic, cross-sectoral perspectives, modelling techniques, and new areas where additional evidence is required for interventions and policy-making. In this work, "energy and behaviour" is broadly understood as the role of people (individuals, groups, or society), organisations and technology in energy use.

2. Methodology

This work first introduces the study of energy and behaviour to show that there is no single approach to this topic. It then explores different aspects of energy and behaviour research across different energy end-use sectors, encompassing households, non-domestic buildings, industry, transport, smart cities and energy communities. Recognising that energy and behaviour research can be quantitative or qualitative or both, an overview of several quantitative approaches to energy and behaviour, including modelling, is presented. A final reflection is made on the opportunities and challenges to implementing energy and behaviour change in the real world, including in policies and programmes.

3. Findings

Different disciplinary fields address energy behaviour differently, through approaches that are sometimes complementary and sometimes competing[2,5]. Economics and psychology share a common focus on individual choices and make policy prescriptions that seek to influence them[6]. Going beyond the individual perspective of energy behaviour, social sciences such as sociology and anthropology argue that energy is a means of providing useful services that enable normal and socially acceptable activities to be carried out as part of one's daily life[7,8]. Hence, energy demand is not a consequence of individual decisions but a reflection of the social organisation in which rules, practices and routines are embedded[9,10].

Many policy strategies for promoting energy efficiency and reducing energy demand have focused on technological development, regulation, financial incentives and the provision of information[3], which are strongly influenced by the Physical-Technical-Economic Model (PTEM) framework and an individual perspective. Decades of interventions to change behaviour in Europe have not yet succeeded in achieving long-term and significant improvements in energy efficiency or in reducing energy demand[11,12]. Emerging research is revealing that when behavioural interventions are focused on individual actions, the effects are uncertain and only deliver marginal short-term benefits. When aiming to reduce energy demand and GHG emissions, the most promising actions are those with the greater impacts when considering both the technical potential (i.e., the amount of reduction) and behavioural plasticity (i.e., the ability to deliver effective changes in behaviour)[3].

4. Conclusions

Relevant conclusions can be drawn regarding the interaction between energy and behaviour to achieve a low carbon future, which include but are not limited to:

- The need to go beyond the usual scale of disciplinary problem-solving to redesign the sociotechnical energy system (rather than redesigning individual technologies or expecting to change people's behaviour)
- The importance of interdisciplinary work in real-world practice and in close cooperation between all stakeholders (e.g., researchers, policy-makers, industry, businesses, intermediary actors, interest groups and other organisations)
- The value of modelling tools to gain insights about problems, design methodological approaches to derive effective solutions and assess the upscaling of interventions
- The opportunity to reengineer regulations and integrate policies while maximising the co-benefits for society, leveraging citizen participation and fostering interactivity.

Transitioning to a low-carbon energy system will involve profound and large-scale transformations in the sociotechnical energy system and in how people fit in and interact with it and with each other[6]. Finding alternative paths requires innovative interdisciplinary work at all scales, bringing together engineering, economics and the environmental, social and political sciences[3]. More than a challenge that lies ahead, interdisciplinary work to achieve a more sustainable low-carbon future offers the opportunity to design more participatory and effective development strategies on a global scale.

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12.7 Factors Affecting Public Awareness and Acceptance of CO_2 Capture, Transport, and Storage Infrastructure: a Transnational Comparison

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KEYWORDS

CCS, carbon dioxide, capture, storage, awareness, social acceptance, local communities

1. Introduction

Carbon capture and storage (CCS) refers to the capture of carbon dioxide (CO_2) from energy or heavy industrial processes and its redirection to long-term geological storage structures, such as depleted oil wells. In this way, CCS can contribute to global efforts to mitigate climate change. However, it remains a controversial technology that often faces public resistance in terms of the acceptance of specific projects. Therefore, the fact that social acceptance of CCS infrastucture is a prerequisite for the further development and dissemination of this technology should not be overlooked.

2. Methodology

To this end, a quantitative survey (2020) is carried out at the local level focusing on the factors that may influence awareness and acceptance of carbon capture, transport and storage facilities, including: a) level of information, b) perceived benefits and risks, c) trust in stakeholders in terms of their intentions and capabilities, d) personal beliefs about climate change and energy issues, e) socio-economic characteristics, f) place attachment, g) engagement activities, h) fairness (procedural and distributional) and i) other issues related to risk and safety attitudes, and general knowledge of relevant technologies.

The survey examines respondents' perceptions on the local and national level and is being conducted in the eight countries that are participating in the European MOF4AIR project (Metal Organic Frameworks for Carbon Dioxide Adsorption in Power Production and Energy Intensive Industries), which is being funded under Horizon 2020 and involves Belgium, France, Norway, Italy, Greece, Turkey, the United Kingdom and Korea. The innovative aspects of the present study, compared to previous research performed on this topic, include a transnational comparison, comparisons between different phases (capturing, transferring, storing) and between general and local acceptance, and an emphasis on factors that have not been thoroughly examined as yet relating to public acceptance of CCS, such as engagement activities and fairness.

3. Results

Based on the conducted survey, the factors that affect acceptance of CCS are identified on the basis of a) socio-political and community acceptance (as classified by Wüstenhagen et al.[1]), and b) acceptance of the different types of infrastructure (capture, transport and storage). In addition, factors affecting awareness of CCS are defined. Overall, the determinants of the above-mentioned themes include, among others, pre-existing knowledge of CO_2 and CCS, trust in involved stakeholders, procedural and distributional justice, environmental attitudes, perceived benefits and risks, and engagement activities. In addition, a further comparison is performed between the participating countries, taking into account not only individual characteristics, but also Hofstede's[2] cross-cultural dimensions, namely Power Distance, Individualism, Masculinity, Uncertainty Avoidance, Long Term Orientation and Indulgence. The statistical methods applied in relation to the above analyses include logistic regressions, structural equation modelling (SEM) and non-parametric methods such as Kruskal-Wallis H tests.

4. Discussions and Conclusions

The results of the present research can provide decision-makers and project developers or operators with useful empirical findings that can assist in the planning of tailor-made public awareness and engagement activities based on each particular case that can enhance acceptance of the different types of CCS infrastructure on the socio-political and community levels.

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