Filling the Information Gap of House Owners and Technologies: A Design Case Study of a smart recommender for home energy system

In partial fulfilment of the requirement for the degree of

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in

Human Computer Interaction

by

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ABSTRACT

The transition to clean energy and energy-efficient technologies is crucial for reducing carbon emissions and mitigating climate change. However, households lack the sufficient knowledge and guidance on these technologies, including the potential benefits that can be obtained through their adoption. This study aims to fill the information gap and support decision-making on the adoption of clean energy and energy technologies. Design Case Studies will be used as the research framework, and a website software will be developed to provide households with personalised and professional home energy system recommendations and techno-economic assessments. The interfaces will be designed based on the findings from a pre-study conducted through literature review. Real household users will use the intervention and provide feedback through both qualitative and quantitative data collection methods. This research will contribute to the HCI community by providing an understanding of how technology can be used to promote the adoption of clean energy and energy technologies in households, and by identifying the effectiveness of personalised recommendations in supporting behaviour change.

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Notations and Abbreviations

CO_2 Carbon dioxide. 1

EE Energy efficiency. 11

EU European Union. 2, 3, 11, 29

GHG Greenhouse gas. 1

HP Heat pump. 13, 14

NAPE The National Action Plan on Energy Efficiency. 11

PV Photovoltaic. 13–15, 18, 20

RE Renewable energy. 11

SEMS Smart energy management system. 13

Chapter 1

Introduction

Human-induced climate change is causing dangerous and widespread disruption in nature, thereby affecting billions of lives globally. [15]. To tackle climate change and its negative impacts, two main strategies are addressed: climate change mitigation and adaptation.

- **Climate change mitigation** refers to the actions taken to reduce or prevent greenhouse gas (GHG) emissions and ultimately stabilize the concentration of these gases in the atmosphere to limit global warming and its adverse effects [22]. This goal entails a range of related projects, spanning farming, land use, peatland management, renewable energies, and energy efficiency. Integrated projects that implement climate change mitigation strategies and action plans at regional or national levels are also pertinent [6]. Notably, to curb carbon dioxide (CO_2) emissions in the energy system, two main approaches are pursued: *(1) reducing energy consumption on the demand side through* *efficiency improvement and behavioral changes and (2) transitioning to renewable energy sources on the supply side.*

- **Climate change adaptation** encompasses measures to manage the adverse impacts of climate change, such as natural disasters, changes in precipitation patterns, and rising sea levels, among others [22], which includes projects relating to urban adaptation and land-use planning, infrastructure resilience, sustainable water management in drought-prone areas, flood and coastal management, as well as the resilience of the agricultural, forestry, and tourism sectors [6].

The work in this thesis belongs to the category of climate change mitigation.

1.1 Mitigating Climate Change through Energy Transition

The Paris Agreement, a historic international agreement, sets long-term goals to substantially reduce global emissions and limit the global temperature increase to 2 degrees Celsius in this century [24]. To achieve this ambitious goal, the world is facing an unprecedented imperative to a rapid transition in the energy sector. The European Union (EU)'s "Energy 2020. A strategy for competitive, sustainable and secure energy" and "Energy Roadmap 2050" are key strategy papers guiding energy developments in the EU [18], aiming to lead in global climate action and achieve net-zero emissions by 2050 through a socially-fair and cost-efficient transition [5].

1.2 Households in energy transition

Households are a crucial component of the energy transition, as they are responsible for a significant proportion of final energy consumption in the EU, as highlighted by Eurostat's 2023 report. In fact, in 2020, the residential sector accounted for 27.4% of total final energy consumption or 18.7% of gross inland energy consumption in the EU [7]. Therefore, reducing energy consumption in households through energy-efficient building construction and renovations, as well as digitalisation and smart demand-side management, can have a significant impact on achieving the EU's energy and climate targets [13]. This underscores the importance of developing and implementing effective policies and strategies to promote energy efficiency and renewable energy use in households to facilitate the energy transition.

1.3 Technologies for home energy system

Technologies for home energy systems have rapidly advanced in recent years, with a growing focus on energy efficiency and renewable energy sources. Smart home technologies, such as energy management systems, allow households to optimise their energy consumption and reduce waste. Moreover, rooftop solar panels and home battery storage systems enable households to generate and store their own renewable energy, reducing dependence on the grid and lowering electricity bills. In addition, the integration of electric vehicles with home energy systems can further reduce household carbon emissions and provide a source of backup power. These technologies have the potential to significantly transform the way households consume and generate energy, contributing to a more sustainable and resilient energy system.

1.4 Research gaps

Despite the growing availability and accessibility of home energy technologies, there remains a significant information gap regarding their effective utilisation. Government policies aimed at promoting the adoption of these technologies have resulted in an infrastructure that supports the use of electricity and lowers the costs of using renewable energy. However, a survey conducted by Palmer et al. identified a lack of knowledge and guidance among homeowners, preventing them from maximising the benefits of these investments in terms of reducing future energy expenses [20]. As a result, there is a research gap in exploring effective ways to educate and inform house owners on the utilisation of home energy technologies.

1.5 Research questions and aims

The following research questions will guide this study:

1. How can HCI help fill the information gap in households' knowledge of energy technology and support decision-making on the adoption of clean energy and energy-efficient technologies?
2. Is the information making a difference?

The aim of this study is to address the information gap and support homeowners in their decision-making process regarding the adoption of clean energy and energy-efficient technologies. The study also seeks to evaluate the effectiveness of such a nudging approach.

The following research objectives will aid in answering the research questions:

- Conduct a thorough review of relevant literature to identify existing gaps and opportunities in the field.
- Develop a user-friendly and accessible interface for providing information about energy-efficient technologies and their benefits to households.
- Design and implement interactive tools that enable households to estimate the costs and benefits of adopting different energy-efficient technologies and renewable energy sources.
- Conduct user studies to evaluate the impact of the developed interventions on households' thoughts of energy-efficient technologies and renewable energy sources, using both quantitative and qualitative methods.
- Analyse the data collected from the user studies to gain insights into the users' needs and preferences, as well as the effectiveness of the interventions.
- Write the thesis that presents the findings, conclusions and recommendations based on the research conducted.

This thesis aims to contribute to the HCI community by exploring the use of technology to fill the information gap in households' knowledge of energy technology and support decision-making on the adoption of clean energy and energy-efficient technologies. It will offer insights into the design and development of personalised and professional home energy system recommendations and their effectiveness in promoting the adoption of those technologies. The study will also provide insights into the user experience of the intervention and how it can be further improved to support sustainable energy choices. Overall, this thesis seeks to advance the understanding of the role of technology in promoting sustainable energy consumption in households, and its findings can inform the development of future HCI interventions to address environmental challenges.

1.6 Supervision and planning

The proposed thesis project will combine research and application aspects, which is important because it will allow for a comprehensive understanding of the topic being studied. Conducting a thorough literature review will provide a strong foundation for the research, while the development of software applications will allow for practical implementation of the findings. In addition, interviews with industry professionals and stakeholders will provide valuable insights into the real-world challenges and opportunities in the field. Finally, the evaluation process will involve much data analysis, enabling the research to draw valid and reliable conclusions. Thus, the proposed thesis project will contribute to a well-rounded and informative study, and is believed to be justified for 30 credits.

1.6.1 Supervision

This master thesis project will be supervised by Prof. Dr. Gunnar Stevens (gunnar.stevens@uni-siegen.de) at Siegen University and Dr. Songming Yu (songmin.yu@isi.fraunhofer.de) from The Fraunhofer Institute for Systems and Innovation Research.

1.6.2 Time planning

The following is the time allocation for the research objectives, which are scheduled to be completed in 26 weeks.

1	Literature review
2	Design interfaces
3	Develope the software tool
4	User studies
5	Analyse data
6	Write thesis

Table 1.1: Research objectives

		1	**2**	**3**	**4**	**5**	**6**
	w1						
	w2						
Feb	w3						
	w4						
	w5						
	w6						
Mar	w7						
	w8						
	w9						
	w10						
Apr	w11						
	w12						
	w13						
	w14						
May	w15						
	w16						
	w17						
	w18						
	w19						
Jun	w20						
	w21						
	w22						
	w23						
Jul	w24						
	w25						
	w26						

Table 1.2: Time planning

Chapter 2

Methodology

The methodology adopted in this study is based on the Design Case Studies framework. The pre-study phase will begin by conducting a comprehensive review of the literature to identify best practices for providing households with personalised and professional home energy system recommendations, as well as techno-economic assessments. Based on the findings from the pre-study, I will then design the interfaces of the intervention. The interfaces will be developed to provide an intuitive and user-friendly experience that can easily be understood by households. Following the development phase, real users will be invited to use the intervention, and feedback will be collected both qualitatively and quantitatively. The qualitative data will be collected through interviews with participants, while the quantitative data will be collected through surveys. Finally, the collected data will be analysed to evaluate households thoughts about the recommendations and energy technologies. The entire process will be documented and reported in the form of a thesis.

Appendices

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