

Digitalizing Whom? On the Early Adopters of Smart Energy Technology

BY BORIS ORTEGA MORENO AND LAURA ANDOLFI

Abstract

Digitalization has become an integral part of today's energy system, with households slowly taking on a more proactive role in adopting cutting-edge technologies. This study surveyed Luxembourgish households to characterize early adopters of smart energy technology. The findings show a strong positive correlation among technology awareness, adoption, energy literacy, and some household characteristics. Nevertheless, technology awareness is relatively low, highlighting the need for energy education and increased visibility of smart energy products to encourage adoption.

Introduction

The ongoing renewable energy transition heavily relies on supporting policies and technological innovations. The rapid evolution of technology has positioned digitalization as a crucial factor in ensuring the success of this transition (Veskioja et al., 2022; Xu et al., 2022). Countries like Germany, France, the U.S., and Luxembourg have actively promoted digital technologies due to their numerous social benefits, including increased energy efficiency (Lange et al., 2020; Lin & Huang, 2023), a higher flexibility potential (Baidya et al., 2021; Li et al., 2023), and improved information sharing (Stermieri et al., 2023).

While the potential social benefits of a digitalized energy market are significant, several challenges remain to be solved to fully realize this potential. One key challenge is the uneven adoption of new technologies, which risks exacerbating existing socioeconomic inequalities.¹ The rate of household-level technology adoption is particularly inconsistent. This highlights the need to identify and learn from early adopters to catalyze broader acceptance across the population.

This paper surveys Luxembourgish households to shed light on the demographic profile of early smart technology adopters and suggests possible next steps towards a more widespread adoption.

Context

Luxembourg is undergoing an ambitious digitalization strategy that began with the replacement of all traditional electricity and gas meters with smart meters (European Commission, 2019; Government of the Grand Duchy of Luxembourg, 2020). By 2021, Luxembourg had equipped 95% of its households with smart meters (ACER, 2022), enabling customers to access detailed information about their energy consumption and costs. In addition, in 2021, the main distribution system operator (DSO), Creos, launched Smarty+, a new digital technology and the focus of this study.

The Smarty+ dongle, costing 40€, provides households with detailed real-time insights into their energy data.

When the Smarty+ dongle is connected to the smart meter, households can consult their energy data in real time via the Smarty+ application on a tablet or smartphone. Additionally, they have the option to share their data with Creos, contributing to enhanced management of electricity distribution grids and supporting the energy transition. To date, around 1500 households have adopted the Smarty+ device. However, despite the initial campaign's goal of widespread adoption, little is known about the demographics of the actual adopters, making it difficult to assess the campaign's success and determine future strategies for increasing technology uptake. To address these challenges, this paper performs a household-level survey targeting a sample of the Luxembourgish population.

Survey Design

The survey analyzed in this paper is part of the data collection for FlexBeAn, which aims to study the energy flexibility potential in Luxembourg. Specifically, the survey focuses on the relations between personal characteristics and the intention to provide flexibility with different appliances in households.

The survey was conducted online through three distinct channels: an email outreach to Creos customers, social media platforms, and the personal networks of Creos employees. The email outreach targeted 3,959 customers who requested a power connection upgrade, such as for installing an EV charger or solar panels at their home. To broaden participation, a social media campaign promoted the survey on X and LinkedIn. Additionally, Creos encouraged its employees and their families to participate in the survey.

A total of 544 respondents completed the survey, with 472 from the email campaign, 57 from social media, and 14 from Creos internal campaign. After reviewing the responses, 461 surveys were deemed valid for analysis (395 from the email campaign, 52 for the social media campaign, 14 from Creos internal campaign).

Table 1 summarizes the main characteristics studied in this paper. The variable Smarty+ Adoption only considers households that are familiar with the device. Among those households, approximately 42% have adopted it. However, nearly half of the sample is unaware of this new technology, highlighting a significant gap in awareness. Approximately 88% of the households

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report a net household income above 5,000€ a month. The majority of participants are homeowners, and a substantial portion owns electric vehicles (49%) and solar panels (43%).

Energy literacy measures the understanding of the nature and role of energy in the world and daily lives accompanied by the ability to apply this understanding to answer questions and solve problems (U.S. Department of Energy, 2017). To assess energy literacy, we developed an index based on a comprehensive review of existing literature and incorporated questions from widely used energy literacy surveys. This index evaluates respondents' general knowledge related to energy consumption, generation, and transmission. Scores range from 1 to 13, with higher scores indicating greater energy literacy.

Table 1: Summary Statistics

Variable	Mean	Obs.
Smarty+ Adoption	41.8%	232
Unaware	49.7%	461
Income > 5,000	87.5%	368
Age	48	461
Has Bachelor's Degree or Higher	65.2%	461
Home Owner	92.8%	461
Electric Vehicle	49.2%	461
Solar Panels	43.1%	461
Home Members	2.5	456
Detached Home	46.6%	461
Energy Literacy	7.7	461

Notes: energy literacy represents the average score from 1 to 13. Income is presented in net household income per month.

To mitigate response bias, participants were assured of the anonymity of their answers and test scores (Podsakoff et al., 2003). This anonymity helped encourage honest and uninfluenced responses.

It is important to note that the population sample primarily consists of customers who requested an upgrade of their power connection from Creos. As a result, caution is warranted when generalizing these findings to the broader population.

The Early Adopters

The correlation analysis, illustrated in Figure 1, shows distinct characteristics of early adopters of the Smarty+ device. These adopters are typically older homeowners with higher incomes, residing in detached houses. The analysis also indicates a higher adoption rate among households that own electric vehicles and solar panels, likely because these households perceive greater benefits from using the Smarty+ device. Furthermore, there is a positive correlation between the number of household members and the likelihood of adopting the technology, suggesting that larger households might find the real-time energy insights more valuable for managing their consumption effectively.

Exploring the Awareness Gap

A surprising finding from our survey is that about half of the households reported being unaware of the

Smarty+ device (which differs from households that are aware but decide not to adopt it). This low awareness raises several questions, such as whether marketing campaigns were ineffective or if the unaware households were not initially part of the target group. To explore these questions, Figure 2 highlights the main characteristics of households that are unaware of Smarty+.

On average, unaware households present slightly lower levels of income and education. Younger respondents and women show lower awareness rates compared to their counterparts. Additionally, larger families living in detached homes are less likely to be unaware of the technology. Finally, households that own electric vehicles and solar panels are generally more knowledgeable about the new technology, likely because they are more engaged with advanced energy technologies.

The Role of Energy Literacy

Figure 3 illustrates the correlation among the energy literacy score, SMARTY+ adoption, and unawareness. Among households familiar with Smarty+, higher energy literacy scores are linked to a greater adoption rate of the technology. Additionally, comparing households familiar with Smarty+ to those unaware of it reveals that higher energy literacy scores correspond to increased awareness of this digital innovation. These results suggest a new venue for policymakers and private companies to boost the adoption of these new digital technologies.

Figure 1: Early Adopters of Smarty+

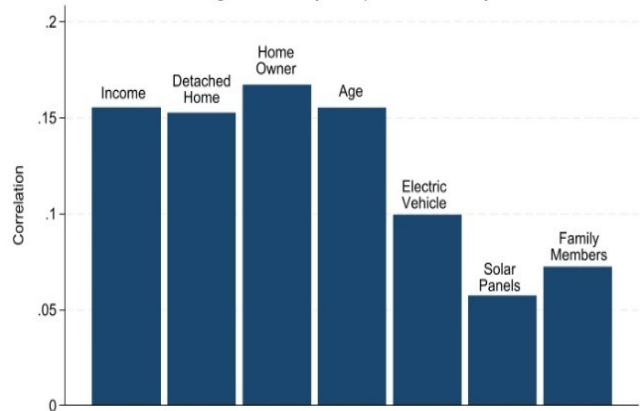


Figure 2: Technology Awareness

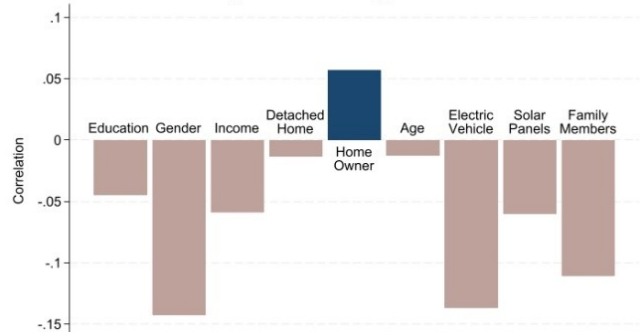
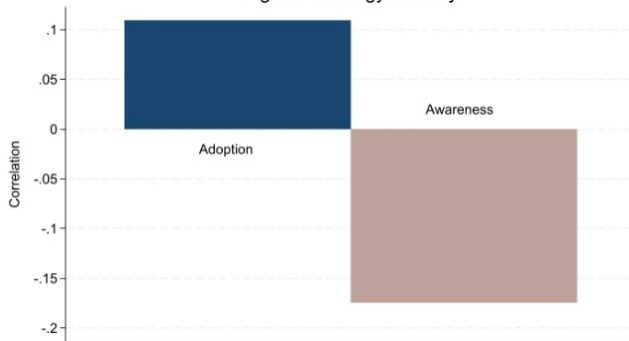


Figure 3: Energy Literacy



Discussion and Implications

The results suggest that relatively wealthier and larger households, particularly those with electric vehicles and solar panels who own their homes, are more inclined to adopt Smarty+. Intuitively, these characteristics increase the potential benefits obtained by a digital technology that allows to optimize consumption patterns. However, these findings also highlight a concerning trend: less wealthy households might be falling behind in profiting from technological advancements. To be able to harvest the full social benefits of such technology, targeted policies should be put in place to mitigate possible undesirable distributional effects. For instance, offering a subsidized version of the Smarty+ dongle may boost adoption rates among lower-income households.

Additionally, this study reveals that technological awareness is low, with only around half of the sample being familiar with Smarty+. This is particularly relevant as awareness serves as the initial step for households to consider adopting new technologies. Moreover, the data reveals that the lack of awareness is disproportionately concentrated among relatively less wealthy and educated households, exacerbating the potential undesirable distributional effects mentioned earlier. Therefore, increasing the visibility of emerging digital technologies like Smarty+ should be a central focus for policymakers and private firms alike. By implementing targeted awareness campaigns and educational initiatives, stakeholders can ensure that all households have equitable access to information about these technologies, thereby fostering more inclusive and sustainable adoption patterns.

Another important factor influencing adoption decisions and technology awareness is energy literacy. The results show a strong positive correlation among these variables, highlighting the importance of energy education in the successful widespread adoption of digital technologies. Intuitively, more energy literate households are more likely to be more aware of the potential benefits of new technologies, increasing the likelihood of adoption. In addition, energy literate households may be inclined to actively seek out innovative ways to save money and contribute to environmental sustainability, enhancing their awareness of digital tools like Smarty+. Consequently, regulators, policymakers, and

private companies may find value in investing in energy education as an additional mechanism to promote the adoption of new digital technologies.

Conclusion and Future Research

Digitalization has become an integral part of today's energy system, with households slowly taking on a more proactive role in adopting cutting-edge technologies. This paper provides a first glimpse at the profile of early adopters of a new digital energy technology in Luxembourg. Additionally, the paper presents new insights on the widespread low awareness of this type of technology and the role of energy literacy. However, some limitations need to be acknowledged.

Firstly, the survey sample may not be fully representative of the Luxembourgish population, potentially limiting the generalizability of the findings. Future research should include a bigger, more representative sample to be able to draw conclusions at the country level. Nevertheless, we anticipate that the results will be robust to a bigger sample size.

Secondly, while this paper considers key demographic characteristics, other factors may influence technology adoption and awareness, such as peer and network effects. Future research could expand on our work by exploring additional relevant factors in greater detail.

Finally, while the results are expected to be robust across developed countries, they may vary in developing country contexts or regions with differing levels of technological penetration (e.g., lower adoption of smart meters). It is anticipated that some factors like income and energy literacy will have an even more prominent role, while others like house ownership, might become less relevant. Consequently, replicating this study in different contexts to test its robustness could be explored in future research.

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Footnotes

¹ See (Castaneda et al., 2017) for an overview of increased socioeconomic inequalities due to solar PV adoption (i.e., the death spiral).