Knowledge-Driven Sustainability: Leveraging Technology for Resource Management in Household Operations

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Abstract: Conserving energy is a worldwide dilemma for nations as well as individual households. Data indicates that European nations face a significant issue in this regard. Energy conservation is a global issue that both nations and individual households must address. Statistics reveal that European nations face a significant issue in this regard. The literature study revealed that several studies primarily focus on energy conservation, whereas there is a dearth of research examining social consciousness and user proficiency. A report outlines the study findings, aiming to ascertain the level of awareness across various generations about the resources, information, and expertise required for energy management. The objective of the paper was to examine the use of the Internet of Things as a technological instrument for residential energy management in Poland, Portugal, and Italy. We administered an online survey to a total of 18,683 customers from February 2022 to February 2023. The survey used a kind of sampling known as convenience sampling. The research used a survey that included 26 inquiries about customers' awareness and behaviour in the field of energy conservation. Research indicates that the elderly population struggles with vocabulary and often lacks comprehension of instruments. This suggests that they are unable to effectively control the energy use in their households, resulting in inefficient measures. Additionally, future research endeavours were established to explore knowledge acquisition, solution utilisation, and proficient utilisation of technologies for conserving and controlling energy within residential settings.

Keywords: Energy Saving, Sustainable Household, Household Resources, Knowledge Management

1. Introduction

Today's technology development, including the Internet of Things (IoT) and related technologies, finds further applications for this solution, including primarily in enterprises and organisations (Carpino et al. 2018; Amine Chatti 2012), but also in the immediate environment of an employee, client, or user. This necessitates conducting research on how companies and employees perceive IoT technology and devices, as well as establishing a model that verifies the acceptance factors of IoT in private applications by consumers. The purpose of this article is to try to explain and illustrate the acceptance of IoT technologies by different generations of consumers using constructs relating to consumer confidence in these IoT technologies and devices. Employees of different ages accept new technologies to a different degree (Fawkes 2017), which allows us to recognise the studied phenomenon in different age groups but also determines the size of the company or industry.

2. Literature Review

The IoT is not a new concept, as it was invented and proposed in 1999 (Khan et al. 2022), while it was implemented as a practical solution approx. 7–10 years later, but for 3–4 years it has been gaining applications with an ever wider range and is currently experiencing a period of development, and a dynamic one at that . More broadly, we can conceptualize the IoT as an ecosystem where items equipped with sensors interact with computers, both manually and automatically, primarily through wireless networks (Żywiołek 2019). Taking into account the variety of technologies connecting devices included in the IoT category, the very concept of IoT is defined in various ways. K. Ashton, who described the IoT as a sophisticated system where devices communicate with sensors to gather environmental data, provides the most common definition in scientific research. This communication concerns computers and objects connected by ICT networks, mainly the Internet (Tiwari et al. 2022; Himeur et al. 2020). Internet-connected gadgets with advanced intelligence capabilities form the Internet of Things (IoT) system. These gadgets use integrated sensors, processors, and communication equipment to gather, process, and transmit data. IoT devices transmit sensor data by establishing a connection with an IoT gateway or similar device. Typically, the cloud receives this data for analysis (Sayed et al. 2022; Żywiołek et al. 2022b; Shang et al. 2024). The devices do most of the work without user intervention, although it is possible for people to interact with them (Alsalemi et al. 2022). The specific IoT applications implemented and supported by the Internet largely determine connectivity, network, and communication protocols (Krishnan and Jacob 2022). This article categorizes consumer applications into four main groups: wearables, "connected" home appliances, including "smart" home appliances, and consumer building automation. "Intelligent" personal medical devices (personal health), as well as "connected" cars, remain beyond the author's area of interest due to the different specifics of their application (Razip et al. 2022).

The author, when preparing to conduct the study, set a goal for it and then divide it into a theoretical part illustrating the social acceptance of such a solution for energy saving and a practical goal obtained through a qualitative study, giving a practical picture of the level of awareness with particular attention to the older generation. Conversely, the research aims to foster sustainable societies that utilize resources in a comprehensible and mindful manner.

3. Materials and Methods

For the majority of service providers, determining the quality of their offerings is a difficult task because it substantially differs depending on factors including cultural variations, demographics, and individual circumstances (Rosak-Szyrocka and Żywiołek 2022). The individuals involved, their behaviour, and their understanding of the quality of service can also have an impact on how satisfied a client, patient, or city resident is. In conclusion, a number of variables served as the catalyst for this research investigation. (Żywiołek et al. 2022c). First, few studies have measured the quality of services, but this did not apply to city dwellers or the use of media for the functioning of the household. This study focused on filling the gap in urban service quality research, in particular in households.

The analysis of the literature based on research in the field of the use of IoT solutions using the Servqual methods allowed the author to identify research gaps and indicate actions to fill them, as shown in Figure 1.

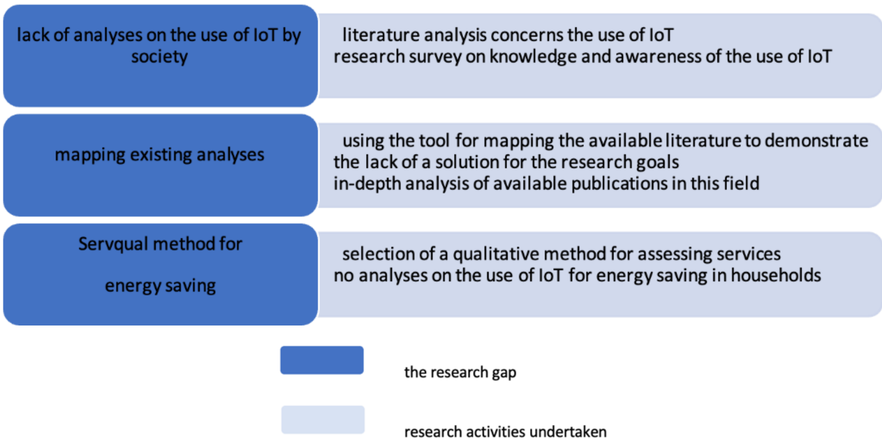

Figure 1: Identifying research gaps and research activities undertaken.

Identification of research gaps and determining what research activities will be undertaken made it easier to conduct them. The sequence of actions was adopted as shown in Figure 1, because it made it possible to achieve individual assumptions, and each subsequent step made it possible to state that the adopted methodology was correct and verified the adopted assumptions. While preparing the literature analysis, the authors made science mappings and found 826 manuscripts concerning the quality of services and the Servqual method. With the use of Vosviewers prop-programming, Figure 2 relating to keywords and Figure 2 relating to the countries in which research is conducted on this subject have been prepared.

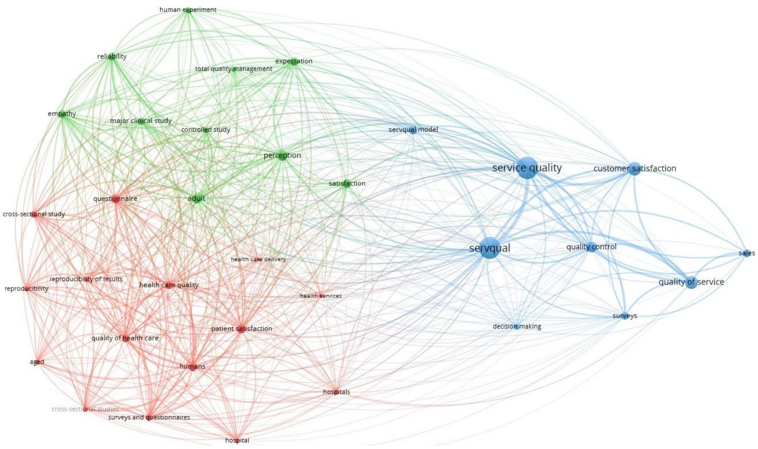

Figure 2: Analysis of keywords that appear in publications in 2019-2022 on quality and the Servqual method.

The completed study in Poland reveals that the quality and Servqual technique are also published. An examination of the publication's keywords suggests that customer satisfaction holds significant importance, and urban residents are also consumers. It is important to focus on those who oversee homes, since they are the ones responsible for determining the effectiveness of energy-saving measures.

The Green Deal for Europe, proposed at the conclusion of 2019, sets the stage for a very ambitious programme aimed at safeguarding the environment. We expect Europe to achieve carbon neutrality by 2050 (Alberg Østergaard et al. 2010). The European Union has implemented a sequence of measures (Żywiołek et al. 2022a; Zografakis et al. 2012). The Green Deal aims to facilitate a sustainable green transition for enterprises and communities in Europe, enabling them to reap its benefits. The ideas, along with a first "roadmap" outlining crucial policies, tackle several concerns, such as reducing emissions, financing cutting-edge research and development, and protecting Europe's ecology (Żywiołek et al. 2021; Valerio-Ureña and Rogers 2019). Implementing the "Green Deal for Europe" initiative would enable EU countries to achieve energy self-sufficiency, potentially leading to significant effects on the energy market and their regional policies. Furthermore, it is expected that achieving climate neutrality in the economy would improve its competitiveness and facilitate its vigorous expansion.

The introduction of the aforementioned legislation in EU states fuelled an increase in the adoption of renewable energy across the entire community. In 1990, renewable sources accounted for 3.8% of the EU-28's overall energy consumption. This figure increased to 5.1% in 2000 and further rose to 10.2% in 2019. The household sector's use of renewable energy sources (RES) accounted for 8.5% of total home final energy consumption in 1990, increased to 10.8% in 2004, and further rose to 7.4% after 16 years. This indicates that the household sector plays a significant role in the utilisation of RES. The construction industry in Europe has a carbon dioxide (CO2) emission rate that is 36% higher and consumes 40% more energy compared to other sectors. The European Union's framework for decreasing energy consumption in buildings encompasses various policy initiatives, such as the Energy Performance of Construction Directive (EPBD), the Energy Efficiency in Buildings Directive (EED), the Sustainable Design Directive, Energy Labelling Compliance, and the aforementioned Renewable Energy Directive (RED) (Di Foggia 2018; Żywiołek and Schiavone 2021; Tezde et al. 2019).

Ultimately, the policies implemented in European Union countries have progressively increased the importance and role of renewable energy sources (RES) in the energy sector's organisation since the 1990s. The National Energy Efficiency Action Plan 2020 (Varlamis et al. 2022) encompasses all the strategies and initiatives devised to achieve the predicted targets.

The approach to achieving national renewable energy objectives varies across countries and is formulated at various levels, which influences the utilisation of renewable energy sources in residential settings. Energy resources have consistently played a vital role in the survival and development of humanity. Energy resources have a significant influence on both social and economic progress. The advancement of technology, utilisation of energy, and growth in the global population are interconnected to some extent. Ensuring an adequate supply of energy resources for entities such as residential dwellings is vital to meeting fundamental societal requirements. Energy use accounts for a significant portion of household consumer expenditure.

With the rise in environmental consciousness, income levels, the number of children, and solar radiation intensity, there is a greater likelihood that individuals may contemplate investing in renewable energy sources (RES). Compared to the elderly, males and those with higher levels of education had a greater likelihood of engaging in RES initiatives. Age, education, gender, income, and the type of building occupied all affect how socially acceptable renewable energy is. The demographic categories most accepting of RES installation were men, those aged 30-49, those with a secondary technical degree, those with low incomes, and those residing in single-family homes. The justification for RES installation was the anticipated long-term savings, but the biggest barrier was a lack of funding (Appel-Meulenbroek et al. 2018; Yi 2009).

The literature frequently discusses sustainable development, which is crucial for energy management. Most of the current publications contain research on technological solutions or describe in detail a solution promoting a given technology. The table contains the research topic, a specific research gap, or a lack thereof. Table 2 presents the latest research and indicates the gap because none of the research shows the social part, the knowledge of people managing households.

In order to identify the research problem, the data available in the reports of the European Union was thoroughly analysed (Yeo and Marquardt 2015). The data analysis covered the five previous years. In order to define the research problem, technical and statistical reports, as well as available research results, were analysed. Defining a research problem that represents the opportunities and barriers that the use of the IoT brings for home users A survey was conducted among household representatives in Poland, Italy, and Portugal to determine whether consumer behaviour in terms of electricity consumption supports the assumptions of using IoT. The decision on the selection of countries for the study resulted from statistical reports; in the countries mentioned, the highest user involvement in the use of IoT tools for renewable energy sources has been recorded in the last 5 years (Perumal and Sreekumaran Nair 2021; Di Foggia 2018). Only EU countries were taken into account, and the utilisation rate ranged from 27% to 0%. The most frequently reported share in the use of IoT for energy savings is 0%. The survey was conducted among 18,683 consumers in the period using an online survey. The data for the study were collected during the COVID-19 pandemic; however, the method of collecting data via an online form and the subject of households indicate that the pandemic had no impact on the collection of data or the result of the study. The respondents were guaranteed anonymity and voluntary participation in the study. The respondents were selected to participate in the study using a convenient sampling technique. The survey questionnaire used in the study consisted of 26 questions concerning the knowledge and behaviour of consumers related to energy saving. For the purposes of this study, questions related to electricity consumption in households were used. The research group is described in Table 1.

Table 1: Description of the research group

	Description of the Research Group				
1	Sex	Man 67%		Woman 33%	
2	Age	18-29 years	21%	18-29 years	11%
		30-39 years	28%	30-39 years	38%
		40-49 years	34%	40-49 years	32%
		Over 50 years	17%	Over 50 years	19%
3	Education	high school 42%		higher education 58%	
4	Using any source of renewable energy	Yes 100%		No 0%	
5	The level of knowledge about technologies for energy saving	Low 3%	Middle 31%	Higher 38%	Expert 28%

Male respondents account for as much as 67% of those surveyed, but this does not result from EU social statistics; it results from statistics on the gender of the person managing the household in the field of bills and savings. EU statistical results in the years 2020–2023 say that this result is from 65% to 70%, where men manage households in the selection of heating, energy bills, and saving (MALINOWSKI 2012; Du et al. 2022; Carpino et al. 2018).

After doing the study, the results were gathered, analysed, and conclusions made. The poll was divided into many sections, and participants were required to score their opinions on a 7-point scale, where 1 represents full disagreement and 7 represents entire agreement. The first section of the survey focused on consumers' familiarity with renewable energy sources for residential use and aimed to assess their understanding of such sources. The second section of the questionnaire verified which individual in the family is responsible for energy management and energy use. The subsequent section included inquiries on investments in farm-centric solutions that provide advantageous outcomes. This segment also encompassed inquiries about information technology solutions, such as apps. The poll also focused on the accessibility of IoT-related solutions, collaboration between users and producers via assistance, and the adoption of these solutions in homes. People's preferences and future behaviour were evaluated using a 7-point Likert scale. The implementation of this scale enabled the classification of respondents into three categories: low, medium, or high levels of pro-ecological and pro-social attitudes. This classification served as the basis for identifying possibilities and obstacles for various groups of individuals with varied levels of awareness. This division facilitated the development of inferences about their future conduct and the potential for further utilisation of IoT. The research focused on the decisions and future behaviour of future generations. The study included individuals between the ages of 26 and 50, with 54% being male and 46% being female. The sample was deemed to be typical of the population.

Given the following parameters: significance level = 0.01, maximum estimate error d = 1% (u = 3.1426), and assuming that the probability of success p is unknown, European Union member nations, known for their cohesive approach to energy management and conservation, conducted the research. This is evident in their apparent collaboration and comparable level of planning and assumptions.

Utilising diverse question types and the seven-point Likert scale enables the evaluation of citizens' and residents' awareness, facilitating the identification of both challenges and prospects. The writers express their professional aspirations and expectations about the energy economy, primarily emphasising the avoidance of financial losses. Hence, the authors directed their attention towards examining the accessibility of consumer information and their inclination to develop not just tangible abilities but also intangible ones that are embedded inside their knowledge. The research further included an evaluation of client satisfaction with the implemented solutions using the Servqual methodology. We examined the data gathered in a Google spreadsheet using Microsoft Excel, Statistica, and SmartPLS3 for analysis. The authors choose to use qualitative techniques, namely the Servqual approach, together with statistical methods like the student's t-test and SmartPLS3 software, to analyse the data.

4. Empirical Results

These constructs are interrelated in terms of the success of actions taken for managing energy resources and consumer awareness, including According to the findings in Table 2, the average value of increasing consumer knowledge in the area of energy management is moderate (4.11). The other four structures that gauge how well energy is managed have mean values that are, at best, low to moderate. Average values include being responsible for managing energy (2.83), putting solutions into practice (2.37), having access to information and producing knowledge (3.05), and using the Internet of Things (3.12). Our contribution to the study focused on the utilisation of IoT, conducting analyses across a range of age groups, and the effectiveness of energy management while assuming varied levels of awareness. Participants in energy management initiatives are required to disclose their involvement in the survey.

This could potentially influence the perception that current energy management efforts, particularly those that emphasize the use of IoT, are effective. However, we found a range of values for the measured performance constructs. The average values are as follows: adept energy management, high social awareness, improved use-related cooperation, and use of IoT-related solutions. The values demonstrate that varying levels of activity are required to use the IoT for energy management. In reality, the actions of the analysed group of firms demonstrate a modest level of efficacy. Table 2 displays the findings of the complete international survey.

Table 2: Mean values and Cronbach's α coefficient

Variable	Average value	Cronbach's α
Consumer awareness	4,11	0,88
Responsibility for energy management	2,83	0,89
Implementation of solutions bringing economic benefits	3,05	0,81
Availability of information using the Internet of Things	2,87	0,93
Availability of energy management application solutions	2,97	0,89
Improved communication	4,53	0,80
Use of renewable energies	5,79	0,95
Strengthened cooperation on the measures used	3,71	0,86
Better learning	3,69	0,71

The Internet of Things has made it feasible for customers to be more involved and knowledgeable in household energy management, which helps to increase elder consumers' awareness and expertise while simultaneously making it easier for younger consumers to understand how applications and systems work. The Internet of Things is extremely important in this regard because of the expanding accessibility of contemporary systems and the development of a culture of energy conservation. Using the qualitative analyses and the research that has been done, SEM structural equations were also prepared, which determine the relationships between the tested factors (Fig. 3). The main study's findings underwent analysis. First, we determined the total number of ratings for each statement. We used these data to conduct a study on the associations between individual summaries, taking into account the ratings provided (Table 3). The next stage was calculating the standardised Cronbach's alpha using the determined correlations.

Table 3: Relationships between factors.

	I1	I2	I3	H1	H2	H3	C1	C2	C3	G1	G2	G3	M1	M2	M3	M4
I1	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I2	0.933	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I3	0.86	0.76	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
H1	0.68	0.62	0.59	1.00	-	-	-	-	-	-	-	-	-	-	-	-
H2	0.51	0.67	0.61	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-
H3	0.24	0.48	0.27	0.13	0.07	1.00	-	-	-	-	-	-	-	-	-	-
C1	0.17	0.38	0.34	0.11	0.09	0.46	1.00	-	-	-	-	-	-	-	-	-
C2	0.29	0.45	0.17	0.56	0.19	0.06	0.31	1.00	-	-	-	-	-	-	-	-
C3	0.34	0.43	0.28	0.04	0.19	0.02	0.18	0.13	1.00	-	-	-	-	-	-	-
G1	0.21	0.03	0.39	0.08	-0.02	0.42	0.61	0.17	0.51	1.00	-	-	-	-	-	-
G2	-0.04	0.26	0.47	0.11	-0.06	0.37	0.08	-0.02	0.38	0.09	1.00	-	-	-	-	-
G3	0.13	0.02	0.24	0.01	0.11	-0.08	0.18	0.05	0.02	-0.09	0.11	1.00	-	-	-	-
M1	0.03	-0.09	0.12	0.18	0.32	0.16	0.25	0.43	0.01	0.29	-0.03	-0.11	1.00	-	-	-
M2	0.17	0.31	0.16	-0.08	-0.12	0.21	-0.16	-0.21	0.14	0.08	0.18	0.22	-0.06	1.00	-	-
M3	0.05	-0.08	0.27	0.06	0.18	0.38	-0.19	-0.07	-0.12	-0.16	-0.05	0.08	0.14	0.22	1.00	-
M4	0.03	0.22	-0.04	0.11	0.07	0.34	0.01	-0.09	-0.17	0.04	0.38	0.06	0.13	0.39	0.17	1.00

We began examining the results using scale statistics. The variance, mean and standard deviation of a scale made up of all five examined items are shown in Table 4. The adopted scale accepts values ranging from 1 to 75. Average 53,2187 on the scale, or almost 2/3 of the total, seems to be relatively high and reflects respondents' positive attitudes towards environmental preservation and RES.

Table 4: The scale statistics.

Mean	Variance	Standard Deviation
51,06127	96,28315	8,90153

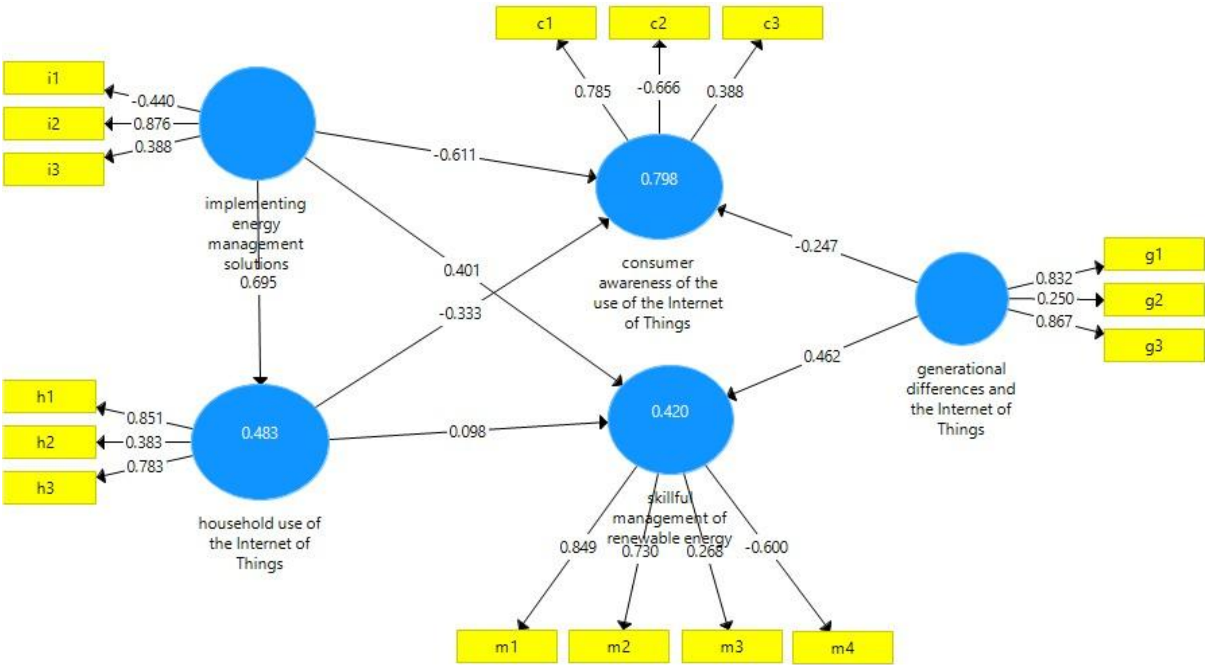

Figure 3: SEM structural equations for renewable energy in households.

Table 4:

Implementing energy Management solutions		Household use of the Internet of things		Consumer awareness Of the use of the internet of things		Skillful management of Renewable energy		Generational differences And the internet of things	
I1	Access to information and knowledge	H1	Choosing the right source of renewable energy	C1	Choosing the right source of renewable energy	M1	Cost management	G1	Generational differences
I2	The use of modern technologic al solutions	H2	Apps	C2	Level of knowledge	M2	Knowledge of energy managem ent	G2	IT resources
I3	Continuous learning in the field of energy management of your household	H3	Consumer involvement in changes in the way energy is managed	C3	Errors in reasoning and using the application	M3	Safety culture	G3	Incorrect reading or interpretation of measurements
						M4	Lack of trust in IT systems		

5. Conclusions

Given that the precision of energy-saving and energy-saving management solutions reflects a favourable stance towards the sustainable operation of society, we can infer from our research that there are statistically significant correlations between energy-saving behaviour and methods of conserving energy, as well as energy-saving management and attitudes towards fostering a sustainable household. These findings align with previous research findings documented in the existing body of literature.

The energy-saving behaviour shown by individuals is a clear demonstration of the environmentally conscious mindset prevalent in this age. Naturally, the prominence of these fundamentals varies to some extent depending on the generation. The findings of our research validate the inclination of young individuals to allocate more funds towards consumption and exhibit superior proficiency in saving. According to the research review, older individuals tend to engage less in these activities owing to variables such as reduced social awareness, limited interest in technical advancements, and a lack of understanding about saving possibilities. While all the energy-saving behaviours we examined had a substantial influence on their adoption of energy-efficient home management systems, it is worth noting the conspicuous omission of considering the user's technical skills. This research aims to address this gap. The findings align with research suggesting that the degree of knowledge among young individuals on the need to conserve energy is substantial. (Bogers 2011; Himeur et al. 2021). The results of our study show that although the percentage of users declaring pro-ecological behaviour in all surveys is still growing, there is a lack of education in this area and low social awareness.

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