

**Designing an explainable techno-economic  
assessment software for household energy  
system: A case study for the newTRENDS  
project**

In partial fulfilment of the requirement for the degree of

**MASTER OF SCIENCE**

in

**Human Computer Interaction**

*by*

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# ABSTRACT

Text...

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# Notations and Abbreviations

**EU** European Union. [2](#), [15](#)

**GHG** greenhouse gas. [1](#), [2](#)

**PV** photovoltaic. [7](#)

# Chapter 1

## Introduction

Human-induced climate change is causing dangerous and widespread disruption in nature and affecting the lives of billions of people around the world [[IPCC, 2022](#)]. To tackle climate change and its negative impacts, two main strategies are addressed: climate change mitigation and adaptation. Mitigating climate change means cutting and sequestering emissions of greenhouse gases (GHG) to prevent further increases in their atmospheric concentrations [[Ruth, 2017](#)]. Adaptation means finding ways that can help reduce the impacts of climate change on society, the various sectors of its economy, and the places in which we live [[Ruth, 2017](#)]. These terms go hand-in-hand while navigating through the climate crisis [[World Wildlife Fund, 2023](#)].



## 1.1 Climate change mitigation

The historic Paris Agreement sets long-term goals to guide all nations to substantially reduce global GHG emissions to limit the global temperature increase to 2 degrees Celsius in this century [UNFCCC, 2015]. On European Union (EU) level, “Energy 2020. A strategy for competitive, sustainable and secure energy”, published in November 2010, and “Energy Roadmap 2050”, published at the end of 2011, are the most important strategy papers currently, pointing the direction for energy developments in the EU [Langsdorf, 2011]. The aim is to confirm Europe’s commitment to lead in global climate action and to present a vision that can lead to achieving net-zero GHG emissions by 2050 through a socially-fair transition in a cost-efficient manner [European Commission, 2018].

### 1.1.1 Energy transition

## 1.2 The newTRENDs Project

The aim of NewTRENDs is to increase the qualitative and quantitative understanding of impacts of New Societal Trends on energy consumption and to improve the modelling of energy demand, energy efficiency and policy instruments [Fraunhofer ISI, 2023].

### 1.2.1 Background

With increasing renewable generation integrated into the power system, supply-side fluctuations must be balanced by demand-side flexibility. Electrification and demand response (DR) are becoming increasingly relevant to the heating transition of buildings, which demands the diffusion of

- heat pumps (HPs),
- photovoltaic (PV) and energy storage (e.g., battery and hot water tank),
- smart energy management systems (SEMSs).

Combining the three technologies is also beneficial from an individual household (or building) perspective. The household can optimize the heat pump operation to reduce energy costs by saving energy in the tanks or pre-heat the building when the electricity price is lower. Besides, the energy-saving benefit could be further increased with PV and battery system. From a market perspective, DR flexibility and PV generation also facilitate the concept of "energy community". The households can trade electricity with each other (peer-to-peer, P2P) within a local micro-grid or even trade with the other side of the country through the national grid, depending on the infrastructure, business model, and policies. In addition, households can also buy the services from an "aggregator", who bundles and manages the flexibility of small consumers and producers and participate in the market activities (Kerscher and Arboleya 2022). Promoted by the declining costs of technologies and support policies, more and more household "consumers" are

expected to become "prosumers" (with PV) and "prosumagers" (plus energy storage and SEMS) (Fereidoon Sioshansi 2019).

## FLEX models

The FLEX-Operation and FLEX-Community models were built to improve the building modeling suite and to analyze the societal trends of prosumaging and energy communities. The figure 1.1 shows how FLEX interacts with other bottom-up models involved in the newTRENDS project.

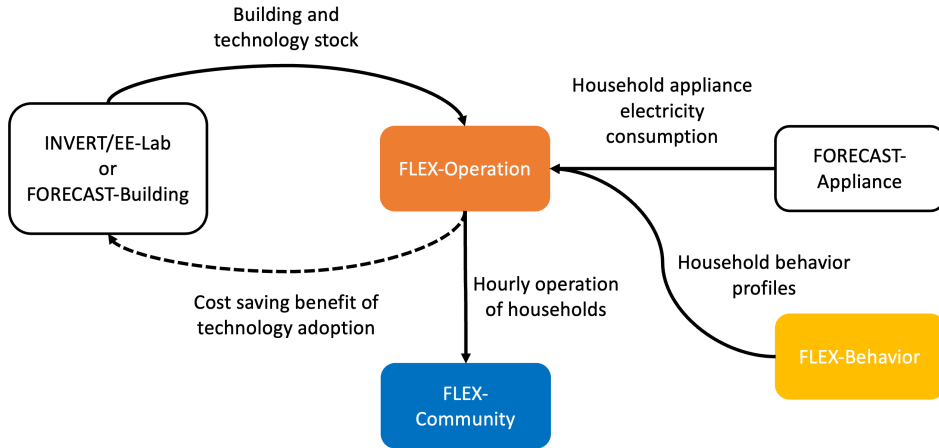


Figure 1.1: FLEX modeling suite

INVERT/EE-Lab and FORECAST-Appliance are the two models that can cover the energy consumption of residential buildings. The two models complement each other and cover the total energy consumption of households. However, both INVERT/EE-Lab and FORECAST-Appliance calculate the energy consumption at the annual resolution and cannot model the prosumaging behavior and energy community, which requires an hourly resolution to consider the impact of household behavior, PV generation, and

energy storage (thermal and battery) on energy consumption. In this regard, we developed the FLEX- Operation and FLEX-Community models to improve the building modeling suite and support relevant policy analysis.

### **FLEX-Community**

FLEX-Community models the operation of an energy community, i.e., household interaction, aggregator optimisation. It can be applied to support the aggregators designing and evaluating business models, as well as making investment decisions, for example, the self-owned battery, PV panels, etc.

### **FLEX-Behavior**

FLEX-Behavior models the behavior (activity profile) of households' and corresponding load profiles. It generates the hourly activity and energy demand profile of a pre-defined individual household. The results include

1. appliance electricity demand,
2. domestic hot water demand,
3. driving profile, and
4. building occupation.

### **FLEX-Operation**

FLEX-Operation models the energy system operation of an individual household in hourly resolution. It calculates the energy consumption of each rep-

representative building, including operation of technologies (e.g., battery, PV, heat pump, etc.) and load profiles in hourly resolution.

Data is considered by the model

- building,
- heating system (heat pump, fuel-based boiler, electric heater),
- thermal storages for space heating and domestic hot water,
- space cooling technology,
- PV,
- battery, and
- electric vehicle.

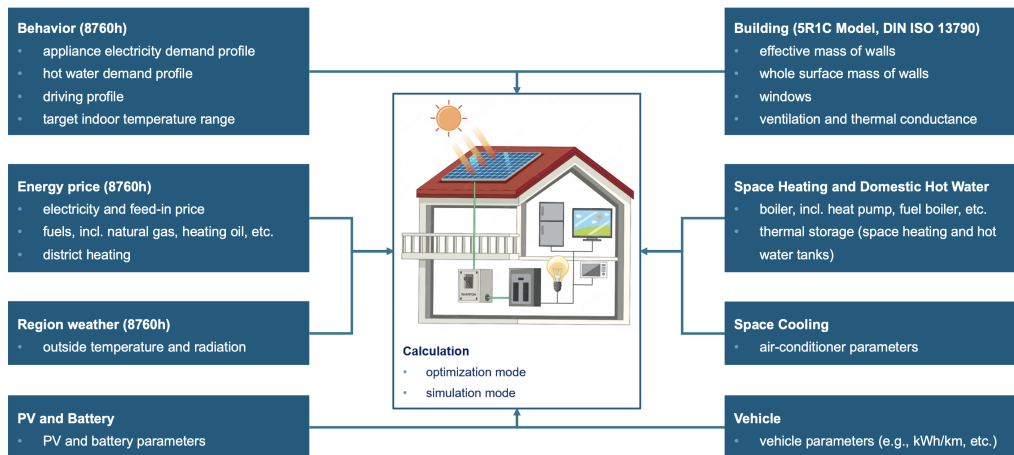


Figure 1.2: FLEX-Operation

## 1.3 Motivations

As a part of the newTRENDS project, the proposed thesis will focus solely on the implementation of the FLEX-Operation model. By employing the model to suggest reliable, cost-effective energy optimisation solutions while giving households with comparable predicted statistics on their energy consumption for the time frame. Despite the fact that the model primarily responds to societal trends for 2030, which means it provides more flexible suggestions when a household already owns a photovoltaic (PV) system, this could be as well an opportunity to nudge the European households who currently rely on other energy resources to switch to renewable energy when feasible. And it will be beneficial not only to the environment but also to consumers.

### 1.3.1 Research gaps and questions

There is a lack of case study research of promoting energy optimisation solutions. The aim of this proposed thesis is to design and develop a user-friendly web application for recommending energy optimisation solutions.

The following criteria should be taken into account while building a software application from a user's perspective:

- It should be easy and effortless for using.
- The interactions should be intuitive.
- The recommendations should be clear explained to users.

Objectives:

- Investigate the data of the FLEX-Operation model to build an energy optimisation recommendation system.
- Determine the typical European household types.
- Design the web application with user-centred approaches.
- Use data visualisation techniques to provide explainable suggestions.
- Develop the frontend and backend web application.
- Evaluate the explainability of the smart energy optimisation recommender at the user level and measuring the impact of the households perceptions towards energy optimisation solutions.
- Allow long-term event tracking for iteration.

Research questions:

1. What are the data required by the FLEX-Operation model from households?
2. What are the typical European household profiles?
3. How to build a trustworthy and user-friendly energy optimisation recommendation system?

Is there any literature review to add?

## **1.4 Supervision agreements and time planning**

Introductory lines...

### **1.4.1 Justification for 30 ECTS**

Research + design + develop

### **1.4.2 Supervision**

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

### **1.4.3 Time planning**

Some text



1	Investigate the data of the FLEX-Operation model to build an energy optimisation recommendation system.
2	Determine the typical European household types.
3	Design the web application with user-centred approaches.
4	Use data visualisation techniques to provide explainable suggestions.
5	Develop the frontend and backend web application.
6	Evaluate the explainability of the smart energy optimisation recommender at the user level and measuring the impact of the households perceptions towards energy optimisation solutions.
7	Allow long-term event tracking for iteration.

Table 1.1: Objectives

		1	2	3	4	5	6	7
<b>Feb</b>	w1							
	w2							
	w3							
	w4							
	w5							
<b>Mar</b>	w6							
	w7							
	w8							
	w9							
	w10							
<b>Apr</b>	w11							
	w12							
	w13							
	w14							
	w15							
<b>May</b>	w16							
	w17							
	w14							
	w15							
	w16							
<b>Jun</b>	w17							
	w18							
	w19							
	w20							
	w21							
<b>Jul</b>	w22							

Table 1.2: Task planning

# Chapter 2

## Methodology

Introductory lines...

### **2.1 Design case studies**

Some text here ...

### **2.2 Grounded design**

# Appendices

# Bibliography

- [Anderson, 2012] Anderson, A. (2012). Climate change education for mitigation and adaptation. *Journal of Education for Sustainable Development*, 6(2):191–206.
- [Bertram et al., 2021] Bertram, C., Riahi, K., Hilaire, J., Bosetti, V., Drouet, L., Fricko, O., Malik, A., Nogueira, L. P., van der Zwaan, B., van Ruijven, B., van Vuuren, D., Weitzel, M., Longa, F. D., de Boer, H.-S., Emmerling, J., Fosse, F., Fragkiadakis, K., Harmsen, M., Keramidas, K., Kishimoto, P. N., Kriegler, E., Krey, V., Paroussos, L., Saygin, D., Vrontisi, Z., and Luderer, G. (2021). Energy system developments and investments in the decisive decade for the paris agreement goals. *Environmental Research Letters*, 16(7):074020.
- [Brugger et al., 2021] Brugger, H., Eichhammer, W., Mikova, N., and Dönitz, E. (2021). Energy efficiency vision 2050: How will new societal trends influence future energy demand in the european countries? *Energy Policy*, 152:112216.
- [European Commission, 2018] European Commission (2018). A clean planet for all. a european long-term strategic vision for a prosperous, modern, competitive and climate neutral economy.

- [Fraunhofer ISI, 2023] Fraunhofer ISI (2023). Newtrends: New trends in energy demand modeling.
- [IEA, 2021] IEA (2021). Key world energy statistics.
- [IPCC, 2022] IPCC (2022). Climate change: a threat to human wellbeing and health of the planet. taking action now can secure our future.
- [Lacal Arantegui and Jäger-Waldau, 2018] Lacal Arantegui, R. and Jäger-Waldau, A. (2018). Photovoltaics and wind status in the european union after the paris agreement. *Renewable and Sustainable Energy Reviews*, 81:2460–2471.
- [Langsdorf, 2011] Langsdorf, S. (2011). [EU](#) energy policy: from the ecsc to the energy roadmap 2050. *Green European Foundation: Brussels, Belgium*.
- [Ruth, 2017] Ruth, M. (2017). *Handbook of Climate Change Mitigation and Adaptation*. Springer Nature, 2 edition. Foreword.
- [UNFCCC, 2015] UNFCCC (2015). Paris agreement. In *Paris Climate Change Conference*.
- [World Wildlife Fund, 2023] World Wildlife Fund (2023). What’s the difference between climate change mitigation and adaptation?
- [Yu et al., 2022] Yu, S., Mascherbauer, P., and Kranzl, L. (2022). New trends in energy demand modeling.