ELECTRIFYING THE FUTURE: THE ROLE OF ENERGY LITERACY IN THE ADOPTION OF SUSTAINABLE ENERGY TECHNOLOGIES

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Overview

Several activities and services, such as transport and heating, are being electrified as part of the energy transition to combat climate change (IEA, 2023). Despite the great benefits of electrification and the active role of policymakers in encouraging this process, the penetration of sustainable energy technologies such as electric vehicles (EVs), heat pumps (HPs), and rooftop photovoltaic (RPV) is still below the necessary to reach the Paris Agreement targets (Breyer et al., 2020). To understand the low adoption rates, much of the literature has focused on the role of socio-demographic factors (e.g., education, income, and household size) and regulatory frameworks (Heiskanen & Matschoss, 2017; Chueca et al., 2023). While the role of education has played a consistent role in the adoption of sustainable energy technologies, recent evidence has pointed out the importance of a specific type of education: energy literacy.

Energy literacy involves understanding the nature and role of energy in daily life and applying this knowledge to solve problems. Evidence suggests that it can lead to better decision-making regarding energy consumption, such as choosing the most cost-efficient appliance and adopting energy-efficient lightbulbs (Filippini et al., 2020; Blasch et al., 2021). Notably, the effects of energy literacy on the adoption of sustainable energy technologies remain an open question (Andolfi & Ortega, 2024).

This paper studies the effects of energy literacy on the probability of adopting one or multiple sustainable energy technologies (e.g., EVs, RPVs, HPs, and home energy management systems (HEMSs)). Using household-level survey data from Luxembourg, we develop a 13-point scale to approximate the level of energy literacy in the population. The analysis relies on (ordered) logistic regression models to first identify the aggregated effects of energy literacy on adopting sustainable energy technologies. Subsequently, the analysis focuses on the effects of energy literacy on the adoption of each technology.

Building upon previous research, our contribution is twofold. First, this paper is among the first to assess the relationship between energy literacy and the adoption of several sustainable technologies individually and as a bundle. This allows us to incorporate numerous technologies that, taken together, lead the way for an electrified society.[1] Second, we run our study in Luxembourg, a high-income country where 95% of households have a smart meter, which allows us to mitigate the effects of confounding factors affecting the adoption of sustainable energy technologies.

The results show positive and statistically significant effects of energy literacy on technology adoption. Additionally, we find that the effect heavily depends on the technology analyzed. For instance, energy literacy has a great effect on EV adoption, but it does not impact RPV adoption. This suggests that tailored energy literacy programs can be a successful strategy to encourage the adoption of electrification technologies. This is particularly relevant in the context of the energy transition as important synergies can be established. For example, households can take advantage of HEMS to optimize the charging of their EVs. By increasing energy education, policymakers can give a positive boost to the adoption of specific electrification technologies.

Methods

The data analyzed in this paper is part of a project which investigates the energy flexibility potential in Luxembourg. The online survey was distributed through three channels: an email outreach to Creos (the main grid operator in Luxembourg) customers, social media platforms, and the personal networks of Creos employees. From the 3,959 surveys distributed, a total of 544 responses were collected, with 472 from the email campaign, 57 from social media, and 14 from the internal Creos campaign. After data cleaning, 461 responses were considered valid for analysis.

To assess energy literacy, we developed an index based on existing literature and included questions from established energy literacy surveys. This index measures respondents' general knowledge of energy consumption, generation, and transmission, and ranges from 1 to 13. Higher scores indicate greater energy literacy. Additionally, we construct an indicator of technology adoption, *tech*. This indicator ranges from 0 to 4 depending on the number of technologies adopted by the household (EV, RPV, HEMS, HP). Further, we analyze the effects on each technology independently. We define four dichotomic variables equal to one if the technology is adopted and zero otherwise.

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[1] The main results presented in this abstract contain four sustainable energy technologies; however, in the extended study a complete analysis is carried out including other technologies such as electricity water heaters and smart home appliances.

The estimation of the effects of energy literacy on the variables of interest relies on (ordered) logistic regression analysis. (Ordered) logistic regression analysis is well-suited due to the nature of the variables of interest. As mentioned above, we analyze an ordered categorical variable, *tech*, that ranges from 0 to 4 and a set of dichotomic variables for each technology. Therefore, the result of the logit model can be interpreted as a change in the probability of adopting specific sustainable energy technologies due to a one-point change in the energy literacy score. Similarly, for the ordered categorical variable, the results represent the probability change of owning a certain number of sustainable energy technologies due to a one-point change in the energy literacy score. We include several control variables, such as demographics and household characteristics.

Results

The preliminary results show that energy literacy has a positive and statistically significant effect on technology adoption (Table 1). A one-point increase in the energy literacy score increases the probability of having two, three, and four technologies by 0.9%, 2%, and 0.4%, respectively. By contrast, the probabilities of having no technologies or one, decrease by 1.4% and 2%, respectively. These effects on technology adoption not only confirm that higher energy literacy leads to higher technology adoption but also higher energy literacy decreases the probability of low technology adoption. This "double" effect reaffirms the positive relationship between these two variables.

Table 1: Marginal Effects on Technology Adoption

Number of Appliances	Marginal Effect	Std. Error
0	-1.39%	0.003
1	-1.95%	0.004
2	0.91%	0.002
3	2.0%	0.005
4	0.4%	0.001

Note: Marginal effects represent the probability response to a one point change in the energy literacy score.

The above effects are stronger when the sample is restricted to household owners (leaving renters out) and when we include households that report the *intention* to adopt the technologies analyzed. Additionally, the preliminary results show heterogeneous effects of energy literacy depending on the technology adopted. The most significant effects are reported for EV and HEMS, while for RPV our results suggest that energy literacy does not play a crucial role. Finally, the survey revealed a low awareness of the HEMS studied in this analysis (about half of the sample). Conditional to being aware of the HEMS, our results suggest a greater effect of energy literacy (compared to analyzing the whole sample), hinting at the importance of widespread knowledge of new technologies.

Conclusions

Understanding what drives the adoption and combined use of sustainable energy technologies is becoming increasingly important to advance towards a successful energy transition. Based on (ordered) logit regressions and household-level data, we study how energy literacy influences the probability of adopting one or multiple sustainable energy technologies. Our preliminary results suggest that higher levels of literacy lead to the adoption of more technologies, but this effect varies by technology. This variation suggests new venues for tailored education strategies. Finally, we must acknowledge the limitations and future research areas of this study. First, the survey targeted a specific sub-sample of the population, with a higher share of wealthy and well-educated early adopters of the studied technologies. To enhance the external validity of the study, a more representative sample is required. Second, while in this paper we consider the adoption of four technologies: EV, RPV, HP, and HEMS, the results could become even more accurate by including other technologies, such as electric water heaters and other whiteware household appliances. This shortcoming is addressed in the extended version of this study. Third, in our sample, some households stated their intention to adopt sustainable energy technologies. Due to the cross-sectional nature of our data, we are unable to follow up on households' behaviour. Future research should focus on understanding and estimating the relationship between the intention to adopt and the actual adoption of these technologies.

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