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Abbreviations

Abbreviation	Term
A/C	Air Conditioning
AC	Alternating Current
AFM	Automated Flexibility Manager
API	Application Programming Interface
BUC	Business Use-Cases
BSEs	Balancing Service Entities
COSEM	Companion Specification for Energy Metering
DH	District Heating
DLMS	Device Language Message Specification
DoA	Delegation Of Authority
DPIA	Data Protection Impact Assessment
DR	Demand Response
DSO	Distribution System Operators
EAB	Ethics Advisory Board
EU	European Union
EUI	End User Interface
FFNN	Feed Forward Neural Network
GDPR	General Data Protection Regulation
HAN	Home Area Network
HEMS	Home Energy Management System
HOAS	Foundation for student housing in the Helsinki region
HVAC	Heating, Ventilation, And Air Conditioning
IC	Information Commissioners
iFA	iFLEX Assistant
IHD	Energy House Display
IoT	Internet Of Things
ISP	Integrated Scheduling Process
JCA	Joint Controller Agreement
KPI	Key Performance Indicators
LightGBM	Light Gradient-Boosting Machine
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MSE	Mean Squared Error
NMS	Network Management System
NODE	Neural Ordinary Differential Equations
NRMSE	Normalised Root Mean Square Error
ODE	Ordinary Differential Equation
OSI	Open Systems Interconnection
PLC	Power-Line Communication

PURES	"Pravilnik O Učinkoviti Rabi Energije V Stavbah" (Regulation On The Efficient Use Of Energy In Buildings)
PUSH	Help Of Schedules According to The PUSH Principle
PV	Photovoltaic
QR	Quick Response Code
RAI	Resource Abstraction Interface
RC	Radio Controlled
RE	Relative Error
RES	Renewable Energy Sources
REST	Representational State Transfer
RF	Radio Frequency
RMSE	Root Mean Square Error
SotA	State-Of-The-Art
TRL	Technology Readiness Level
TSO	Transmission System Operator
UEQ	User Experience Questionnaire
UI	User Interface
UTC	Universal Time Coordinated
VPP	Virtual Power Plant

1 Executive summary

Deliverable D7.7 serves as the third consecutive validation document that provides a summary of the outcomes from the third pilot phase conducted in three pilot clusters: Greece, Finland, and Slovenia. The document encompasses the findings and conclusions obtained from this phase of the project's validation process, offering insights into the performance and effectiveness of the implemented solutions within each pilot region.

The Greek pilot aims to address imbalances in the generation of a 500 kW PV plant owned by OPTIMUS by demonstrating the interaction between renewable energy sources (RES) and demand response (DR) aggregators. In the first two phases several challenges were identified which required partial redesign of the Greek pilot. The third phase built upon the experience accumulated through the first two phases trials in which HERON's energy monitoring infrastructure was deployed and tested.

The Slovenian pilot added new households and industrial clients in the large-scale deployment phase. They were equipped with the home energy management system (HEMS) for remote control and data collection of users devices. There were also deployment of end user interface (EUI) which procedure enables connection to resource abstraction interface (RAI). Few improvements were added to RAI too and some of them were quite important.

The Finnish pilot focused on the iFLEX Assistant which aimed to provide users with personalized energy-related recommendations. The iFLEX Assistant was deployed into two large buildings: an apartment building and a supermarket linked through MakingCity co-operation. Both buildings are connected to Enerim's aggregation platform and via MQTT interface of the AFM module. There was also organized a common pilot with the OneNet project which aimed to demonstrate how demand flexibility can be used to solve bottlenecks in the TSO and DSO network.

The validation plan in the iFLEX, outlined in D7.4 [1], encompasses end-user, technical, and business aspects. End-user validation, focusing on functionality, usability, and pleasure, varied across pilots. Greek validation utilized a User Experience Questionnaire (UEQ), while Slovenia conducted interviews and interface tests. The Finnish pilot assessed comfort alongside user perceptions. Technical validation involved requirements and pilot testing. Business validation employed a 3-step approach to evaluate iFLEX's business potential. Additionally, KPI validation was conducted in post-phase 3. Adjustments were made to methods and activities as pilots progressed to ensure alignment with specific contexts and objectives.

In the Greek pilot cluster, a workshop in Athens gathered feedback on the iFLEX Assistant's objectives and Phase 2 implementation. A survey with 15 participants revealed positive responses. 79% showed interest in personalized advice and found the app easy to use. The Landing Page and Tariff changes received mostly positive ratings. While Auto Mode lacked interest, participants engaged through goal notifications and setting personal goals.

The Slovenian segment of the iFLEX project engaged users through tailored recruitment, workshops, and local events. Testing campaigns and End User Interviews gathered feedback on the End User Interface (EUI) app. Strategies included personalized mailings and notifications to guide users in managing preferences, monitoring consumption, and setting objectives. Participants appreciated the ease of use of the app but sought clearer instructions and more concise data presentation. They expressed willingness to engage in demand response events and trust in digital assistants for energy optimization. Feedback informs app improvements, aiming for a user-friendly interface aligned with diverse user needs and preferences.

In the Finnish pilot of the iFLEX project, user recruitment involved email invitations to residents of a pilot building, with prizes offered for registration. Apartment-specific sensors were installed for 9 registered users, allowing monitoring of temperature, humidity, and CO_2 levels. Test periods involved intermittent heating cuts to assess demand response. Feedback was collected through online surveys in all three phases, revealing increased energy awareness, willingness to engage in demand flexibility, and positive experiences with the project. Despite small survey samples, trends showed heightened energy consciousness, a desire for more information, and a positive perception of the iFLEX project among participants.

The technical validation of the iFLEX Assistant (iFA) was conducted through pilots in Greece, Slovenia, and Finland, focusing on the implementation and testing of its components. In the Greek pilot, extensive functional, unit, and integration testing was performed to ensure the interoperability of iFA components, culminating in the decision to host the system on Heron's server due to implementation issues. The Slovenian pilot gradually introduced iFA components in all phases, validating them through large-scale pilot tests, smart meter integration, and updates to the end-user interface. These tests included experiments comparing the iFA’s performance to traditional methods, particularly focusing on Automated Flexibility Management (AFM). In Finland, the validation process spanned phases 2 and 3, incorporating a supermarket pilot alongside the existing apartment building tests. System tests confirmed the functionality of Demand Response (DR) solutions with ENERIM’s Aggregation Platform, with a focus on improving modelling accuracy. Each pilot's requirements and their implementation were documented, highlighting the various functionalities tested and validated across different scenarios. These efforts collectively ensured that the iFA met its designed specifications and demonstrated effective interoperability in real-world environments.

2 Introduction

Document D7.7 provides a comprehensive overview of the final third pilot phase of the iFLEX project across Greece, Finland, and Slovenia. This section introduces the purpose, context, and scope of the document, emphasizing its significance in evaluating the performance and effectiveness of implemented solutions within each pilot region. It outlines key objectives, including addressing imbalances in renewable energy sources, establishing residential energy management systems, and providing personalized energy recommendations. Additionally, the introduction underscores the importance of end user validation, technical validation, and business validation in assessing various facets of the iFLEX project's implementation and impact.

2.1 Purpose, context and scope

This document serves as a validation report for the final third pilot phase conducted in three pilot clusters: Greece, Finland, and Slovenia. It provides a summary of the outcomes obtained from this phase, highlighting the performance and effectiveness of the implemented solutions within each pilot region. The Greek pilot focuses on addressing imbalances in a PV plant owned by OPTIMUS through the interaction between renewable energy sources and demand response aggregators. The Slovenian pilot aims to establish a pilot area with residential and small business users equipped with home energy management systems. The Finnish pilot emphasizes the iFLEX Assistant, providing personalized energy-related recommendations. The document also includes the results of the end user validation process and a comprehensive business analysis. Additionally, it summarizes the current values of various key performance indicators (KPIs) measured after each pilot phase, encompassing stakeholder contributions, accuracy of load forecasting and flexibility modelling, effectiveness of automated flexibility management, level of interoperability, compliance with privacy and data management regulations, return on investment, technology readiness, demand response services, number of consumers, and targeted consumer groups.

2.2 Content and structure

Document D7.7 is structured into six main chapters, each focusing on different aspects of the iFLEX project and its pilot deployments in phase 3. These chapters provide valuable insights and information regarding various stages of the project:

- Large-Scale Pilot Deployment in Phase 3
  This chapter details the progress made in integrating the iFLEX Framework for end-users during the large-scale pilot deployment. It highlights the advancements and developments made in implementing the framework within the pilot regions.
- Validation Plan for Phase 3
  In this chapter, the validation procedures employed during phase 3 are described. It outlines the systematic approach taken to validate the effectiveness and functionality of the iFLEX project, ensuring its alignment with the project's objectives.
- End User Validation
  This chapter focuses on the validation process involving end-users. It presents the methodology used and the results obtained from public surveys and interviews conducted in each pilot region (Greek, Slovenian, and Finnish). The survey results are presented in statistical and graphical form. Additionally, the chapter discusses the outcomes and methods used for the usability test of the iFLEX graphical user mobile application.
- Technical Validation
  This chapter is dedicated to the technical validation of the iFLEX assistance blocks at the regional level within each pilot region. It delves into the validation process, examining the technical aspects of the project and ensuring its smooth operation.
- Business Validation
  The business validation chapter focuses on evaluating iFLEX business potential in three steps: defining baseline smart-grid business models using Value Network and Business Model Canvas methodologies; creating iFLEX-enabled business models based on Business Use-Cases (BUCs); and conducting a techno-economic analysis to assess viability and profitability, adapting models for different pilot countries.
- Validation Progress Monitoring:

The final chapter covers the monitoring of validation progress through Key Performance Indicators (KPIs). It presents a KPI table that tracks the achievement of objectives during all three pilot phases, providing a snapshot of the project's overall progress.

Through these chapters, Document D7.7 offers a comprehensive and structured overview of the iFLEX project's pilot deployments, validation processes, and progress monitoring.

3 Pilot deployment phase 3 (large-scale pilot)

The third phase of pilot deployments in the iFLEX project marks advancement in the implementation of innovative energy management solutions across various European countries. In Greece, the pilot led by HERON and Optimus Energy addresses challenges in user recruitment and IoT device deployment to enhance energy flexibility and management. Expansion includes smart metering, relay-controlled boilers, and smart plugs for data collection, aiming at optimizing energy usage and managing flexibility requests at individual premises. The iFLEX Assistant receives feature enhancements, and new PV plants join the portfolio for coordinated operation with demand response, showcasing a comprehensive approach to residential energy management and renewable integration.

Concurrently, the Slovenian pilot phase demonstrates substantial progress in deploying and refining household and industrial energy management systems. Through the integration of systems for electricity generation, heating, and data monitoring with Home Energy Management Systems, users gain control and monitoring capabilities, while industrial setups focus on minimizing disruptions to production processes. The streamlined deployment of the End User Interface and updates to the Resource Abstraction Interface facilitate real-time data collection and aggregation, supporting use case experimentation and adaptation to new tariff systems. Notably, successful predictions of household thermal parameters and automated flexibility management illustrate the potential for optimizing energy usage, enhancing user comfort, and promoting sustainable energy practices.

Additionally, the Finnish pilot demonstrates sophisticated energy management strategies in apartment and supermarket buildings, emphasizing demand response, cost reduction, and CO_2 emission minimization. Through advanced modeling methods and flexibility activation tests, significant improvements in baseline load and flexibility forecasts are achieved, showcasing the effectiveness of innovative technologies in achieving energy efficiency and sustainability goals.

3.1 Greek large-scale pilot deployment

During the large-scale pilot deployment (Phase 3) Greek pilot partners (HERON & OPTIMUS Energy) demonstrated the interaction between RES and DR Aggregators as a means of mitigating the imbalances in the generation of the 500 kW PV plant owned by OPTIMUS. The iFLEX Assistant was integrated and tested in HERON's EnergiQ mobile application also developed in the context of the iFLEX project.

Specifically, HERON mainly focused on demonstrating the following use cases from D2.1 [2]: BUC-5 concerning customer's load profile analysis/overview, the deployment of HLUC-1 concerning energy management in an optimal way as, well as HLCU-2: Manage flexibility requests or price signals at individual premise level. HERON's customers participating in the pilot and equipped with smart relay were asked to offer balancing services to OPTIMUS Energy based on the scheduled use of their water boiler. This allowed OPTIMUS Energy to demonstrate HLUC-1 concerning energy management in an optimal way and HLUC-2: Manage flexibility requests or price signals at individual premise level.

Furthermore, Phase 3 expanded available flexibility through, real-time advice offered to those who had a smart plug installed to monitor the usage of their washing machines, dishwashers, A/C units or other heavy consumer appliances (appliances that consume the majority of electrical energy). In order to do so, HERON's Pilot Phase 1 and 2 setups were extended, building on the Phase 2 infrastructure enhancements. These extensions enabled more residential customers to participate by using their smart meters and smart plugs, even for those who did not have remotely controlled relays. Those users provided their consumption data enabling the setting of consumption and CO_2 generation rules through the iFLEX Assistant, promoting sustainable consumption based on the ability to set and track goals, and customized energy advice. Finally, through HERON's mobile app, pilot participants were informed on the hours of the day with high Renewable Energy Sources (RES) in the system as additional means to turn their consumption more renewable energy driven.

The aforementioned Phase 3 capabilities required significant expansion in the infrastructure of the Greek pilot: most notably in HERON's Smart Metering Platform (HERON Energy Control) and its interface with iFLEX RAI and in the offered visualizations through Phase 1 & 2 Grafana Dashboards and Phase 3 EnergiQ mobile app.

3.1.1 Phase 3 expansion of the Greek pilot API infrastructure

As mentioned, in Phase 3 the Greek pilot builds upon the experience accumulated through Phase 1 and 2 trials in which HERON's energy monitoring infrastructure was deployed and tested. In Phase 1, a number of selected users had a smart meter installed in their homes and could access their electricity consumption, active power and power factor calculations. Through an API, HERON's platform was integrated into iFLEX RAI allowing data crucial for the iFLEX Assistant to be harvested. In Phase 2, HERON API was updated to include more IoT devices, while the electrical boiler's remote control through a relay was tested in a lab environment. With the increase of IoT devices available to each household, HERON's hierarchy of devices was updated for the final deployment and validation of the Greek pilot in Phase 3. HERON Energy Control and the API integrated in iFLEX RAI had three major updates:

- Introduction of a new API request "home" which returns the anonymized (under an alpha-numeric identification i.e. home39) list of households.
- Overhaul of the API request "devices" to include keys identifying the home in which a device belongs to and assigning devices to multiple new appliances including smart meters attached in Heat Pumps and Electric Vehicle chargers. Although Heat Pump and EV smart meters share the same interface with the smart meter attached in house electrical board (fuse box), they measure a subset of the household consumption and hence are modelled as new and distinct data type.
- Introduction of a new API request "notifications" facilitating the interface between HERON Energy Control and EnergiQ with iFLEX Assistant through iFLEX RAI.

Phase 3 "home" API request

HERON API provides a list of iFLEX households through: GET: https://<domain>/api/v1/homes and GET: https://<domain>/api/v1/homes/home_id

```
{
      "home_id": "1",
      "devices": [
                  {
                  "deviceid": "domxem-05CBCF",
                  "device_type_text": "1-phase EM",
                  "device_name": "XYX-meter",
                  "device_type": 1,
                  "home_id": "XYZ",
                  "registeredat": "2024-01-22T12:02:45.964Z"
                  }
      ]
}
```

It should be noted that "XYZ" used in the examples, denotes the pseudo-anonymized alphanumeric identifier of a household.

Phase 3 overhaul "devices" API request

HERON API updated "devices" API request so that it can assign a device at a specific household (house_id) and give it an appropriate appliance type. To this end, "device_name" provides the appliance type assigned from HERON, with “device_apliance_name” taking values from a set of universal appliance types that cannot be modified by application users (Table 1). It should be noted that app users can change “device_name”.

GET All Devices: GET: https://<domain>/api/v1/devices
Required: none
Optional: “tag”
Body: empty
Response 200 (Regular & Project User):


```
[
	{
	"deviceid": "domxem3-XXXXXXXXX",
	"device_type_text": "3-phase EM",
	"device_type_name": "SHELLY_EM_3PH",
	"device_name": "XYZ-meter",
	"device_type": 2,
	"home_id": "XYZ"
	“registerdat”: “XXXX-XX-XXTYY...”,
	“device_appliance_type”: “HOME”
	},
	"deviceid": "domxem3-XXXXXXXXX",
	"device_type_text": "Shelly Plug",
	"device_type_name": "SHELLY_PLUG",
	"device_name": "XYZ-Dishwasher",
	"device_type": 4,
	"home_id": "XYZ"
	“registerdat”: “XXXX-XX-XXTYY...”,
	“device_appliance_type”: “DISHWASHER”
	},
]
```


Types of appliances and are described in Table 1 below.

Table 1: Appliance list for HERON API.

device_name	Device_applicance_type	Appliance
-XYZ-meter	HOME	Entire Home
-TV	TV	TV and related electronics
-PC	PC	PC / Laptop
-WM	WASHING_MACHINE	Washing Machine
-WM/Dr	WASHER_DRYER_MACHINE	Washing Machine Dryer (same appliance)
-Dryer	DRYER	Dryer

-Dryer(S)	DRYER_SMART	Smart Dryer
-DW	DISHWASHER	Dishwasher
-A/C RoomX	AC	A/C in a specific room
-A/C	AC	A/C (user has not reported room)
-Xmas Lights	CHRISTMAS LIGHTS	Christmas Lights
-Lamp RoomX	LAMP	Lamp in a specific room
-Microwave	MICROWAVE	Microwave
-Toaster	TOASTER	Toaster
-Kettle	KETTLE	Kettle
-Steam Iron	STEAM_IRON	Steam Iron
-Air Fryer	AIR_FRYER	Air Fryer
-Dehumidifier	DEHUMIDIFIER	Dehumidifier
-Cooker	COOKER	Cooker
-Vacuum Cleaner	VACUUM_CLEANER	Vacuum Cleaner
-meter_HP	HEAT_PUMP	Meter assigned to Heat Pump
-meter-EV	EV	Meter assigned to EV charger
-meter-relay-PX	BOILER	Meter which has a relay attached at Phase X (home with electric boiler)

Phase 3 “notification” API request

HERON EnergiQ can inform its users about the iFLEX specific events by connecting EnergiQ with iFLEX Assistant through the integration of HERON API into iFLEX RAI. HERON API supports two types of notifications: a) send to an entire home, b) send to a specific appliance.

POST: http://<domain>/api/v1/homes/message

```
{
  "action":"relay",
  "action_value": "pulse"
}

{
  "home_id": 1,
  "type": {
      "id": 1,
      "text": "IFLEX"
      },
  "notification": {
      "title": {
             "gr": "συμβουλές εξοικονόμησης",
             "en": "saving tips"
             },
      "body": {
             "gr": "Μειώνοντας την επιθυμητή θερμοκρασία κατά 1°C, μπορείς να
εξοικονομήσεις έως 7% στο κόστος θέρμανσης.",
             "en": "Reducing the room target by 1°C, you can save up to 7% in heating
costs."
             }
      }
}
```


POST: http://<domain>/api/v1/devices/message


```
{
  "device_id": "domx_ot_a8:03:2a:d5:81:51",
  "type": {
    "id": 1,
    "text": "GENERAL"
  },
  "notification": {
    "title": {
      "gr": "συμβουλές εξοικονόμησης",
      "en": "saving tips"
    },
    "body": {
      "gr": "Μειώνοντας την επιθυμητή θερμοκρασία κατά 1°C, μπορείς να εξοικονομήσεις
έως 7% στο κόστος θέρμανσης.",
      "en": "Reducing the room target by 1°C, you can save up to 7% in heating costs."
    }
  }
}
```

3.1.2 Phase 3 expansion of the Greek pilot visualisations

Grafana dashboards

Throughout Phases 1 and 2 iFLEX pilot participants were given access to HERON Energy Control multi-format Grafana dashboard as a recruitment instrument that would familiarize them with iFLEX objectives such as energy efficiency and sustainable consumption. Through the dashboards, pilot participants were informed about how they consume electricity in their homes, businesses and electric cars, leading to more responsible consumption. Figure 1 to Figure 4 demonstrate the progression of the dashboards until Phase 3 which could offer more detailed information on the consumption of EV chargers and Heat Pumps.

Figure 1: Phase 1 consumption metrics from a smart meter.

Figure 2: Phase 2 consumption metrics from smart plugs.

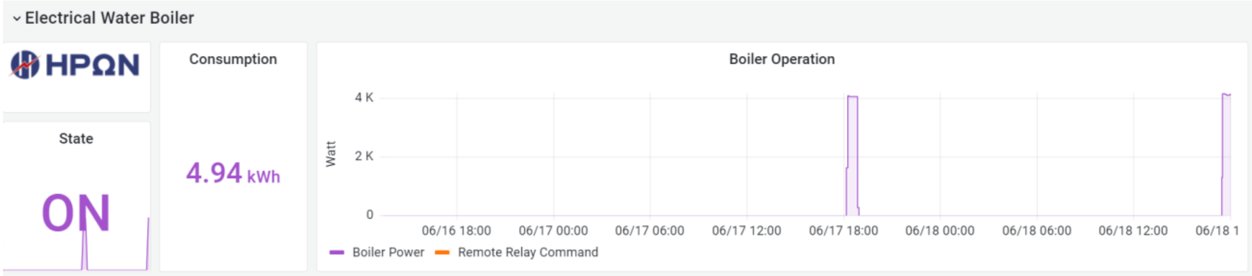


Figure 3: Phase 2 water boiler consumption and remote operation.

Figure 4: Phase 3 sub-meter measurements (here an example for a Heat Pump).

EnergiQ Mobile app and the iFLEX Assistant integration

Through HERON's mobile app EnergiQ, the pilot users can access the iFLEX app, which was developed by ICOM. HERON EnergiQ's primary aim is to promote sustainable energy consumption by informing its users on the sources of the energy they consume, e.g. how much of the energy we consume comes from RES and how much from fossil fuels. In Figure 5 the introductory screen which communicates the application's main theme and aim is shown. Home and historical data screens provide deep insights on household consumption and how much of it comes from renewable sources by aggregating 30 sec real-time energy consumption measurements into 30-minute intervals (in alignment with RES data) and then calculating for user defined daily, weekly and monthly periods. Figure 6 provides insights on the consumption of specific appliances linked to the pilot participants' smart plugs. Consumption is given as a percentage of the consumption among the smart plug appliances in addition to the consumption linked to the devices. Finally, Figure 7 presents the shares of renewable energy based on the methodology analyzed in Section 3.1.4.

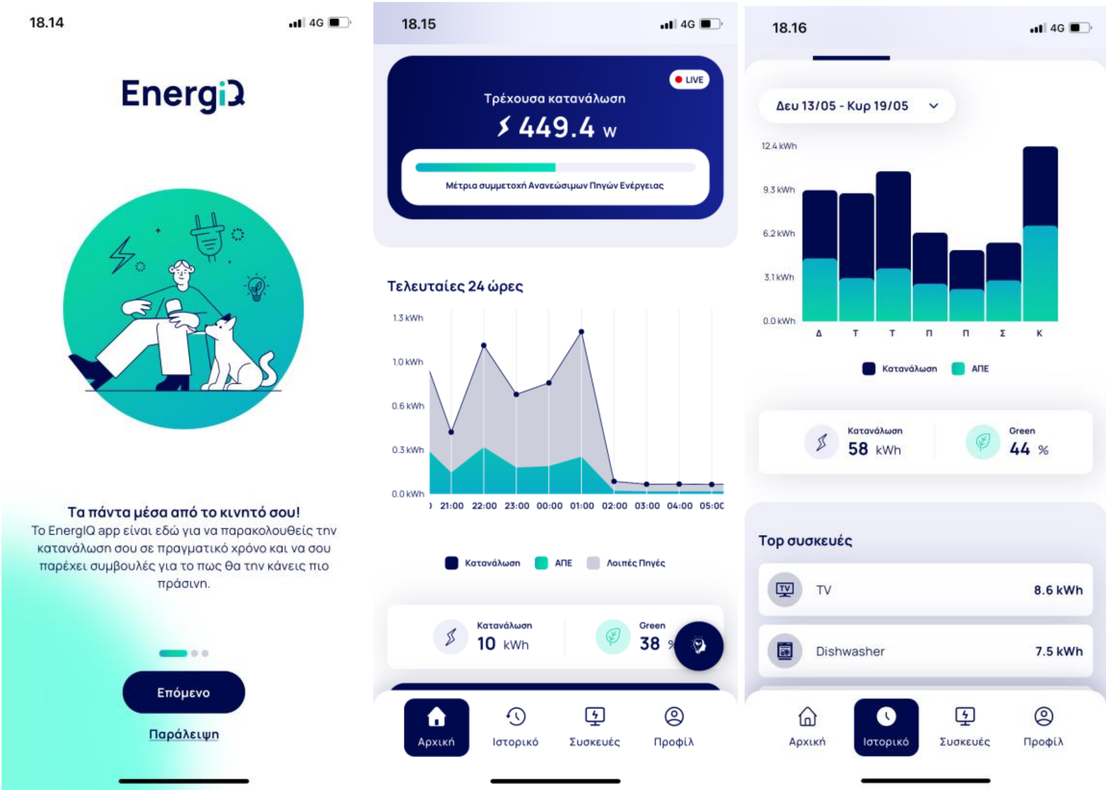


Figure 5: Intro, home and historical data screens.

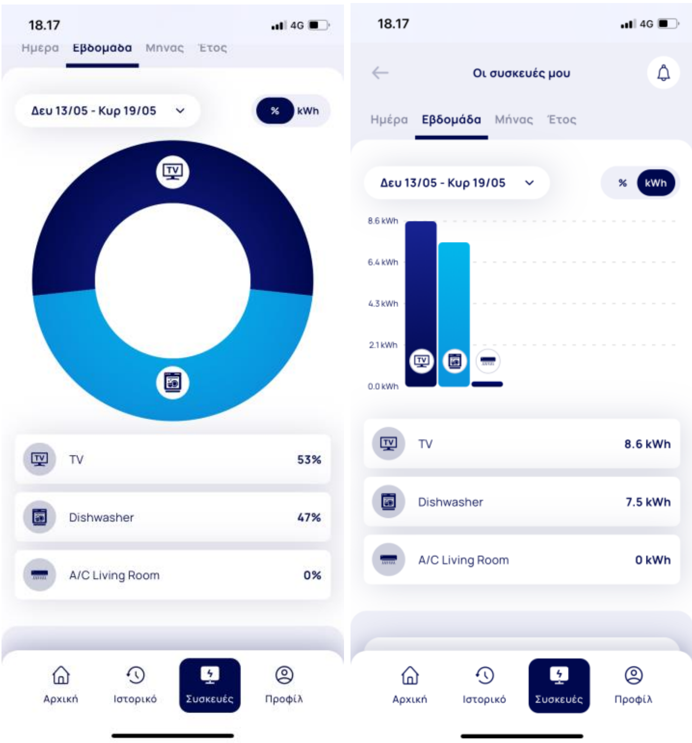


Figure 6: Multiple appliances (in smart plugs) screens.

Figure 7: Renewable energy shares projects for the Greek energy system.

The iFLEX app, developed as a web view app for the Greek pilot, provides the end-users with the additional features specific to the iFLEX project. Most notably, the DR interface incl. scheduling, operation, notification and rewarding and the advanced monitoring capabilities which allow pilot participants to set their consumption targets. The web view format was chosen as the means of integrating the iFLEX Assistant into HERON's mobile app securing a smooth transition from one app to the other for the users. Indicatively, the main dashboard of the iFLEX app in the Greek pilot is presented in Figure 8 which demonstrates the home screen showing the assets and the weekly consumption targets. Weekly and Monthly targets and alerts are further introduced. It can be seen that for the week 13/5 – 19/5, consumption is fully aligned.

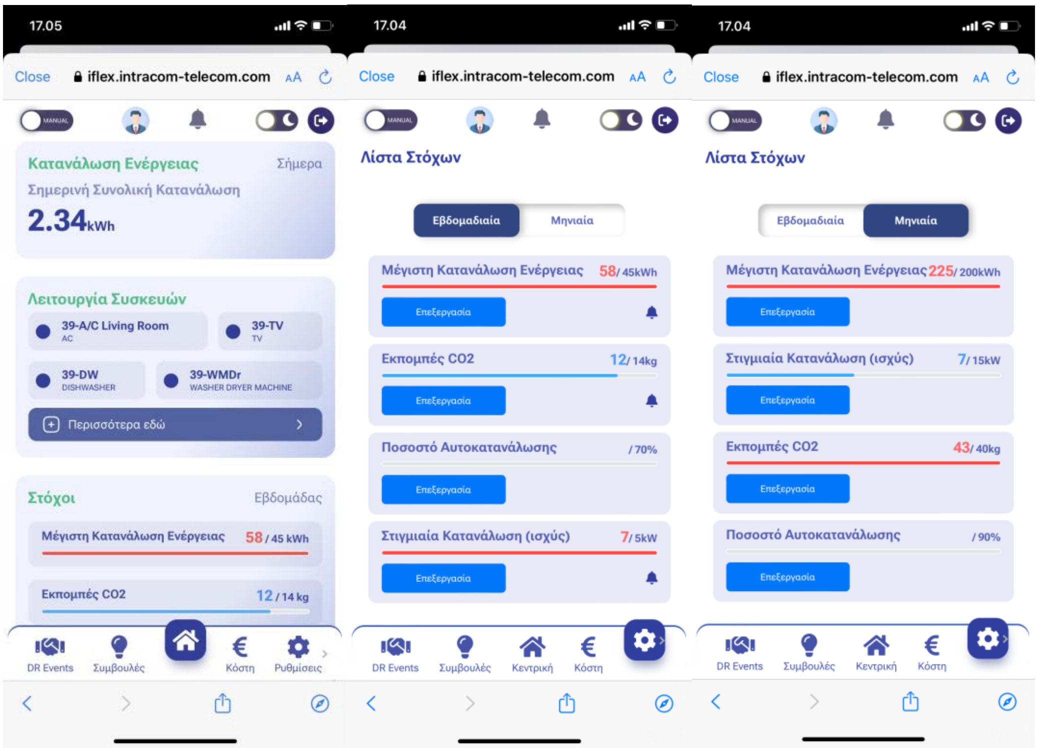


Figure 8: iFLEX assistant as webview app within HERON EnergiQ.

3.1.3 Calculation of Sustainability driven metric and tariff

The sustainability driven metric generates an Incentive Table based on the percentage of System Load satisfied by RES, drawn from Load and RES generation from the Integrated Scheduling Programming (ISP) provided by the TSO. In general, the ISP is carried out by TSOs that use Central Dispatch Systems. The process aims at covering the forecasted generation/demand imbalances and procuring the required reserves. Consequently, the ISP results involve:

- procurement of the Balancing Energy and Capacity needed to cover the forecasted generation/demand imbalances as well as the reserves requirement, for the following Dispatch Day
- scheduling of the commitment of Balancing Service Entities (BSEs) in a way that meets the constraints of the Transmission Systems and the BSEs

The ISP is solved as a co-optimization problem taking into account the Balancing Energy and Balancing Capacity Offers of the BSEs as well as their respective constraints, Transmission System constraints and the TSO's needs, in order to minimize the cost of Balancing Energy and Balancing Capacity procurement.

For the Greek system, the ISP is managed by the Greek TSO (IPTO) and is executed at three scheduled times for each Dispatch Day D for half hour blocks as follows:

- ISP1 is executed at 16:15 EET on calendar day D-1 and concerns all Dispatch Periods (48 Dispatch Periods) of Dispatch Day D – Forecasts are published.
- ISP2 is executed after ISP1, considering the updated input data. It is executed at 00:00 EET on calendar day D and concerns all Dispatch Periods (48 Dispatch Periods) of Dispatch Day D.
- ISP3 is executed at 12:00 EET on calendar day D, considering the updated input data. The time interval taken into account is from 13:00 EET till the end of Dispatch Day D (24 Dispatch Periods).

ISP blocks may also be carried out on demand, each time the TSO deems that there are significant changes that need to be balanced. For the purposes of the Proactive DR solution under development we are collecting RES (HV assets) and Load Forecasts as they are generated from the TSO. The TSO's ISP forecasts are not issued based on the aforementioned ISP schedule.

According to the relevant code[1], ISP forecasts are given as follows:

- ISP1 zonal Load and RES forecasts and system requirements are published on IPTO's website by 09:30 EET on calendar day D-1 (v1 forecasts & requirements)
- ISP1 zonal Load and RES forecasts and system requirements are updated and published on the website by 13:30 on calendar day D-1 (v2 forecasts & requirements)
  - *ISP1 is executed at 16:15 EET, D-1*
- ISP2 zonal Load and RES forecasts and system requirements are published on IPTO's website by 21:00, D-1
  - *ISP2 is executed at 00:00 EET, D*
- ISP3 zonal Load and RES forecasts and system requirements are published on IPTO's website by 09:00, D
  - *ISP3 is executed at 12:00 EET, D*

The data can be found from the Greek TSO's <website> under <Market / Market Statistics / Data> by downloading the "ISP Requirements" which includes RES and Load forecasts and Mandatory Hydro declarations given that in Greece, Hydro, although a renewable energy source in principle, It is allocated in the same category, in terms of system planning, with the dispatchable energy sources. Alternatively, the <File Download API> can be used to automate file downloads. HERON automated the process through the development of an API which is accessed through RAI and parsed to iFLEX partners:

```
r_48 = requests.post('http://10.0.7.16:5080/getData', json={"date":"2024-05-21",
"data": "Heron RnD ISP1 schedule"})
```

3.1.4 Definition of flexibility needs

The flexibility needs that were expected to be met through the iFA are driven by the imbalance needs of the 500 kWp ground-mounted PV plant already monitored by the iFLEX during Phases 1 and 2.

As already discussed, in the Greek pilot the end-user DR households' portfolio was called to internally address and mitigate RES generation imbalances. Figure 9 below illustrates indicatively the actual generation imbalances of the 500 kWp ground-mounted PV plant that is involved in the pilot site in April 2024. It is clarified that the said PV generation imbalances are calculated in 15-min time resolution and are defined as the difference between the actual PV generation minus the forecasted (day-ahead) PV generation. These PV generation imbalances indirectly define the flexibility needs to be addressed by the DR resources' portfolio. For the sake of the pilot site testing and validation, only the negative PV imbalances (i.e. time intervals when the actual PV generation is lower than the respective forecasted PV generation) are considered, which, in turn, requires that DR resources should reduce their electricity consumption (e.g. by turning-off their flexible electric loads such as water heaters or smart devices) in order to address and mitigate these PV generation imbalances to the best possible extent.

[1] IPTO Technical Decision: Integrated Scheduling Process (version 2.0, February 2021). Accessed from https://www.admie.gr/sites/default/files/users/dda/KAE/TECHNICAL%20DECISION%20ISP_eng_v2.pdf

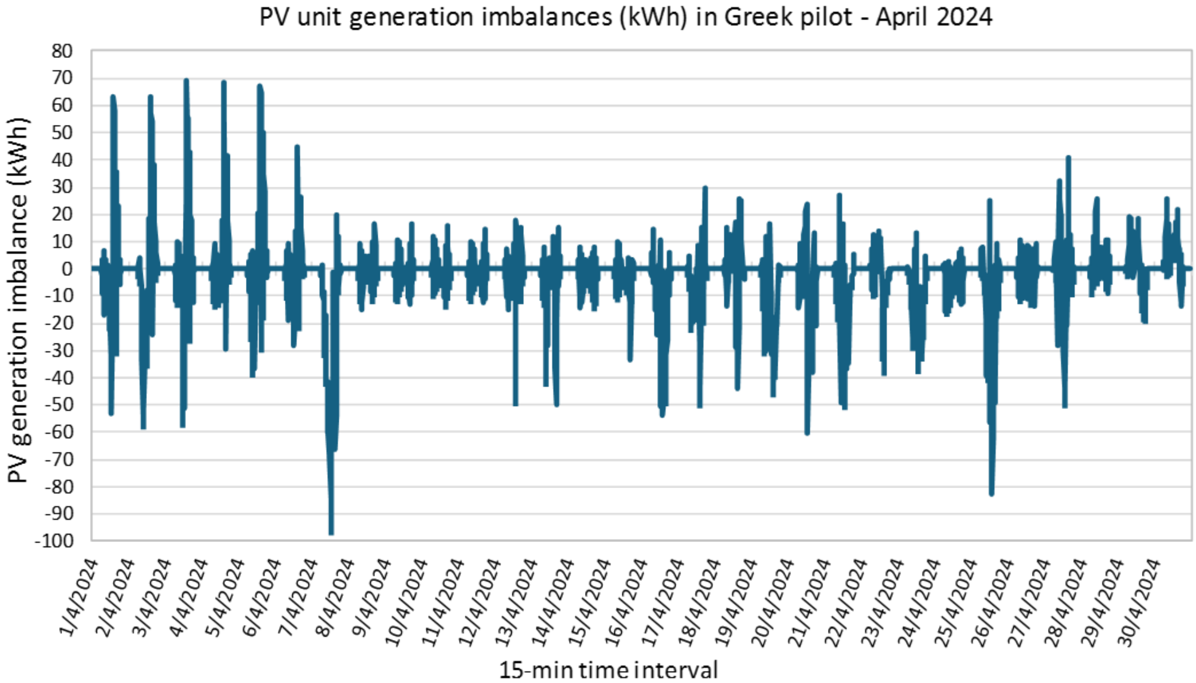


Figure 9: PV unit generation imbalances in the Greek pilot - April 2024.

Based on the aforementioned PV generation imbalances, appropriate flexibility requests were formulated and regularly (every 15-min) sent from the RES Aggregator's information system to the DRMS which, in turn, dispatched appropriate DR events to the iFA end-users to act accordingly (i.e. reduce their electricity consumption). OPTIMUS Energy has provided to ICOM an API to monitor real-time imbalances of the 500 kWp PV plant that is dedicated to the iFLEX. This process is validated in actual conditions in Section 5.1.2 .

3.1.5 Definition of participation incentives

Uncertainty is endogenous in both HERON's portfolio of consumers and OPTIMUS PV asset imbalances. Managing this uncertainty and ultimately rewarding consumers for providing flexibility required the development of a probabilistic user model to account for the uncertainty in the actual provision of the flexibility by a user in conjunction with incentives' offered thereto. This was subsequently introduced in the Demand Response (DR) targeting process. A suitable optimization framework to enable flexibility maximization and budget minimization as separate single-objective expressions with the appropriate constraints was considered to this end, representative problems were defined and solved numerically for a wide range of user parameters, in order to illustrate the applicability and accuracy of developed method, and to extract valuable insights. Finally, techniques to resolve practical issues and to enable real-world implementation of the proposed scheme in pilot sites were developed; namely, a mathematical expression to estimate the confidence intervals of the attained flexibility and a learning algorithm for extracting the individual user parameters according to their participation patterns. Below, the most indicative results of the work are briefly illustrated. More specific information can be found in the respective deliverables, D5.3 [3] and D5.4 [4].

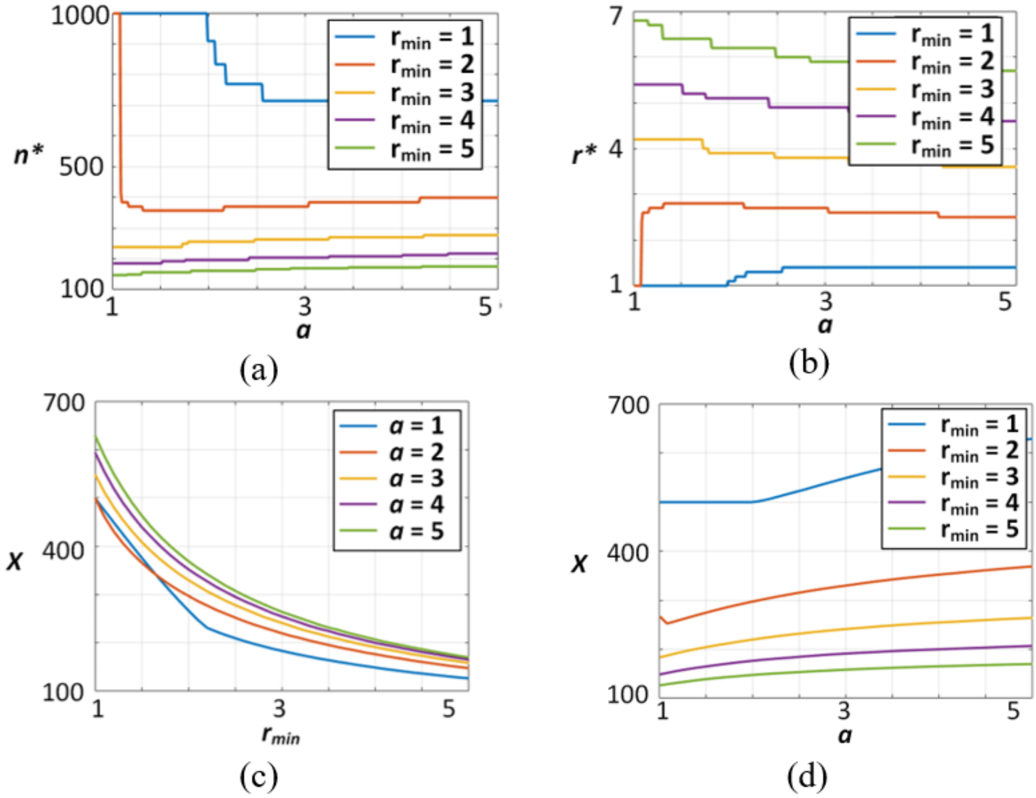


Figure 10: Relationship of (a) n^* and (b) r^* with a for various values of r_{min}. Relationship of X_E with (c) r_{min} for various values of a, and (d) a for various values of r_{min}.

Figure 10 shows the relationship among the most significant variables and parameters when considering symmetric users while maximizing the expected flexibility X_E for a given incentives budget. Figure 10 a and b depict the relationship of the number of selected users n and the amount of provided incentives r with the responsiveness towards incentives a, respectively, for different values of the minimum acceptable incentives r_{min}. Figure 10a shows that when r_min and a both have low values, the max. X_E is attained by targeting all the users. The number of targeted users decreases, however, as a rises and r_{min} increases. Figure 10 b shows that the increase of r_min also boosts r for each user. As a increases, r drops. Figure 10c and Figure 10d exhibit how X_E relates to r_{min}.and a. smaller values of r_{min}. and greater values of a lead to superior flexibility harnessing. The value of r_min has a deeper effect on X_E, than a. When a is big, lower incentives are required to achieve the same amount of flexibility.

Figure 11 regards the evaluation of the proposed learning algorithm of real user parameters. The algorithm to identify 3 random users was complete and two incentive schemes were assumed: random offers (open loop procedure) and a predictive method (closed loop procedure). In the open loop scheme the incentives are provided randomly. In the closed loop scheme, the current estimation of r_{min} and a value in each iteration are employed to predict more relevant incentive values for the next DR event. The procedure was repeated 10 times, the results are averaged and illustrated in Figure 11. Blue colour corresponds to random offering and red colour to the predictive method. It can be seen that only a relatively small number of attempts (i.e., between 5-20 and sometimes even smaller) suffices to approach r_{min} with remarkable accuracy. Prediction of responsiveness a is more challenging but its precise identification is of considerably lower importance than the identification of r_{min}. Finally, the predictive method improves the speed of convergence.

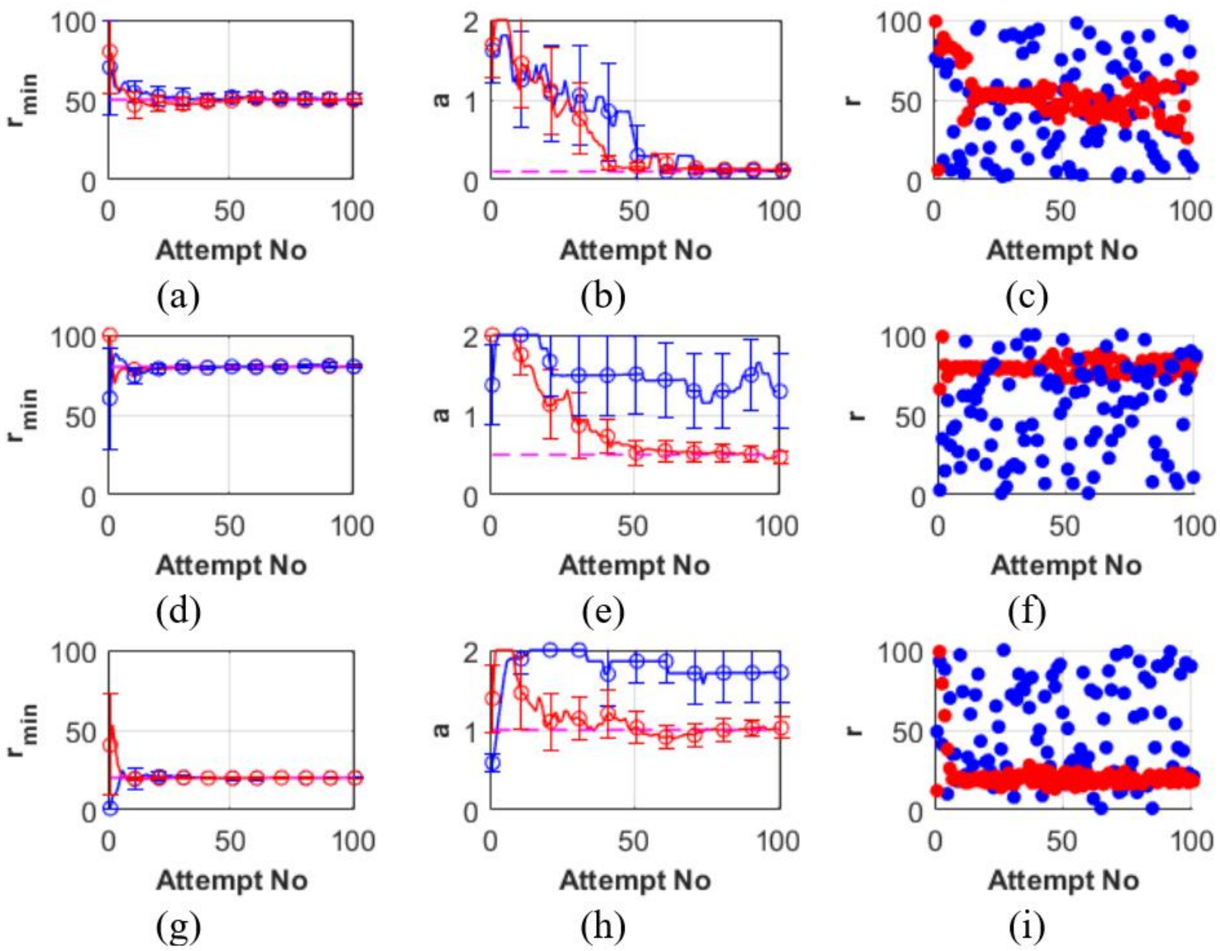


Figure 11: Parameter identification efficiency test for the 3 random users (user A: a, b, c – user B: d, e, f – user C: g, h, i). The first column (a, d, g) illustrates the r_{min} convergence, the second column (b, e, h) the *a* convergence and the third column (c, f, i) shows the values of the *r* offerings. Blue colour corresponds to the random method and red colour to the predictive one.

3.2 Slovenian large-scale pilot deployment

In the large-scale deployment phase new households and industrial clients have been added to the to the pilot, new features have been added to the RAI measurements close to real-time collection from smart-meters and updated and improved collection of data from certain in the pilot devices as well their control as is explained in Section 3.2.1. Improvements and further development has been done on End User Interface, and deployment procedure has been updated as is presented in Section 3.2.3. The RAI interface has received some performance improvements and some new features have been added. A programming interface has been developed further supporting the pilot deployment and piloting as is reported in Section 3.2.4. Automated flexibility management has been tested in the Slovenian pilot as is explained in Section 3.2.8.

3.2.1 New households and industrial clients

In the Slovenian part of the pilot project, the greatest attention was devoted to household and industrial users. The typical number of users within a Slovenian household ranges from 2 to 3 individuals, living together in single-family homes with a usable area of 120 to 300 m2. Key appliances addressing household users included those responsible for electricity generation (small solar power plants up to 15 kW), building heating (heat pumps with a rated thermal power of up to 16 kW), and data collection from the electricity distribution meter. For the monitoring and control of devices, an integration of the Home Energy Management System (HEMS) was implemented in the Slovenian-part of the pilot, with the consent of the household users who agreed in writing to the requirements of the iFLEX project. An example of one of the HEMS system integrations for household users is shown in Figure 12, along with an illustrated communication block diagram.

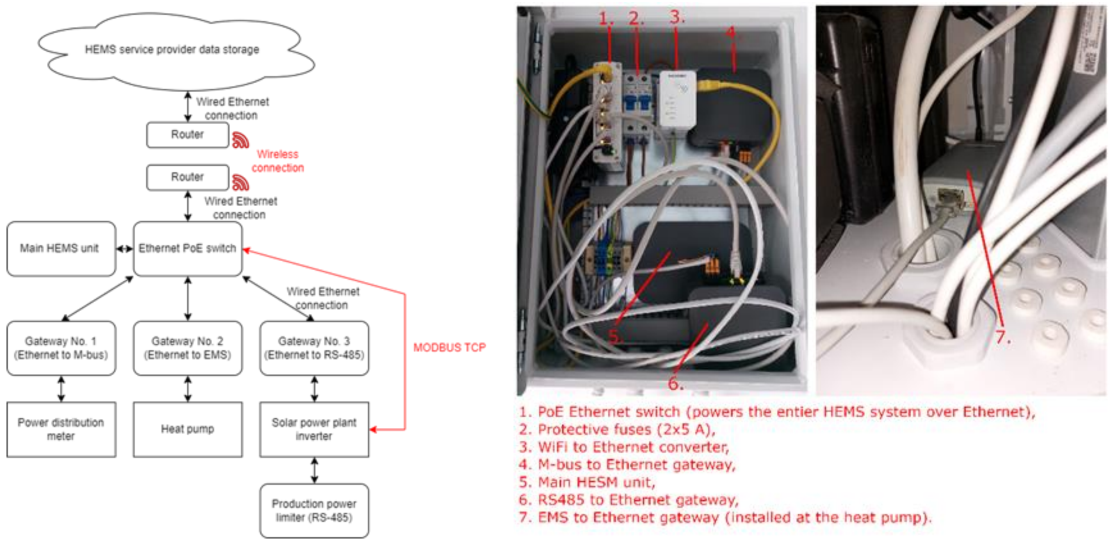


Figure 12: Communication flow diagram (left) and an example of HEMS system installation at one of the household end users (right).

In parallel with equipping household users, small businesses as well as small and large industrial buildings were also equipped, where the number of employees ranges from 60 to 180 individuals. For small business and small to large industrial users, devices for electricity generation (larger solar power plants with a capacity of up to 1 MW), consumer sources (fast AC charging stations with a rated power of 22 kW), and industrial distribution meters for measuring electricity were connected to the HEMS system. During preliminary energy audits at industrial sites, it was found that other devices were not suitable, as they have either a direct or indirect impact on the production process. Controlling devices that affect the production process would pose a significant risk of income loss for industrial users due to potential prototype errors within control algorithms or errors within the HEMS system. An example of HEMS system integration within the environment of a larger industrial user engaged in the production of metal semi-finished products is shown in the figure below, labelled as Figure 13.

Figure 13: Example of HEMS system installation at an industrial user (left) with a 1 MW solar power plant installed (right).

Upon installation of the HEMS system, both household and industrial users received a web application allowing them to monitor measurement and control data in both numerical and graphical formats. In the Slovenian part of the project, this is primarily done to enable the end-user to retain the basic functionalities of the installed HEMS equipment even after the completion of the iFLEX project. Basic functionalities include consumption monitoring (Figure 14), utilization of advanced strategies (Figure 15) which can be locally preset on the HEMS controller (these include strategies related to controlling car chargers, solar panels, and heat pumps according to predefined scenarios), and continuous updates with new advanced features and supported devices for the duration of the equipment.

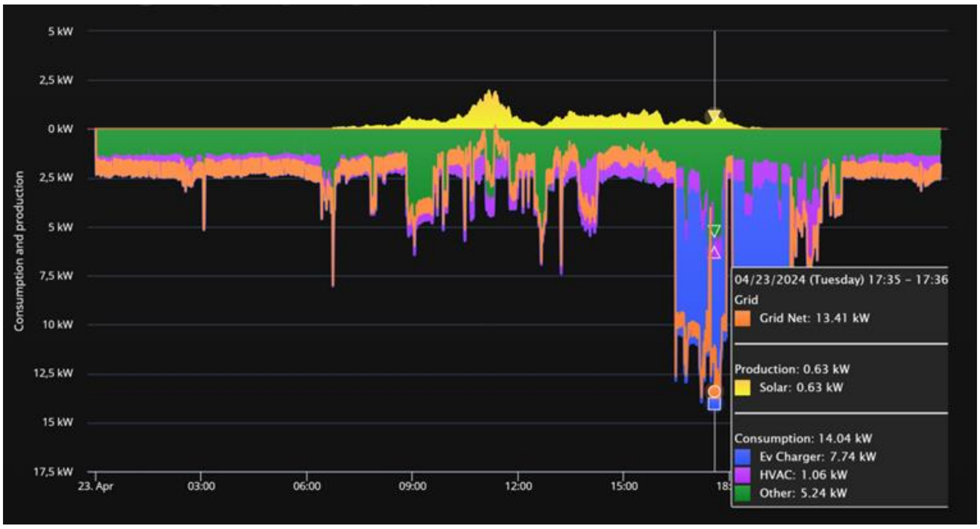


Figure 14: Monitoring of electricity consumption and production on various devices.

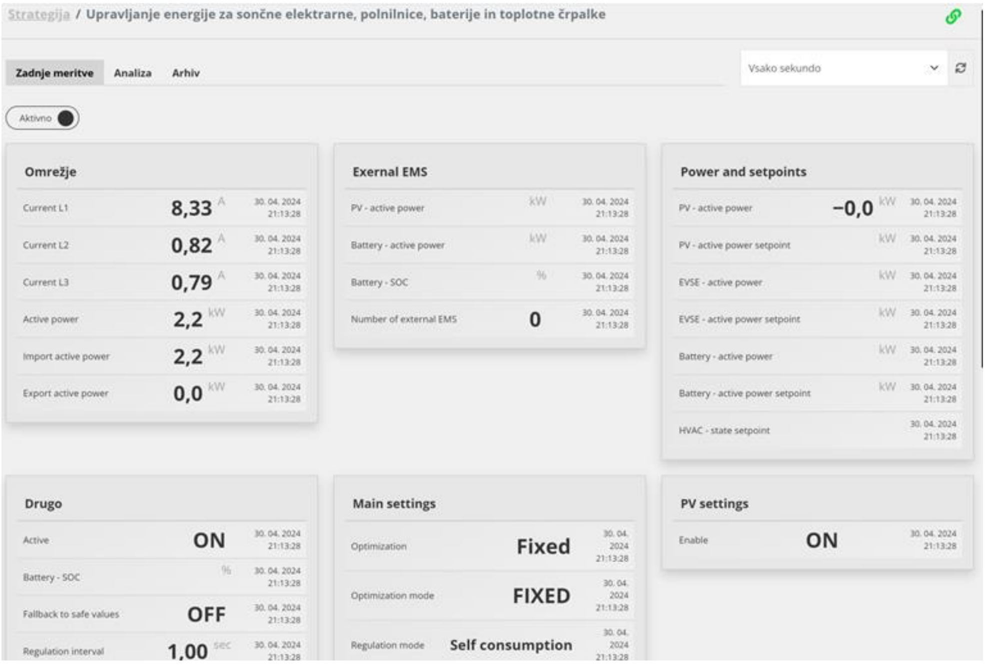


Figure 15: Utilization of advanced control strategies.

After the iFLEX project concludes, end-users, especially industrial users, will have access to the MQTT communication protocol (Figure 16). Through this protocol, users will be able to control devices within their backend systems in real-time, develop their own control strategies, and generate measurement reports.

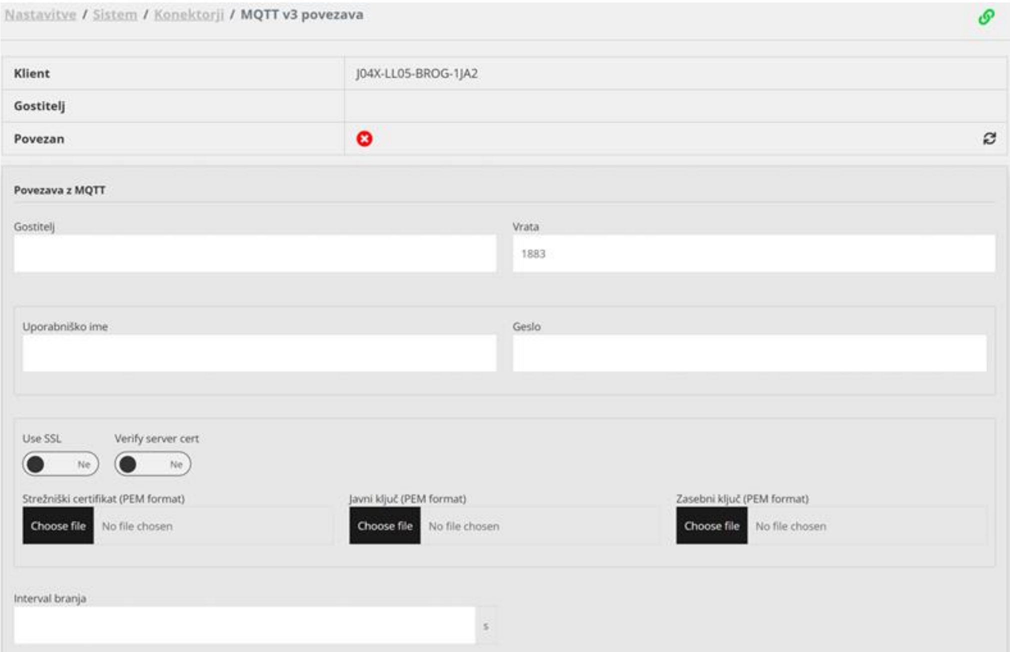


Figure 16: Configuration window within the HEMS controller, where the end user has the option to redirect data traffic to their own MQTT broker.

During the third pilot phase, the HEMS software has been refined to the extent that it allows secure local connections to an external iFLEX MQTT broker with certificate-level authentication (Figure 17). Following installation at the end-user's premises, the HEMS system enables remote configuration and error diagnostics, allowing administrators to remotely connect to the HEMS system and reset settings of connected devices (heat pump, solar panels, etc.), configure communication gateways (iFLEX MQTT), adjust locally running strategies, and programmatically upgrade the HEMS system to support new devices. All of this is feasible if the HEMS system is connected to the internet; however, if the HEMS system lacks internet access, it needs to be configured locally at the end customer's site.

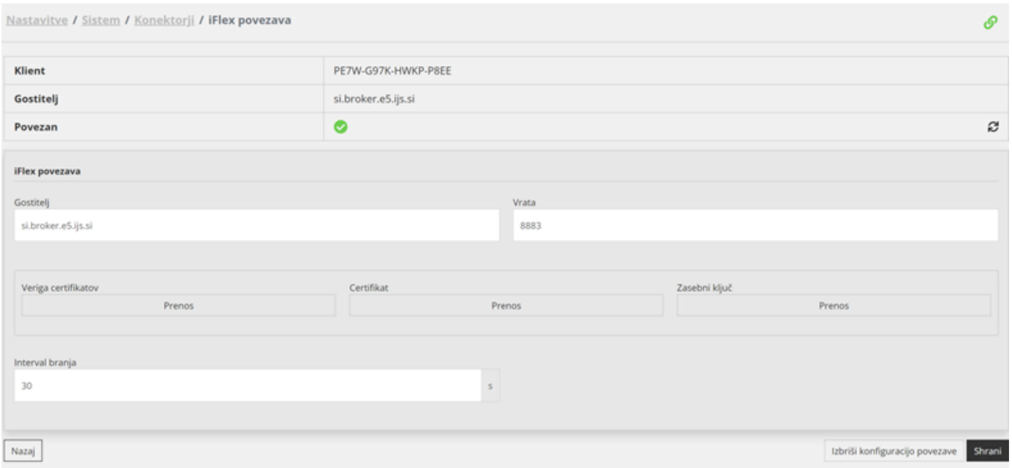


Figure 17: Configuration window within the HEMS system, where the iFLEX project administrator has access to configure the iFLEX MQTT communication protocol.

Detailed description of the functionalities of the HEMS systems installed in the Slovenian part of the iFLEX project can be found in deliverable D6.7 [5].

3.2.2 DSO smart meter interfaces

The I1 interface is an interface intended for users of the system for local access to measurements. This data can be used for displaying data on a dedicated screen or transmitting measurement data to other modules, household devices and systems in accordance with the requirements of Article 177 of the System Operating Instructions for the Electricity Distribution System, which serve users to implement measures for efficient use of energy.

Figure 18: Structure of the I1 profile of the interface compliant with SIST EN 62056-7-5.

The technical requirements for this interface are (see Figure 18):

- one-way communication channel intended exclusively for reading sent data compliant with SIST EN 62056-7-5,
- HAN channel (one-way communication from the meter to house systems and devices such as: energy house displays (IHD), smart house systems (SM) and consumption management systems (HEMS),
- The most important part of the OSI model:
    - data objects and COSEM interface classes in accordance with SIST EN 62056-6-1 and SIST EN 62056-6-2,
    - application layer in accordance with SIST EN 62056-5-3,
    - data connection layer in accordance with SIST EN 62056-46,
    - physical layer in accordance with EIA 485, SIST EN 13757-2, RJ12 or other physical interfaces
- speed ≥ 2400 b/s, basic setting 2400 b/s,
- receiving data requires protection using appropriate cryptographic methods for encryption as described in the DLMS/COSEM standard (Green Book, Edition 7, 8 and Edition 9).

Any DLMS/COSEM counter object can be assigned to the I1 interface. The sending of data must be carried out with the help of schedules according to the PUSH principle. According to the requirements of European recommendations, it is required that the meter supports the use of appropriate cryptographic methods for data encryption and decryption (use of security keys), as described in the DLMS/COSEM standard (Green Book, Edition 7, and Edition 8). The configuration of PUSH intervals and objects that are sent to I1 must be configurable via the I0 and I3 interfaces.

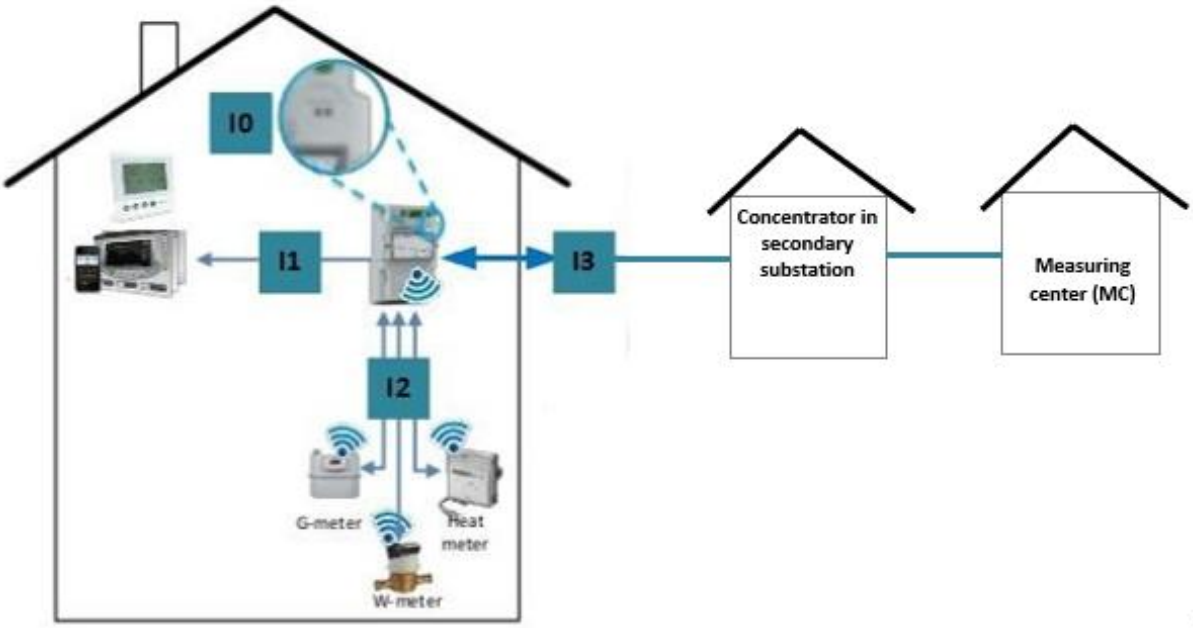


Figure 19: Schematic representation of the intended use of the required communication interfaces in the NMS.

Figure 19 shows a schematic representation of the intended use of the required communication interfaces in the NMSI0 - local service interface:

- I1 - interface intended for system users for local access to data and information (dedicated display, Smart Home systems, etc.).
- I2 - interface for local connection with other meters (gas, heat, water...).
- I3 - interface between the meter and the distribution operator (PLC/RF).
- The default configuration for the test samples is specified in Table 2 and Table 3.

Table 2: Data sent to the I1 interface every 5 seconds.

OBIS	DATASET
0-0:42.0.0	COSEM device name
0-0:96.1.2	ID3 device name
1-0:1.7.0	P+ The current total active power (W) (Q1+Q4)
1-0:2.7.0	P- Current total production active power (W) (Q2+Q3)
1-0:3.7.0	Q+ The current total reactive power (var) (Q1+Q2)
1-0:4.7.0	Q- Current total production reactive power (var) (Q3+Q4)
1-0:32.7.0	The current value of the voltage in the phase L_1 (V)
1-0:52.7.0	The current value of the voltage in the phase L_2 (V)
1-0:72.7.0	The current value of the voltage in the phase L_3 (V)
1-0:31.7.0	The current value of the current in the phase L_1 (A)
1-0:51.7.0	The current value of the current in the phase L_2 (A)
1-0:71.7.0	The current value of the current in the phase L_3 (A)
1-0:21.7.0*	P+ The current active power of the consumption in the phase L1 (W)
1-0:41.7.0*	P+ The current active power of the consumption in the phase L2 (W)
1-0:61.7.0*	P+ The current active power of the consumption in the phase L3 (W)
1-0:22.7.0*	P- The current active power of the production in the phase L1 (W)
1-0:42.7.0*	P- The current active power of the production in the phase L2 (W)

1-0:62.7.0*	P- The current active power of the production in the phase L3 (W)

Table 3: Data sent to the I1 interface every 15 minutes.

OBIS	DATASET
0-0:42.0.0	COSEM device name
0-0:96.1.3	ID4 device name
0-0:96.3.10	State of the switchgear (0-off; 1-on; 2- ready to power on)
0-0:96.14.0	Tariff indication (1-HT; 2-LT)
1-0:1.8.0	The cumulative value of the register of received active energy ST (kWh)
1-0:1.8.1	Received active energy in T_1 (kWh) (Q1+Q4)
1-0:1.8.2	Received active energy in T_2 (kWh) (Q1+Q4)
1-0:2.8.0	The cumulative value of the register of transmitted active energy ST (kWh)
1-0:2.8.1	Transmitted active energy in T_1 (kWh) (Q2+Q3)
1-0:2.8.2	Transmitted active energy T_2 (kWh) (Q2+Q3)
1-0:3.8.0	Cumulative value of the received reactive energy register ST (kVArh)
1-0:4.8.0	Cumulative value of the transmitted reactive energy register ST (kVArh)

3.2.3 EUI deployment

A procedure has been developed for End User Interface (EUI) deployment in the Slovenian pilot. The procedure enables connection between the EUI and Resource Abstraction Interface (RAI) in a loose manner, minimally burdening the users. When an end-user is asked via e-mail to install the app, they are given a short, user-specific code, which they uses to initialize the app. When the app is installed, the user is asked to enter the code. The code links the user with the RAI instance and related Digital Twin. The following procedure has been developed:

1) Pilot host generates user specific codes and relates them to the e-mails of the end-users.
2) The combinations of the codes and households are inserted in the RAI and in the iFA EUI backend database.
3) An e-mail template prepared is used to generate an end-user customized email, together with the link where the app can be downloaded and user specific code.
4) The e-mail is sent to the end-user.
5) The end-user downloads the app and installs it.
6) The end-user enters the code in the app.
7) For verification purposes the user is requested to insert their associated e-mail address, which is tested against the e-mail registered by the pilot host. This extra step raises the barrier to potential malicious users who would try to register through leaked invitation codes. An anti-brute force mechanism is also in place to discourage any such attempts by rate limiting excessive number of requests.
8) If verification process is successful the EUI backend uses the code to obtain the code-household mapping from the RAI and initialize the app based on the household data available in the RAI.
9) The EUI backend notifies the user for the successful onboarding/registration through an auto-generated e-mail.
10) The user can start using the app and access the household data.

The approach is secure as long as the end-user e-mail is not compromised. Even if the invitation code sent via e-mail is shared with others or leaked, the potential malicious user who would try to register on behalf of the user, would still need to access the end-user e-mail inbox.

To ensure that the access to the app deployment RAI interfaces is confined to the entities only that really need access to the mapping information or are the source of the mapping, multiple precaution steps are put in place. Namely, extensive codebase testing through automated tests integrated in the continuous integration (CI) pipeline and reduce user input to the minimum to consequently reduce the available attack surface.

The iFLEX app, which has been distributed in Slovenia, was developed as a hybrid mobile app. More information on the development and the design of the EUI can be found in deliverable D6.7 [5]. In the Figures below, indicative screenshots of the application are presented. Figure 20 shows the main dashboard screen, while the screen through which the temperate setpoints of a heat pump can be inserted/provided is presented in Figure 21.

Figure 20: Main dashboard of the iFLEX app in the Slovenian pilot.

Figure 21: Heat pump settings screen.

3.2.4 RAI updates

The RAI interface itself has received only very few improvements, but some of them were quite important. An interface has been prepared to provide relation between the app code and a household as described in Section 3.2.3. The interface has been updated to support aggregation of the results so the End User Interface (EUI) backends and the EUI has an ability to get the measurements from the RAI in a desired granularity, mostly limited to 15-minute and 1-minute data. The RAI backend database indexing has been improved and elevated which has raised the responsiveness of the EUI for the end-users significantly.

The RAI interface has been wrapped by a Python library called raiprogramming. The library has joined under the same hood a number of scattered functions and scripts, providing an object-oriented view on RAI capabilities, namely:

- Households: from initializing the household from external sources, basic household and building data, configurations, measurements, storing states, tariffs, controls, schedules for controllable devices to utility functions like quick capability checks.
- Fleet: initializing the fleet from external sources, overall households, configurations, buildings and household data overviews and creation of the app cods for EUI.
- iFABackend: iFLEX application backend wrapper allowing access to stored end-user preferences, objectives and goals, and to send notifications and advice.

The raiprogramming library has provided a basis for EUI piloting as is described in Section 5.2.2. Based on the library a complete set of tools has been developed to allow experimentation in the context of piloting use cases. The library has been used to control the experiments as are described in Section 5.2.2, providing anything necessary to schedule the experiment, control the experiment according to the critical variables like temperature limits set by the users and collect relevant measurements after the experiment for further analysis and reporting.

3.2.5 Use cases experimentation

In the large-scale piloting phase use cases experimentation has focused on the following three scenarios: assessment of the building physical construction parameters and its night-time flexibility, increasing self-consumption and adjustment to new tariff system. The scenarios are explained in the next sections, together with a procedure of experimentation.

3.2.5.1 Assessment of the building physical construction parameters and its nighttime flexibility

In this scenario, we aim to assess the building parameters of the house by interrupting heating. In this case, the house begins to cool according to the laws of thermodynamics. Based on the house's response, we can estimate certain building parameters of the house, such as thermal capacity, size of the house floor, heat transfer coefficients, etc. Once we have an estimate of the building parameters, we can use it to estimate future heating needs of the house and the flexibility available in the system.

In modelling, data on the surface area of the house being heated and the type of construction or insulation are useful. Tests are conducted at night, so we can ignore the impact of solar gains and internal gains due to the number of people and the use of electrical appliances.

Procedure

During nighttime, we turn off the heating and leave it off as long as possible. During this time, the temperature in the heated part of the house falls according to the laws of thermodynamics. We assume that the temperature, for example, from 8:00 PM to 6:00 AM, drops by no more than 2°C. Figure 22 shows an example of temperature settings from 6:00 PM onward to 6:00 PM the next day. There is an overheating interval from 6:00 AM to 12:00 PM, when the set temperature is 25°C. We actually overheat only as long as necessary to reach the temperature that was before the test.

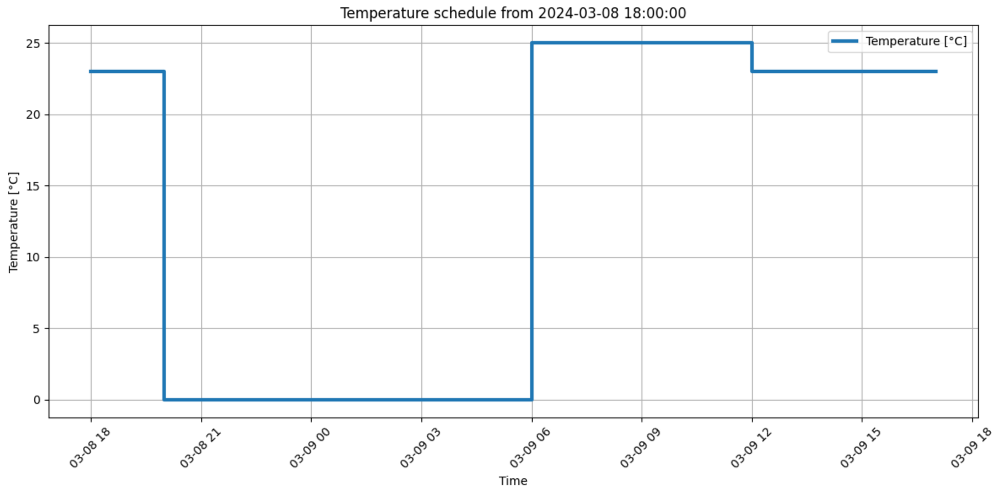


Figure 22: Slovenian pilot, assessment of building physical construction parameters procedure temperature schedule.

3.2.5.2 Increasing Self-consumption

If a household has installed photovoltaic panels, it usually wants to increase the consumption of the generated electricity to reduce the costs of transferring electrical energy to the network. Consumption can be increased by stronger heating during the production of electricity. Within the framework of testing, we aim to estimate how much electricity can be stored in the house during the time when electricity is being produced by solar cells.

Procedure

In the procedure itself, we slightly lower the temperature in the house and then store it in the house by increasing the heating temperature during the production of electricity. After the heating is increased, the heating can be turned off for a while so that the house cools down to the usual set temperature. In the winter and spring, the time for turning off the heating after overheating coincides with the future most expensive network tariff. An example of the temperature settings is shown in Figure 23.

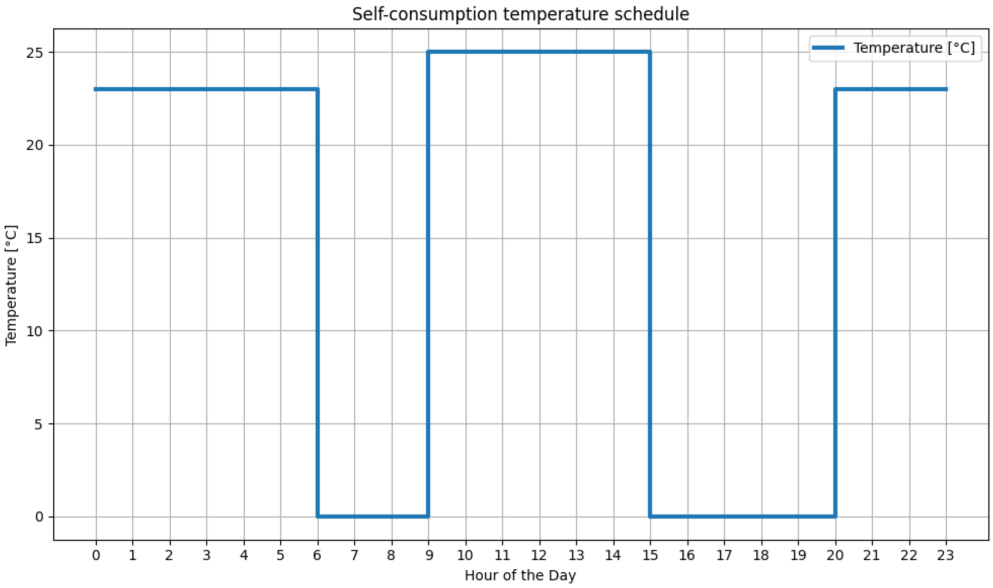


Figure 23: Slovenian pilot, self-consumption temperature schedule.

3.2.5.3 Adjusting to the New Tariff System

Starting July 1, 2024, a new network charge calculation will be implemented in Slovenia. With this new method of calculating network charges, the power industry aims to adjust consumption in a way that limits usage during peak demand times. The new calculation foresees several different time blocks, each with a different electricity transmission price. An example of winter tariffs is shown in Figure 24. The most expensive tariff is the first, followed by the second and then the third.

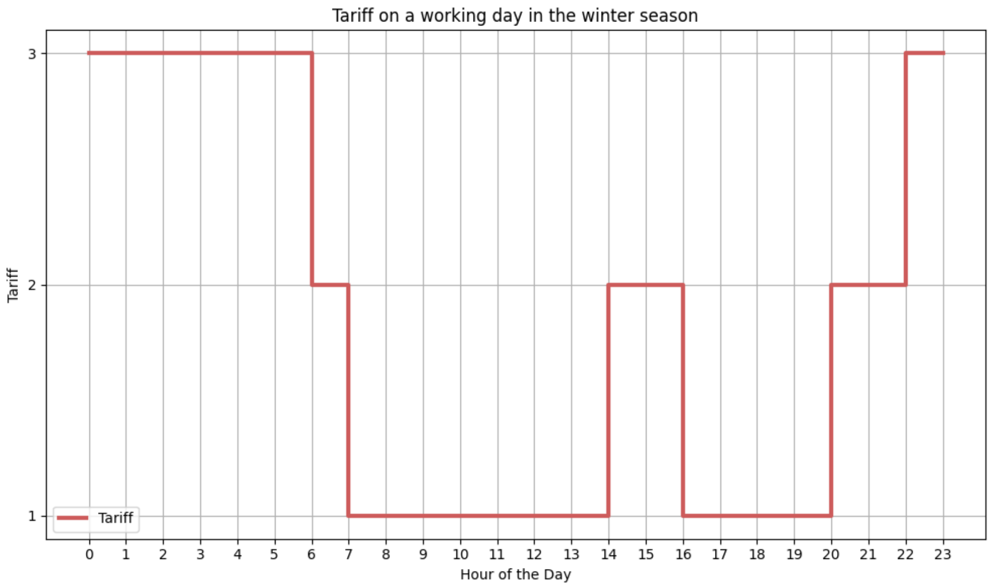


Figure 24: Slovenian pilot, new tariff system in the winter time.

From the diagram of Figure 24, we see that the most expensive network charges are between 7:00 AM and 2:00 PM, and from 4:00 PM to 8:00 PM, with the cheapest being during the night. It would be sensible to heat the house when the energy price is lowest. By doing so, we also help the energy system and reduce CO_2 consumption. By utilizing the thermodynamic flexibility of the house and the joint use of a heat pump, we aim to reduce consumption during this period. Therefore, we want to estimate the flexibility of the house and how the indoor air temperature, which affects comfort, responds in the adjustment process.

The estimated flexibility during the day will likely differ from the flexibility estimated at night in the case of assessing building parameters. Differences arise due to higher daytime temperatures, solar gains (heating due to the sun through window surfaces), and internal gains (radiation from bodies and devices in daily use).

Procedure

We have two options. We can completely avoid heating during the highest tariff (1.) and heat normally at other times (2., 3.). If necessary, we can slightly increase the normal setting above usual. The other option is to lower the temperature by one degree during the highest tariff (1.) and raise it by half a degree during the other tariffs (2., 3.).

Figure 25 ilustrate an example where we slightly increase the temperature during the lowest tariff (3.), maintain the temperature at 23 °C during the time of the second tariff, and lower the temperature by 1 °C during the time of the high tariff (1.).

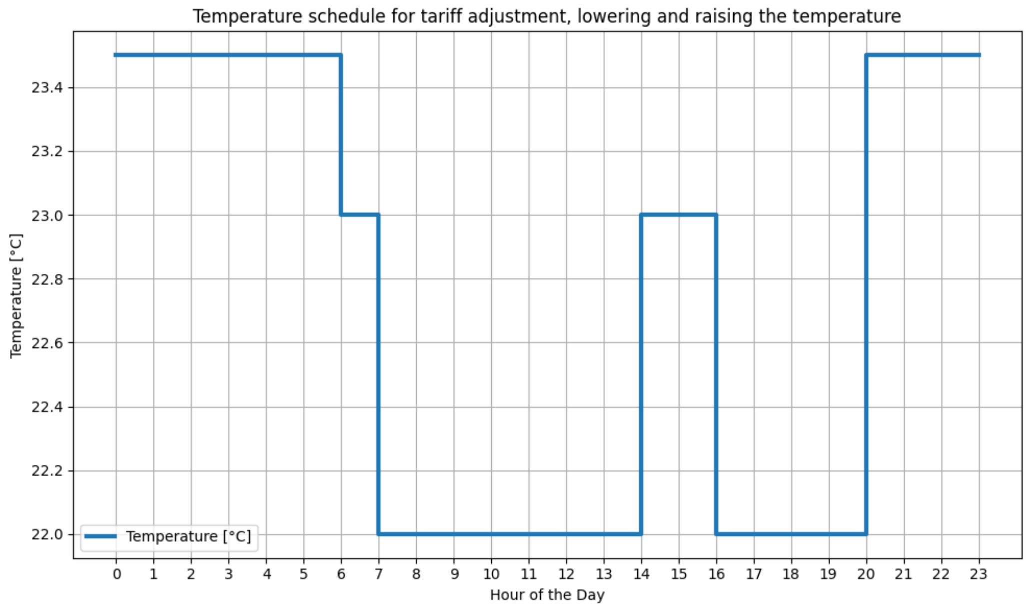


Figure 25: Slovenian pilot, temperature schedule for tariff adjustment.

3.2.6 Use cases experimentation results

3.2.6.1 Assessment of the building physical construction parameters and its nighttime flexibility

In this section, we detail the methodology and outcomes of the first use case, which serves a dual purpose:

- *Assessment of Household Thermal and Physical Parameters*: This objective involves collecting thermal data by monitoring the thermal behaviour of the household to estimate its thermal and physical characteristics. These estimations are crucial for identifying the household's thermal model.
- *Nighttime Flexibility Prediction Based on Heat Demand:* Utilizing the established thermal model, we predict the household's heat demand. This prediction allows for assessing nighttime flexibility in energy use.

The thermal model we utilize for heat demand prediction, and whose parameters we seek to identify, is the 5R1C model, a robust framework integrated into the EN ISO 13790 standard.

Methodology for Assessment of Household Thermal and Physical Parameters

For the first purpose a stepwise methodology was devised. It encompasses the following steps:

- Identification Measurement Procedure: This step involves collecting nighttime data from the household over multiple nights. This data encompasses measurements from two distinct types of heating operation:
    - Normal Operation: Heating is maintained at a steady setpoint.
    - Constrained Heating Operation: Heating is intentionally stopped for specific periods within a temperature comfort range predefined by the occupants.

  The data collected includes:
    - Inside room temperature (T_{air})
    - Heat pump output power (Φ_{HC})
    - Outside temperature (T_{out})

  In addition to measuring these parameters, we obtain information regarding certain parameter ranges from publicly available sources. This can include the range for household's square footage, number of floors, number of occupants, etc.
- Neural ODE Fitting:

- Model Fitting: Using the Neural Ordinary Differential Equations (NODEs) algorithm, each set of nighttime temperature data is fitted to model the household's thermal dynamics.
- Iteration and Averaging: The temperature curvature for each night is fitted multiple times to refine the model accuracy. Subsequently, the trained parameters from these multiple fits are averaged to derive a consistent set of parameters.

Outcomes of the implemented methodology

Here we present the results of the described methodology applied on a residential building of a pilot participant, located in Slovenj Gradec, Slovenia. The 3D model of the household is shown in Figure 26.

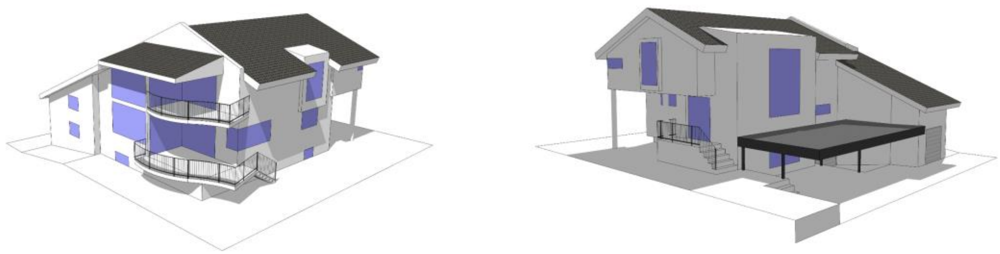


Figure 26: 3D model of the household for Slovenian pilot.

Identification Measurement Procedure

The total collected data for the first step of the methodology spanned from 18. December to 21. December, 2023. The constrained heating took place on the night of 18. December, 2023., while other days, 19., 20., 21. were used as the normal operation.

In the following, we will describe in more detail the data collection from two types of heating operations.

Constrained Heating Operation

Here we provide a detailed description of the constrained heating operation case conducted on 18. December, 2023.

This operation includes constrained heating phase and reheating phase. The purpose of such applied operation is to enhance the thermal response, analyze it and collect the data.

Time and temperature comfort of the constrained heating phase, as defined by the pilot participant, was the following: 19:00 – 04:00 (UTC) and temperature range was from 21 °C to 25°C. Starting with the initial room temperature at 19:00, the heat circuit (H.c.1) was turned off and kept in this state until 04:00 on 19th of December. Subsequently, the household was reheated using the upper limit of the heating circuit as the setpoint. This reheating phase continued until the set point was reached, at which point the regular setpoint was reinstated.

Table 4 shows the start and end times of both constrained and reheating phases as well as duration times.

Table 4: Time event for constrained heating operation. All timestamps are in Coordinated Universal Time (UTC).

Time event	Time	Explanation
Constrained heating start	2023-12-18 19:00:00	Time at which the H.c.1 was turned off
Constrained heating end	2023-12-19 04:00:00	Time at which the H.c.1 was turned on
Constrained heating duration	9.0 h	Total duration of the constrained heating phase
Reheating start	2023-12-19 04:00:00	Time at which the H.c.1 was turned on
Reheating end	2023-12-19 11:00:00	This time is determined according to the time of H.c.1 reaching the setpoint, which is 22 °C.

Reheating duration	7.0 h	Total duration of the reheating phase

Figure 27 shows various measurements observed during the constrained heating night. Top panel shows the heat output power and electricity power of the heat pump. A constrained heating period is highlighted in blue from 19:00 to 04:00. This is followed by a period of reheating, marked in light red, starting from 04:00 to 11:00. Second panel shows room temperature and corresponding temperature setpoint for the heat circuit (H.c.1). Third panel plots different temperature from the heat pump system, as supply temperature, sanitary water temperature, etc. The bottom panel shows the outdoor temperature.

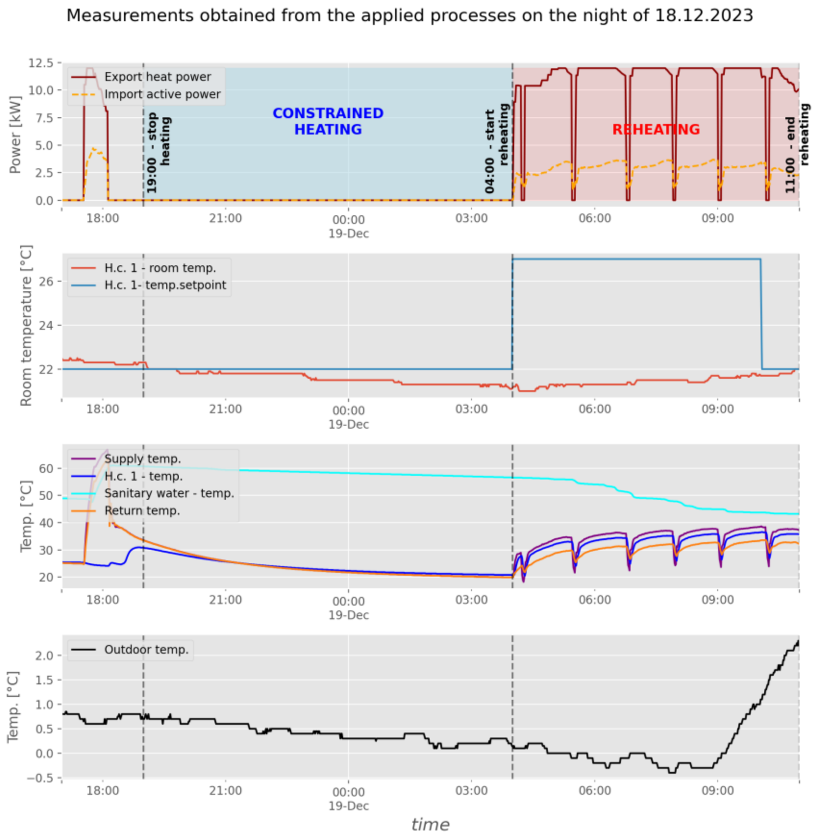


Figure 27: Different measurement for the constrained heating night.

A closer look into temperature behaviour during the constrained heating night is shown with Figure 28.

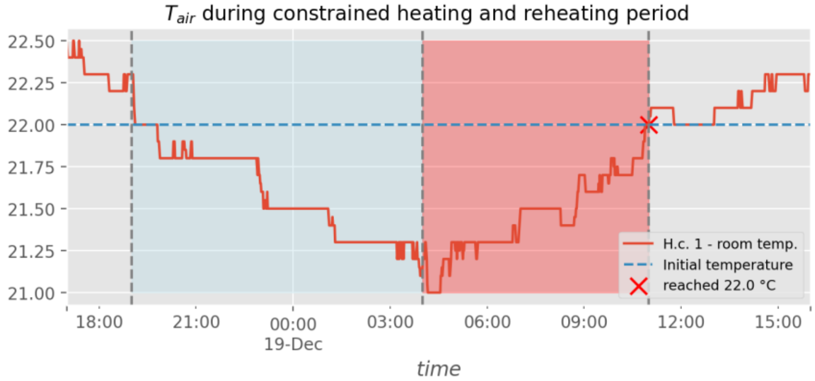


Figure 28: Temperature behaviour during the constrained heating test.

For constrained heating period: 18.12. 19:00 - 19.12. 04:00 (9.0 h):

- Room temperature dropped from 22,3 °C to 21,15 °C, resulting in a temperature difference of 1,15 °C
- This makes the cooling rate of 0,13 °C/h.

For the reheating period: 19.12. 04:00 - 19.12. 11:00 (7.0 h):

- Room temperature increased from 21,15 °C to 22,0 °C, resulting in a temperature difference of 0,85 °C
- This makes the heating rate of 0,12 °C/h.

Normal Operation

This type of measurement does not involve any controlling, we simply maintain the steady temperature setpoint over the nighttime period. Figure 29 shows a snapshot of the data collected throughout a such night of normal operation.

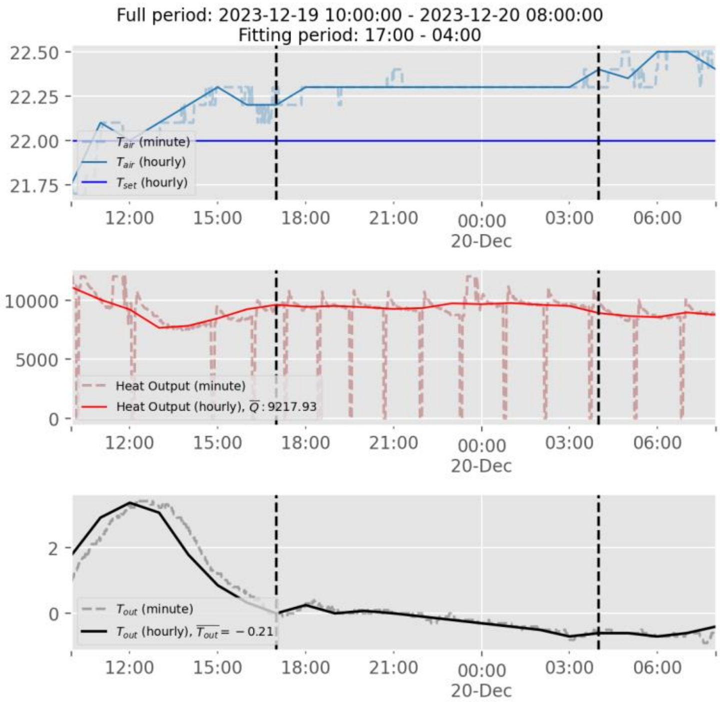


Figure 29: Normal operation night measurements.

Neural ODE fitting

In this step we use the collected data in the previous step and fit each set of nighttime temperature data to the household's thermal dynamics using the NODEs algorithm. For each night, we employ ensemble learning, which means that we train the model a certain number of times and average the results. Specifically, we trained each model 50 times and obtained the final set of parameters by averaging.

There are two methods for validating the trained parameters:

- Comparing trained parameter values to those obtained from an outside source, as detailed in Section 3.3.6. We will refer to these parameters as an outside estimate. Used metric is relative error (RE (%)).

- Evaluating the heat demand prediction of the 5R1C thermal model defined with the trained parameters. This includes observing the deviations between the 5R1C model's predicted heat demand and the actual heat output of the heat pump during the nighttime period, from 22:00 to 5:00, when the demand is primarily for space heating. The available data for this type of validation spans from December 2018 to March 2024. Used metrics is RE and root mean square error (RMSE).

Figure 30 shows the results of both validation methods. The left column shows the RE of the trained parameters from different nights. The middle column displays RE for the estimation of monthly average nighttime heat demand, while the right column shows RMSE for the same. The last row corresponds to the parameters that are obtained by averaging the results across all training sets (from different days). In addition to the prediction of the trained thermal model, we also show RE and RMSE for the 5R1C thermal model defined with the outside estimate.

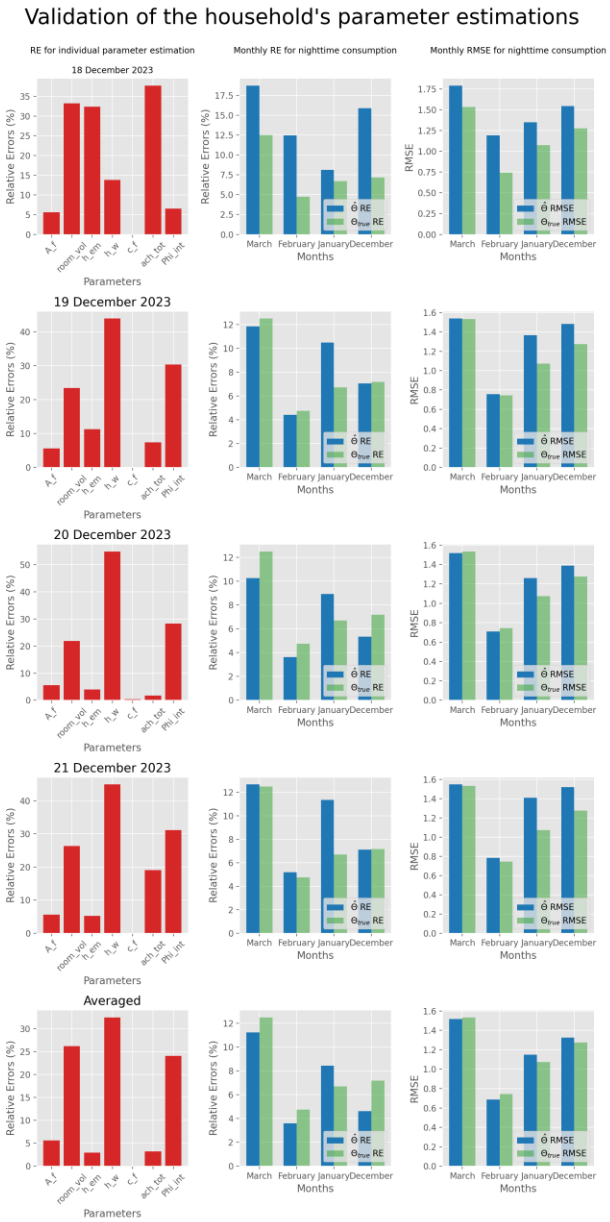


Figure 30: Validation for the trained household's parameters.

The exact values of the final trained parameters are presented in Table 5. Error of the thermal model across different days of different available months is shown in Figure 31.

Table 5: Final trained parameter values.

	$\hat{\theta}$	θ_{true}	RE (%)	Units
A_f	250.00	236.75	5.60	m^2
V_{room}	710.58	562.95	26.22	m^3
H_{em}	203.93	210.16	2.96	W/K
H_w	123.27	93.03	32.50	W/K
c_f	3.70	3.70	0.10	$10^5\ J/Km^2$
ach_{tot}	0.48	0.50	3.24	h^{-1}
Φ_{int}	1175.01	947.00	24.08	W

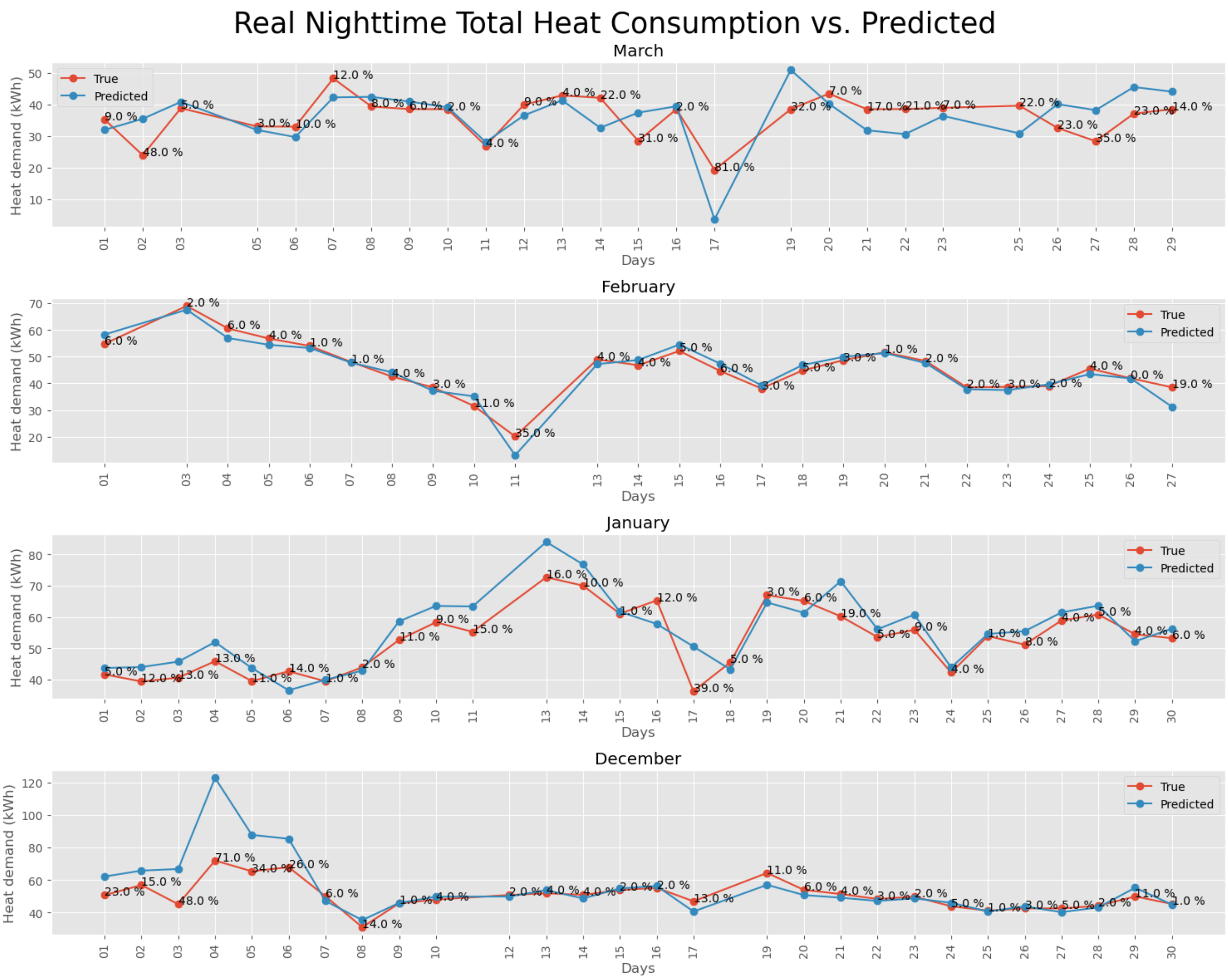


Figure 31: Comparing the 5R1C predicted nighttime heat consumption with the true values.

Based on the presented validation results, we can draw the following conclusions:

- Training the NODEs algorithm on 4 different nights provided a sufficient estimation of the household's parameters necessary to define the 5R1C thermal model. When compared to the values of the outside estimation, RE for the final set of inferred parameters falls below ≈30%.

- Thermal model defined with trained parameter set, performs very similarly to the model defined with the outside estimate, both in terms of RE and RMSE.

Flexibility prediction with thermal model heat demand estimation

After identifying the thermal model, we move on to the flexibility prediction. This step entails comparing the electricity consumption during the constrained heating night, where the defined process is applied, with the thermal model predicted electricity consumption for the normal operating conditions. This comparison enables us to evaluate the potential availability or savings of electricity resulting from the implementation of our processes.

Displayed in the Figure 32 are the observed heat demand and electricity consumption alongside the thermal model's predictions. As it is evident from the provided figure, applying a constrained heating process overnight and reheating the household back to the initial temperature, and without violating the temperature comfort, we gain the following:

- Total heat energy savings: 22,89 kWh. This is 21,17% of the total predicted heat consumption for the normal operation which keeps the temperature setpoint steady.
- Total electric energy savings: 6,34 kWh. This is 22,13% of the total predicted electricity consumption for the normal operation which keeps the temperature setpoint steady.
- Flexibility harvest for the constrained heating hours:
    - Total electricity consumption savings: 14,93 kWh. This 99,67% of predicted total consumption.
    - Electric power savings: 1,66 kW.
    - Total electricity consumption savings per °C drop of the room temperature: 12,98 kWh/°C.

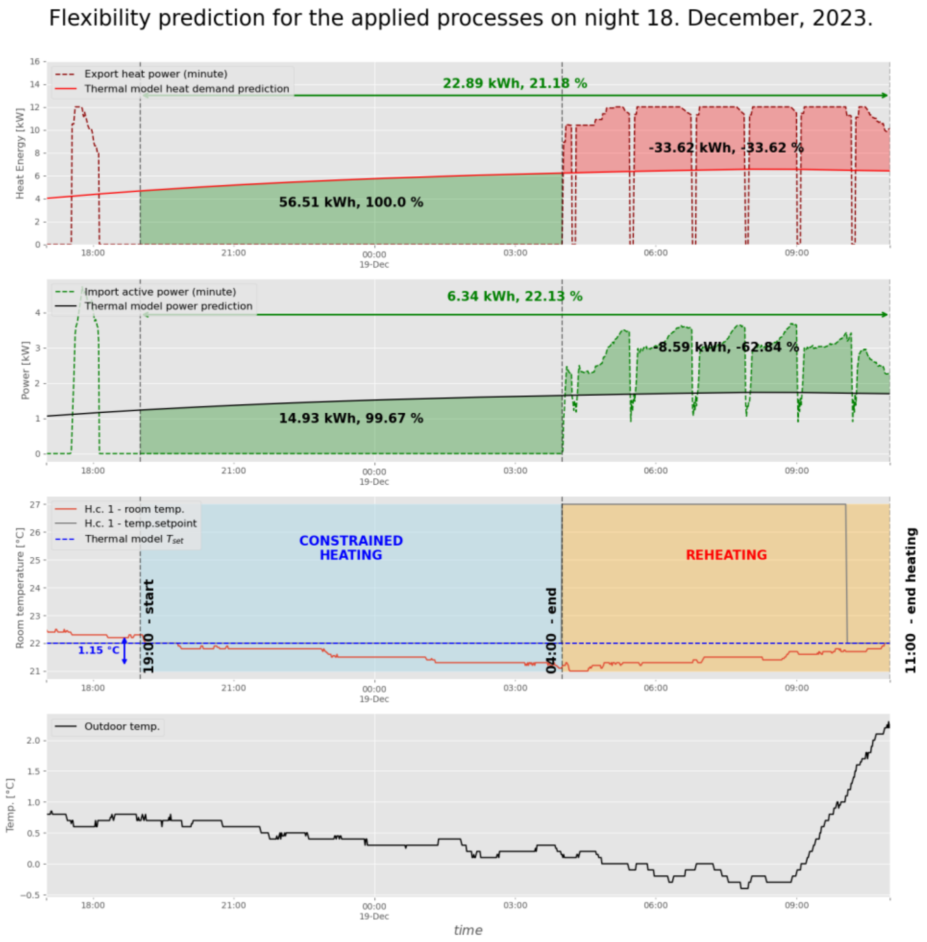


Figure 32: Flexibility prediction for the applied processes on night 18. December, 2023.

The outcomes of the applied process and flexibility predictions are summarized in Table 6.

Table 6: Summary of results on nighttime flexibility prediction.

	General Info		Temperature change (°C)	Electricity Consumption		Flexibility Prediction		
	Phase	**Period**	**H.c. 1**	**Real El. Consumption**	**Predicted El. Consumption**	**Flexibility in kWh**	**Flexibility in kWh/°C**	**Flexibility in %**
0	constrained heating (1)	18.12. 19:00 - 19.12. 04:00	1.15	0.05 kWh	14.98 kWh	14.93 kWh,	12.98 kWh/°C	99.67 %
1	heating (2)	19.12. 04:00 - 19.12. 11:00	0.85	22.26 kWh	13.67 kWh	-8.59 kWh	x	-62.84 %
2	total (1+2)	18.12. 19:00 - 19.12. 11:00	x	22.31 kWh	28.65 kWh	6.34 kWh	x	22.13 %

3.2.6.2 Increasing self-consumption

Here we present the results of the second use case, which aims to increase the consumption of the generated electricity from solar panel during the peak of its generation. Another pilot participant, a household located in Slovenia, was subjected to this use case. This household had first undergone a procedure for identifying thermal model parameters so that flexibility could be calculated against the model's heat demand prediction.

As described in 3.2.5.2, applied heating management processes were structured into three distinct phases to optimize the consumption of electricity generated from photovoltaic panels:

- First Constrained Heating Phase (05:00 to 08:00): The first heating circuit (H.c.1) was turned off during this early morning period, allowing the indoor temperature to decrease slightly below the initial setpoint.
- Overheating Phase (08:00 to 15:00): The heating circuit was activated, and the temperature setpoint was elevated to 25 °C.
- Second Constrained Heating Phase (15:00 to 22:00): Following the overheating phase, H.c.1 was once again turned off. The heating remained off until the house naturally cooled down to the initial temperature setpoint of 23 °C. At this point, H.c.1 was reactivated to maintain the usual thermal comfort by reinstating the initial setpoint.

Measurements and flexibility predictions are shown in Figure 33 and Table 7. As it is evident, by applying the described process without violating the comfort of the temperature, we gain the following:

- Total heat energy savings: 43,46 kWh. This is 57,07% of the total predicted heat consumption for the normal operation, which keeps the temperature setpoint steady.
- Total electric energy savings: 7,18 kWh. This is 56,54% of the total predicted electricity consumption for normal operation, which keeps the temperature setpoint steady.
- Negative flexibility harvest for the overheating hours:
    - Total electricity consumption: -0,86 kWh. This is 53% more than the total consumption.
    - Electric power: -0,12 kW
    - Total electricity consumption per °C drop of the room temperature: -0,82 kWh/°C

An important remark needs to be made here: our model did not take into account solar gains, so the predicted heat demand is significantly higher. If solar gains are included, we can expect the flexibility prediction to be higher.

Table 7: Summary of results on increasing self-consumption use-case.

	General Info		Temperature change (°C)	Electricity Consumption		Flexibility Prediction			
	Phase	Period	H.c. 1	Real El. Consumption	Predicted El. Consumption	Flexibility in kWh	Flexibility in kW	Flexibility in kWh/°C	Flexibility in %
0	constrained heating (1)	15.02. 05:00 - 15.02. 08:00	0.35	0.01 kWh	2.8 kWh	2.79 kWh	0.93 kW	7.97 kWh/°C	99.64 %
1	heating (2)	15.02. 08:00 - 15.02. 15:00	1.05	5.5 kWh	4.64 kWh	-0.86 kWh	-0.12 kW	-0.82 kWh/°C	-18.53 %
2	constrained heating (3)	15.02. 15:00 - 15.02. 22:00	0.7	0.01 kWh	5.26 kWh	5.25 kWh	0.75 kW	7.5 kWh/°C	99.81 %
3	total (1+2+3)	15.02. 05:00 - 15.02. 22:00	x	5.52 kWh	12.7 kWh	7.18 kWh	0.42 kW	x	56.54 %

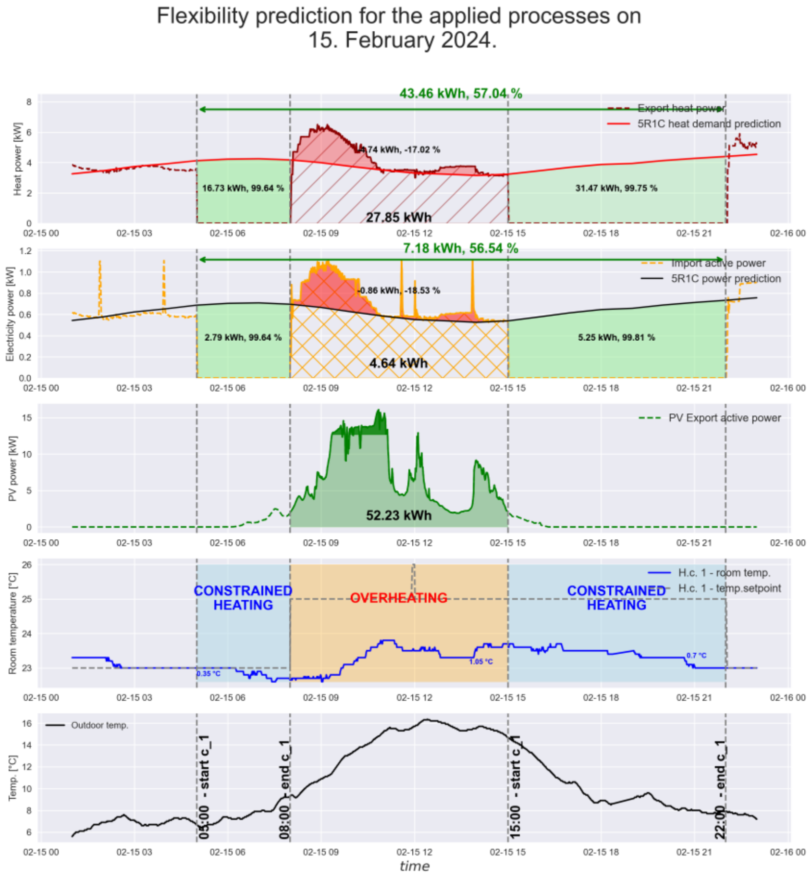


Figure 33: Measurements from increasing self-consumption use-case and flexibility prediction.

3.2.6.3 Adjusting to new tariff system

Here we present the results of the third use case, which aims to adjust energy consumption to the upcoming tariff system in Slovenia. Pilot participant from the second use case was also subjected to this one. Results of the applied processes are shown in Figure 34 and Table 8. Here we looked only on a total consumption of electric energy. In contrast to the predicted electricity consumption, the actual total electricity usage was 6,15 kWh lower, representing a decrease of 39%. Additionally, the power demand decreased by 0,26 kW.

Table 8: Summary of result for new tariff system use case.

	General Info		Electricity Consumption		Flexibility Prediction		
	Phase	**Period**	**Real El. Consumption**	**Predicted El. Consumption**	**Flexibility in kWh**	**Flexibility in kW**	**Flexibility in %**
0	total	29.03. 00:00 - 30.03. 00:00	9.62 kWh	15.77 kWh	6.15 kWh	0.26 kW	39.0 %

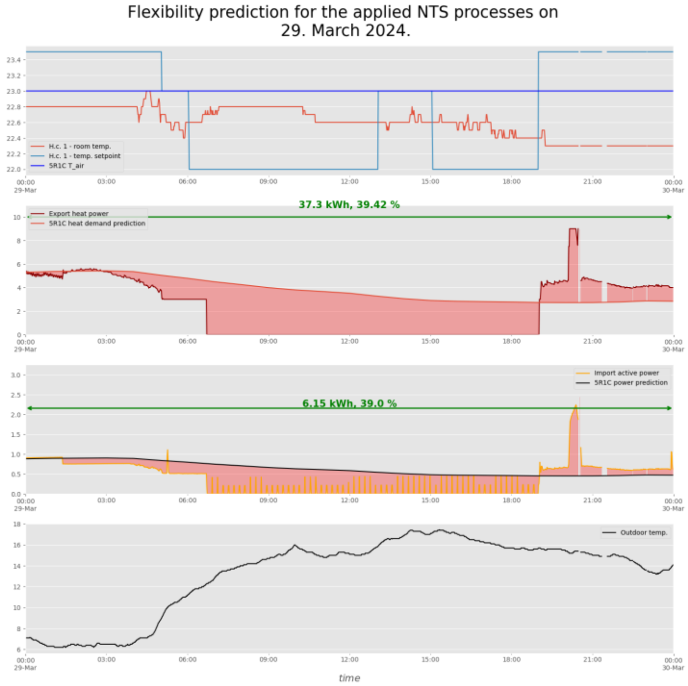


Figure 34: Measurements from new tariff system use case and flexibility prediction.

3.2.7 Classical thermal parameter estimation

To validate the use cases experimentation results presented in Section 3.2.6 a classical study has been ordered for three buildings of the pilot participants. The study helped to assess the accuracy of results obtained through procedural experimentation, RAI based data collection and machine learning based parameter estimation.

The EUTRIP company[2] has prepared a report and estimated requested building parameters based on collected pilot participant buildings dimensions and materials information and on-site local inspection of the buildings. For the calculations a programming package URSA 4.0 has been used. The program supports compliance with the 2010 PURES[3], "Pravilnik o učinkoviti rabi energije v stavbah" (Regulation on the Efficient Use of Energy in Buildings) regulation, facilitating the assessment of thermal protection and energy usage in buildings. An example of estimated parameters through the study is presented in Table 9.

Table 9: Slovenian pilot, classical building physic parameters estimation for one pilot participant building, using program URSA 4.0.

Parameter	Description	Value	Unit
c_f	thermal capacitance per floor area	370.000,00	[J/(m^{2}K)]
floor area	floor area of both conditioned space and (if) total space (according to the owner’s data)	122,00	[m^2]
walls area	total surface of the walls facing the outside	309,83	[m^2]
windows area	total surface of the windows + position and orientation	22,21	[m^2]
total internal area	total area of all inner surfaces facing the room * in accordance with national regulations, when calculating heat losses, only the outer envelope of the building is taken into account or walls against unheated spaces	/	[m^2]

[2]EUTRIP d.o.o focuses on comprehensive investment solutions, particularly in conducting energy audits, facilitating energy transition projects and digital transformation. More about the company can be found on their web pages: https://www.eutrip.si.
[3] See the regulation online: https://pisrs.si/pregledPredpisa?id=PRAV10043

u_{walls}	U-value of the wall material		
	Z1	0,163	[W/m^{2}K]
	S1b	0,134	[W/m^{2}K]
	S1a	0,134	[W/m^{2}K]
	V1	1,100	[W/m^{2}K]
	T1	0,166	[W/m^{2}K]
$u_{windows}$	U-value of the windows material	0,860	[W/m^{2}K]
room vol	volume of both conditioned and (if) total space (according to the owner's data)	352,00	[m^3]
ach_{vent}	air changes per hour through natural ventilation for daytime and nighttime case **air exchange rate determined in a simplified way for natural ventilation	176**	[m^{-3}]
ach_{infl}	air changes per hour through natural infiltration for daytime and nighttime case *** air exchange rate determined for a single-apartment building with high sealed windows and moderate protection of the building (building outside of cities, trees or other buildings)	63,4***	[m^{-3}]

3.2.8 Automated flexibility management in Slovenian pilot

The iFLEX Assistant used in Finnish pilot (3.3 for more details) was tested in Slovenian pilot environment to demonstrate its automated flexibility management capabilities in different environment. Its deployment in controlling HOAS (Foundation for student housing in the Helsinki region) building, a supermarket in Finland and heat pump in Slovenian apartment building showcased its adaptability across diverse settings.

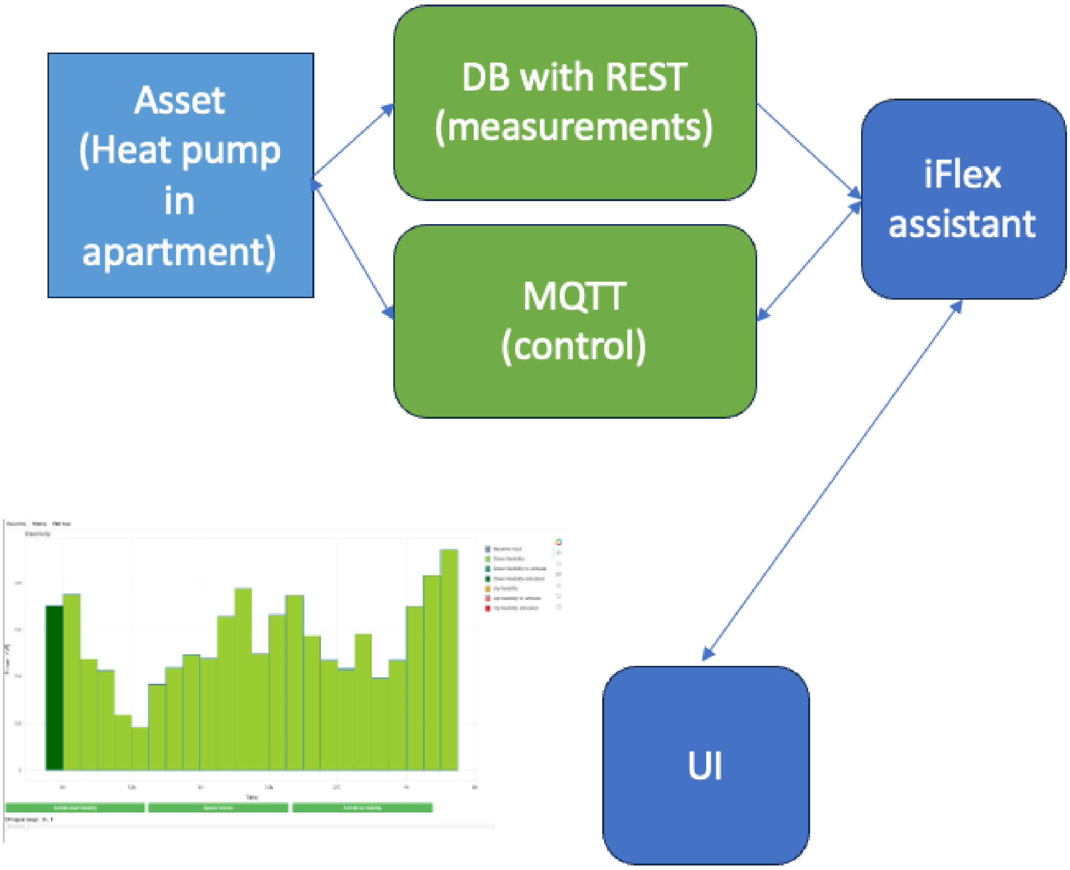


Figure 35: iFLEX assistant controlling flexible asset in Slovenian pilot.

Figure 35 shows the architecture of automated flexibility demonstration, where iFLEX Assistant is forecasting the heat pump baseline consumption, available flexibility and controlling the heat pump according to optimal control policy. iFLEX Assistant generates forecasts for both energy consumption and flexibility, providing valuable insights into future energy demand patterns. Heat pump mode used in iFLEX Assistant was trained using historical data, combining LightGBM algorithms with physics-based models to optimize energy efficiency.

The iFLEX Assistant operates online, retrieving real-time measurements such as weather forecasts and indoor temperatures via a REST service. Using this data, it generates energy and flexibility forecasts and responds to user-generated flexibility activation signals through an UI interface. Control signals generated by the iFLEX Assistant are transmitted through an MQTT server to control the heat pump's operation according to the optimal control policy, ensuring efficient energy usage while maintaining occupant comfort.

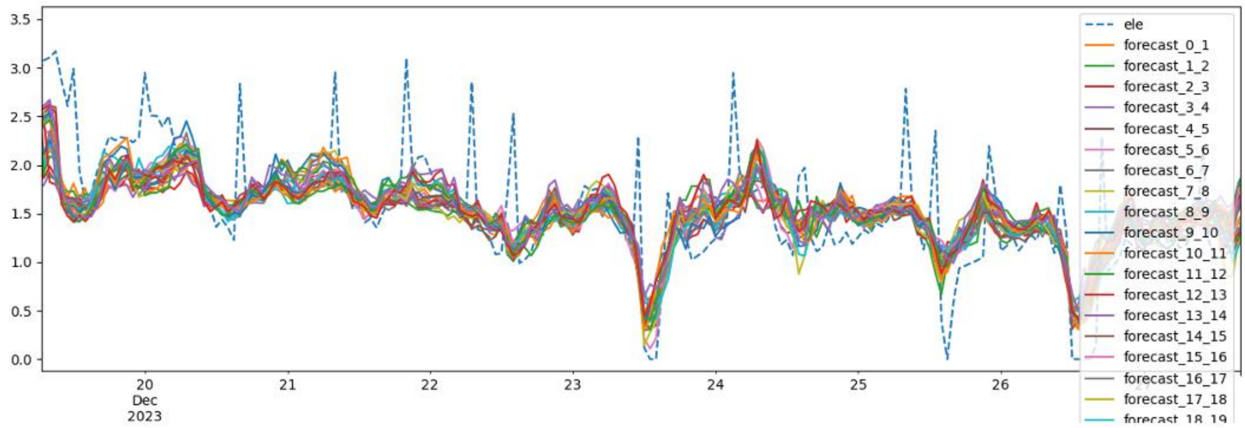


Figure 36: Baseline consumption forecast for the heat pump.

Figure 36 illustrates the forecasts iFLEX Assistant is making during the test period. The iFLEX Assistant updates the 24h forecast every hour so there is 24h overlapping forecast. This is visualised with different colours. Dotted line visualizes the measured electricity consumption of the heat pump and solid lines are forecasts made *n* hours ago, e.g., *forecast_1_2* was made 2 hours before actual time period.

3.3 Finnish large-scale pilot deployment

Figure 37 illustrates an overview of the Finnish pilot. The iFLEX Assistant is deployed into two large buildings: an apartment building and a supermarket linked through MakingCity co-operation. Section 3.3.1 describes the apartment building pilot. The supermarket pilot is presented in section 3.3.2. Both buildings are connected to Enerim's aggregation platform and via MQTT interface of the AFM module presented in D3.9 [6]. Explicit demand response in the energy wholesale market was demonstrated via the Nord Pool intraday test market.

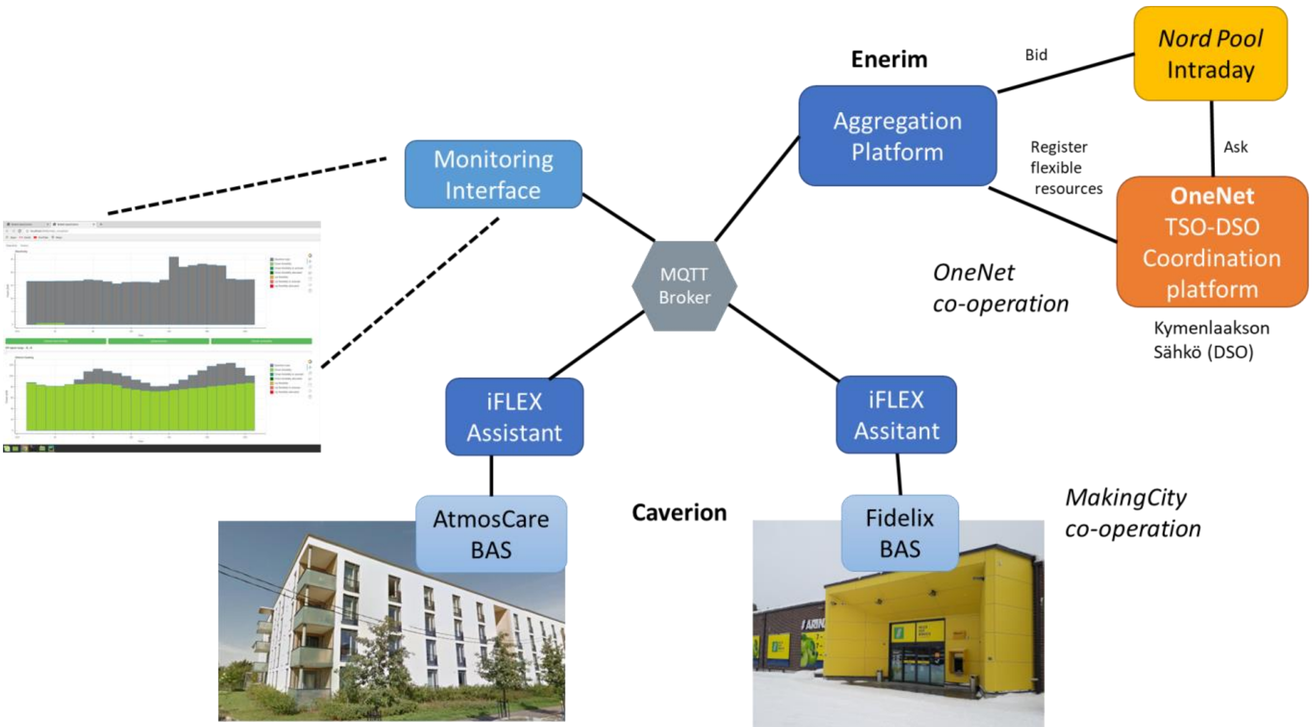


Figure 37: Overview of the Finnish pilot.

We organized also a common pilot with the OneNet project and demonstrated how demand flexibility can be used to solve bottlenecks in the TSO (Fingrid by) and DSO (Kymenlaakson Sähkö) networks. To this end, the pilot buildings were connected to the OneNet's TSO-DSO coordination platform via Enerim's aggregation platform. Please refer to D8.5 [7] for further details on the federated pilot with OneNet and MakingCity.

The objectives planned for the third phase, as outlined in D7.3 [8], include:

1. To implement and deploy a new iFLEX Assistant for the supermarket from the MAKING-CITY project.
2. To integrate the supermarket with Enerim's Aggregation Platform.
3. Utilizing iFLEX Assistant to optimize energy efficiency of the apartment building and the supermarket
4. To systemically evaluate and compare benefits of the local optimization made by the iFLEX Assistant in the HOAS building and the new supermarket pilot.
5. Evaluate the novel baseline and flexibility forecasting models against SotA methods in the pilot sites (see KPI2a for details)
6. To aggregate the pilot sites from iFLEX and MAKING-CITY sites (i.e., apartment building and supermarket) with the ENERIM's Virtual Power Plant platform to Nord Pool intraday market (and theOneNet platform).
7. To evaluate the performance of the new adaptive hybrid modelling methods against the state-of-the-art methods in flexibility forecasting. The objective was evaluated already in phase 2 (see KPI2b but improvements in the model)

3.3.1 Apartment building pilot

The iFLEX Assistant was introduced in a Finnish apartment building as part of a pilot to demonstrate its ability to manage energy flexibility for the entire building community. Its main task is to predict the building's energy usage and flexibility for both electricity and district heating (DH). This flexibility comes from the building's heating system and thermal mass, which can be used to shift DH and electricity consumption (through a heat pump)

The apartment complex shown in Figure 38, owned by HOAS, offers rental flats to students. It consists of 93 apartments and accommodates over 140 residents. Each resident has an access to a User Interface that shows energy consumption, CO_2 emissions, and thermal comfort data (registration required). Residents can also give feedback on their comfort levels. In the pilot's first phase, four residents participated, and sensors for temperature, humidity, and CO_2 levels were installed in their apartments. In the second phase, five more residents received sensors for more accurate measurements.

In phase 3, no new residents were added, but the focus shifted to comprehensive testing of the system as part of the overall Finnish pilot presented in Figure 37. Additionally, in this phase we implemented of new modelling methods for the iFLEX Assistant, allowing for more sophisticated energy management strategies to be explored and refined. Objectives 3,4,5,6 and 7 presented in section 3.3 are valid for apartment building pilot. In addition, D7.3 [8] following actions were planned for phase 3 for HOAS building pilot:

- Action 1: Integrate tree-based methods e.g., random forest and LightGBM to modelling pipeline and evaluate all available forecasting models against current SotA methods.
- Action 2: Develop automatic model deployment for the HOAS pilot iFLEX Assistant.

Figure 38: The apartment building for the Finnish pilot.

The primary use case of the Finnish pilot project is to manage flexibility at the building community level, with a specific focus on HLUC-3, detailed in D2.1 [2]). In the second phase of the pilot, the main objective was to verify and validate the technical functionalities enabling explicit demand response (DR) at the apartment building level, which were partially demonstrated in the initial phase. Concurrently, there is a strong emphasis on optimizing for minimal CO_2 emissions, energy usage, and energy costs. During large-scale pilot phase, the focus remained on managing flexibility within the building community, with HLUC-3 still at the forefront. The aim was to further validate and refine the technical capabilities for explicit demand response, while continuing to prioritize minimal CO_2 emissions, energy usage, and energy costs. This phase allowed for comprehensive testing and optimization of the system on a broader scale, ensuring its readiness for wider deployment.

In phase 3, we improved scalability of the system by utilizing container registry, where instances of the iFLEX can be easily pushed and fetched (action 2). GitLab container registry was used to implement private registry for the instances. Developers can push iFLEX Assistant instances (e.g. iFLEX Assistant controlling HOAS building) to container registry and it can be easily fetched from a server.

Energy optimization of the apartment building was done mainly already in phase 2 and optimization was done using iFLEX Assistant, which tries to find ways to reduce energy consumption, heating costs, and CO_2 emissions in a pilot building (objective 3 and objective 4).

Figure 39 illustrates how the iFLEX Assistant reduced the heating level for six hours and its impact on the indoor temperature. The optimization mode of the iFLEX Assistant was tested during the period from December 1, 2022, to March 20, 2023. Space heating was systematically reduced for varying durations (2-12 hours) every other day or every third day.

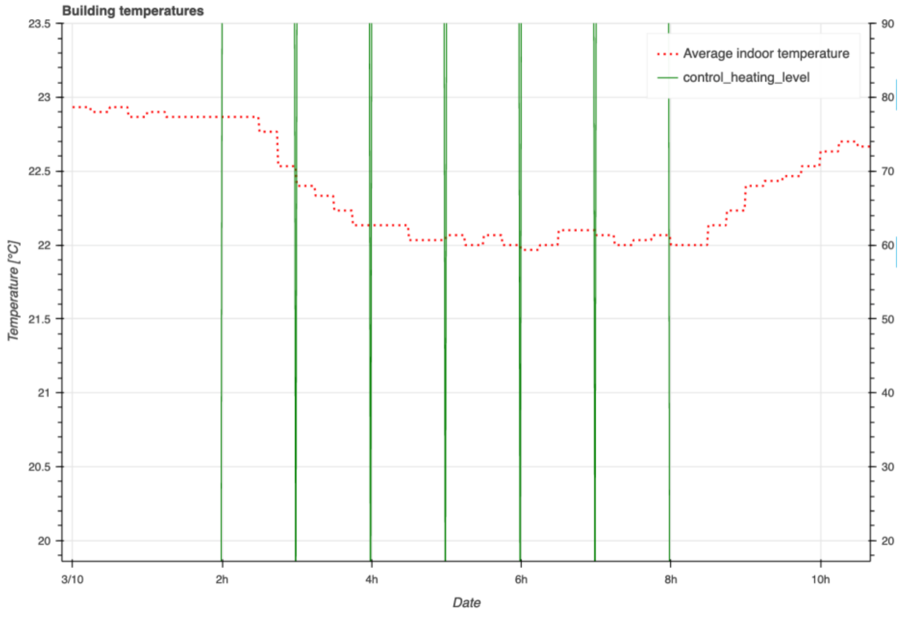


Figure 39: Indoor temperature during the optimization.

The days with and without optimization have been compared and finally presented to the end-user through the end user interface. Following are the initial savings generated by the optimization:

- CO_2 emissions: 10,72%
- Costs: 9,42%

Figure 40 illustrates the average total energy consumption, combining district heating and electricity, with the left bar representing the average for the optimization days and the right bar showing the average for the reference days. The mean outdoor temperature during normal operation was -1,44°C, while during optimized operation, it was -1,22°C. Similarly, the mean indoor temperature during normal operation was 21,53°C, whereas during optimized operation, it was 21,33°C.

The drop in the average indoor temperature helps explain part of the savings observed during optimization. However, due to the large thermal mass of the building, it's plausible that some of the savings may not be actual savings, but rather attributed to long thermal payback delays occurring during the reference periods. In theory, the optimization days could lead to a decrease in the temperature of the building envelope (without visibly impacting indoor temperature measurements), which is then compensated for during the reference days.

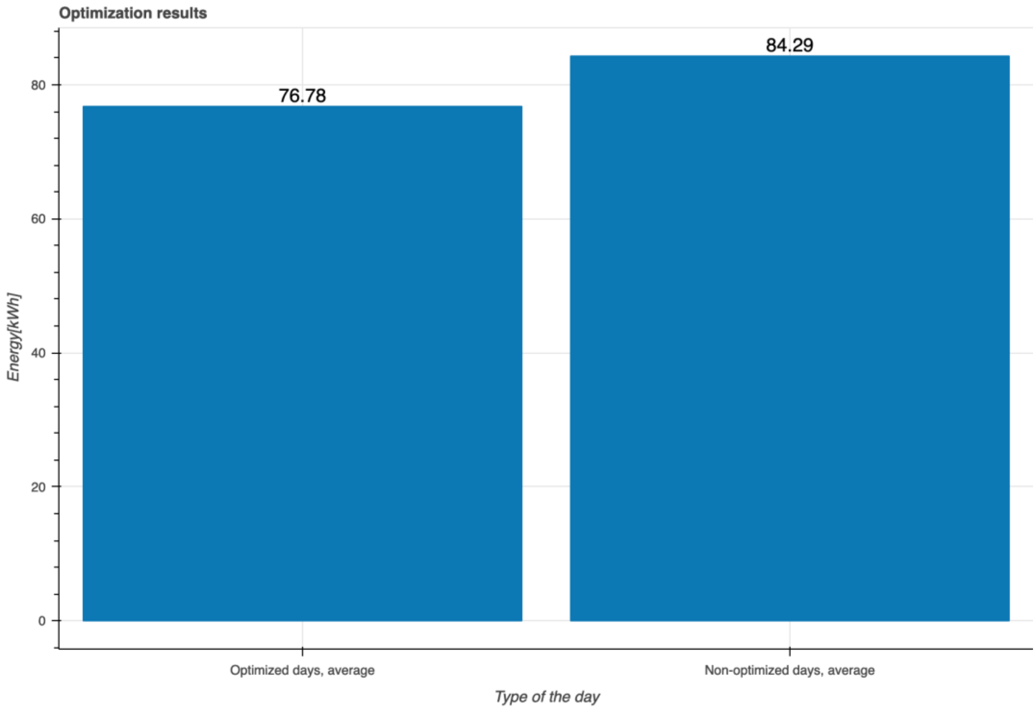


Figure 40: Average energy consumption in optimization days and references days.

Finnish pilot has been tested with Enerim's Virtual Power Plant platform in the second phase of the piloting. On March 24, 2023, the Finnish pilot participated in a test with Enerim and other partners from the OneNet project. Approximately 10 kW of flexibility was provided for trading in the flexibility market via the Enerim's platform. The test involved deactivating the heat pump and reducing the heating level, resulting in flexibility activation depicted in Figure 41. In phase 3 both apartment building and supermarket electricity and apartment building district heating flexibility was published to MQTT broker that could be accessed by Enerim's VPP (objective 6). In addition to flexibility offered by the real HOAS building, virtual buildings with simulated energy consumption and flexibility were used to offer more flexibility.

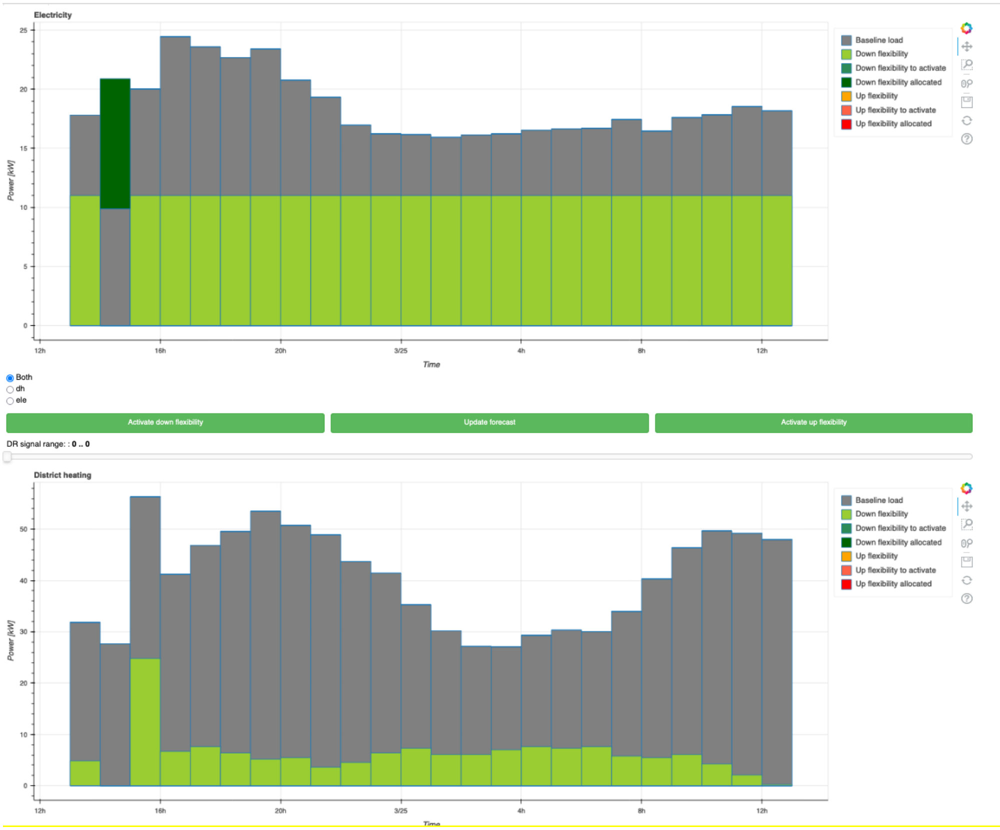


Figure 41: Flexibility activation in Enerim's VPP.

Totally during the iFLEX project (phases 1, 2 and 3), flexibility activation was tested 129 times. The analysis of temperature data from flexibility tests conducted in iFLEX phases 1, 2 and 3 for the HOAS apartment building reveals following insights. Mean temperature across all sensors falls below 20°C totally two hours (A=2) during the piloting period (1.11.2021 – 13.3.2024, 20712 hours, B=20712). The ratio *1−A/B* is computed as follows:

- *1−2/20712 = 0,9999*

This result indicates that approximately 99.99% of the time intervals analyzed had temperatures above 20°C. Therefore, the vast majority of the duration during the flexibility tests exhibited temperatures within the desired threshold.

In phase 3 we deployed an improved version of the hybrid model for the Finnish pilot with the focus to improve the baseline forecast of the SotA models used in phase 2 (objective 5). As explained in D3.1- D3.3 [9] [10] [11] (Hybrid modelling module) the hybrid models consist of machine learning (ML) models that are augmented with physics-based model (actually a greybox model with parameters learned from data with ML techniques). Separate models for electricity and district heating baselines. In phase 2 we implemented and tested several ML models reported in the literature to provide SotA results in different building related demand forecasting tasks. The best model for the apartment building pilot was a feed forward neural network (FFNN) with following features.

- **lagged_target - window [-24:-1]:** 24h of lagged values of the forecast target (either electricity or district heating baseline)
- **weekday - window [0:23]:** Weekday (Monday, Tuesday, etc.) for the forecast period in one-hot encoded format.
- **hour - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.
- **t_out - window [0:23]:** Outdoor temperature for the forecast period.
- **hour - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.
- **holiday - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.

- **dr_control - window [0:23]:** Planned demand response control signal (either space heating or heat pump)

In the feature specification above the window specifies the range of values. Zero (O) indicates the last measurement, 1h the next value in the future, and -23 the period from 24 – 23 hours in the past.

The new hybrid model uses gradient boosting framework, called LightGBM, as the baseline models (action 1 defined for phase 3). The innovative approach in the model is to use past residuals of a SotA model used in phase 2 as one of the features. The idea is that the LightGBM models uses the residuals of the to learn to correct and improve the baseline model forecasts. Additionally, we used the automated feature engineering pipeline presented in D3.3 [11] to find optimal features for the LightGBM model. The features of the LightGBM are listed below.

- **ffnn_residual_N - window [-168:-144], [-24: -1]:** Historical errors of the FFNN model presented above. Separate residual is used for each forecast period N. I.e., 24 residuals from week ago and yesterday.
- **weekday - window [0:23]:** Weekday (Monday, Tuesday, etc.) for the forecast period in one-hot encoded format.
- **hour - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.
- **t_out - window [-8:23]:** Outdoor temperature for the forecast period plus eight hours in the past (past values are used because of the thermal inertia of buildings).
- **hour - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.
- **holiday - window [0:23]:** Weekday (0-23, one-hot encoded) for the forecast period.
- **dr_control - window [0:23]:** Planned demand response control signal (either space heating or heat pump)

To evaluate the model accuracy, we calculated the Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and the normalised RMSE (NRMSE) as presented in equations (1), (2), and (3).

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \qquad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \qquad (2)$$

$$NRMSE = \frac{RMSE}{y_{max} - y_{min}} \qquad (3)$$

The accuracy of baseline load forecasts for electricity and district heating are presented Table 10 and Table 11, respectively.

Table 10: Accuracy of electricity baseline load forecasts.

METRIC	ADA-HYBRID	FFNN
MSE	3,13	3,94
RMSE	1,77	1,98
NRMSE	0,059	0,066

Table 11: Accuracy of district heating baseline load forecasts.

METRIC	ADA-HYBRID	FFNN
MSE	115.78	151,65
RMSE	10.76	12,31
NRMSE	0,075	0,086

When calculated based on the MSE, the new Ada-Hybrid model improves the baseline load forecasts of the state-of-the-art FFNN model by 20.6% (electricity) and 23.7% (district heating). The average improvement is thus 22% (objective 5 and KPI2a).

In the phase 3, the same models were also evaluated for the flexibility forecasting (i.e., the accuracy during a DR event). It should be noted that here the accuracy of the Ada-Hybrid model is heavily influenced by the hybrid greybox model that augments the baseline forecasts (LightGBM) during DR event. Please refer to D3.3 [11] for further details of the hybrid model. The accuracy of the Ada-Hybrid and FFNN forecast during DR events are presented in Table 12 and Table 13.

Table 12: Accuracy of electricity flexibility forecasts.

METRIC	ADA-HYBRID	FFNN
MSE	2,38	3,28
RMSE	1,54	1,81
NRMSE	0,064	0,075

Table 13: Accuracy of district heating flexibility forecasts.

METRIC	ADA-HYBRID	FFNN
MSE	325,67	515,63
RMSE	18,04	22,71
NRMSE	0,125	0,158

When calculated based on the MSE, the new Ada-Hybrid model improves the flexibility forecasts of the state-of-the-art FFNN model by 27,5% (electricity) and 36,8% (district heating). The average improvement is thus 32,2% (objective 7 and KPI2b).

Figure 42 - Figure 47 illustrate the forecasts during the test period. The iFLEX Assistant updates the 24h forecast every hour so there is 24h overlapping forecast. This is visualized with different colours in Figure 42 - Figure 45. To make the individual forecasts more visible and highlight the model behaviour during DR events, 24h forecasts from periods with one or several DR events are represented in Figure 46 and Figure 47.

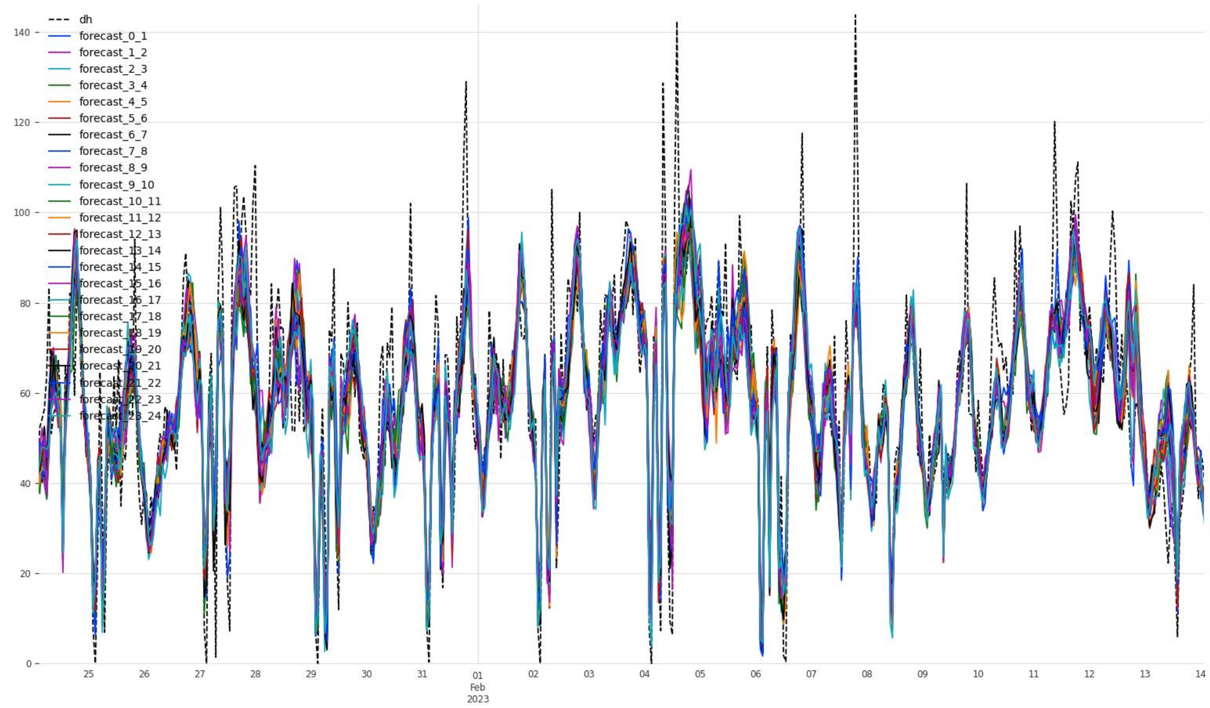


Figure 42: A random 21-day sample of the district heating baseline forecast during from the test period. The different forecast periods are presented with different colours.

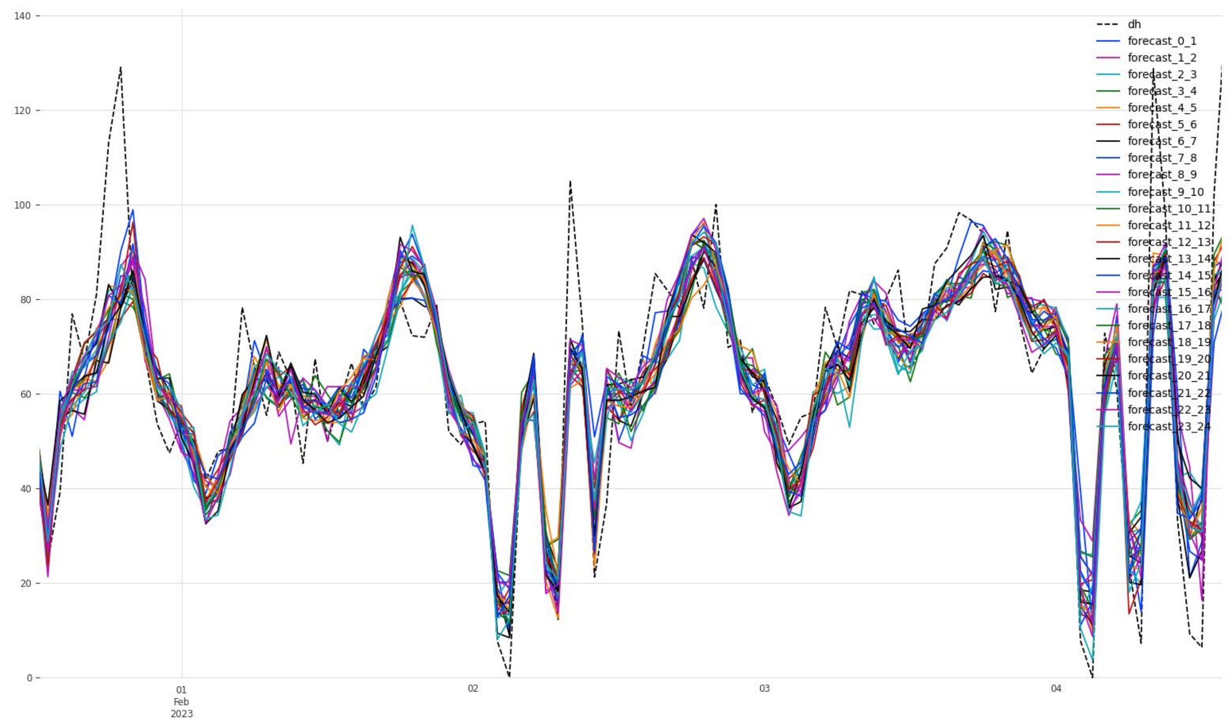


Figure 43: A random four-day sample (subset of the 21 sample above) of the district heating baseline forecast during from the test period. The different forecast periods are presented with different colours.

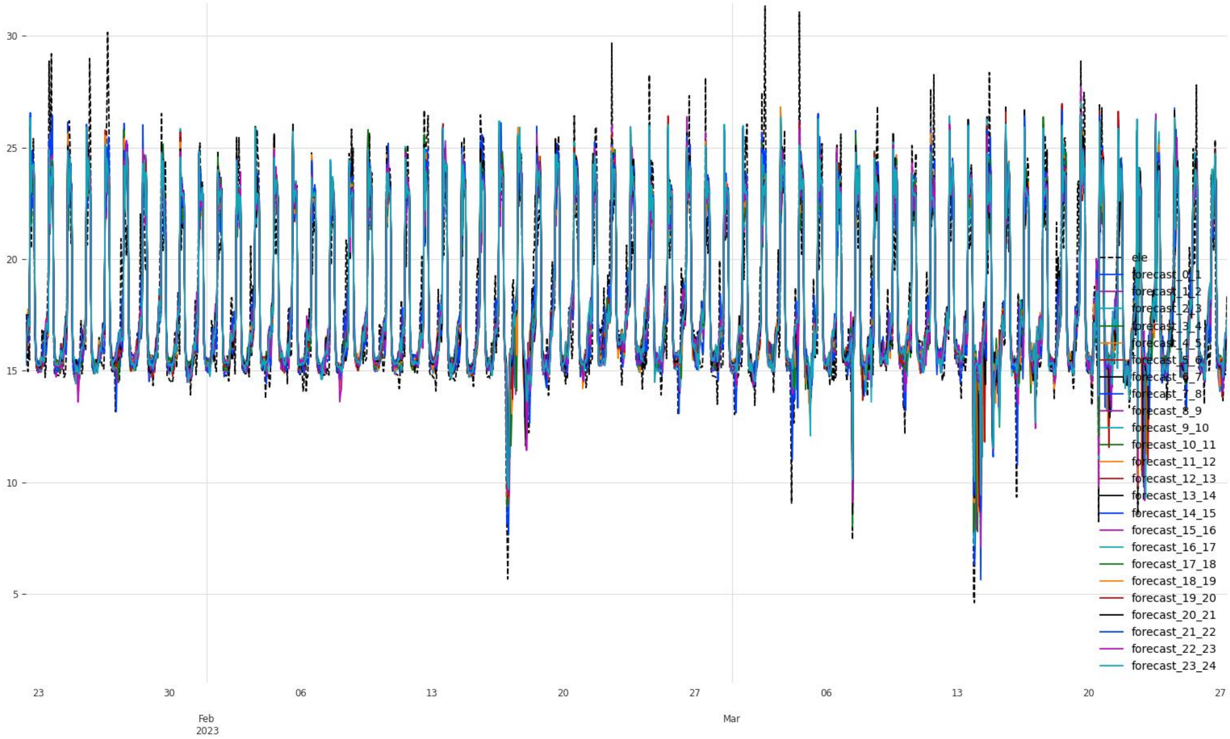


Figure 44: A random 34-day sample of the electricity baseline forecast during from the test period. The different forecast periods are presented with different colours.

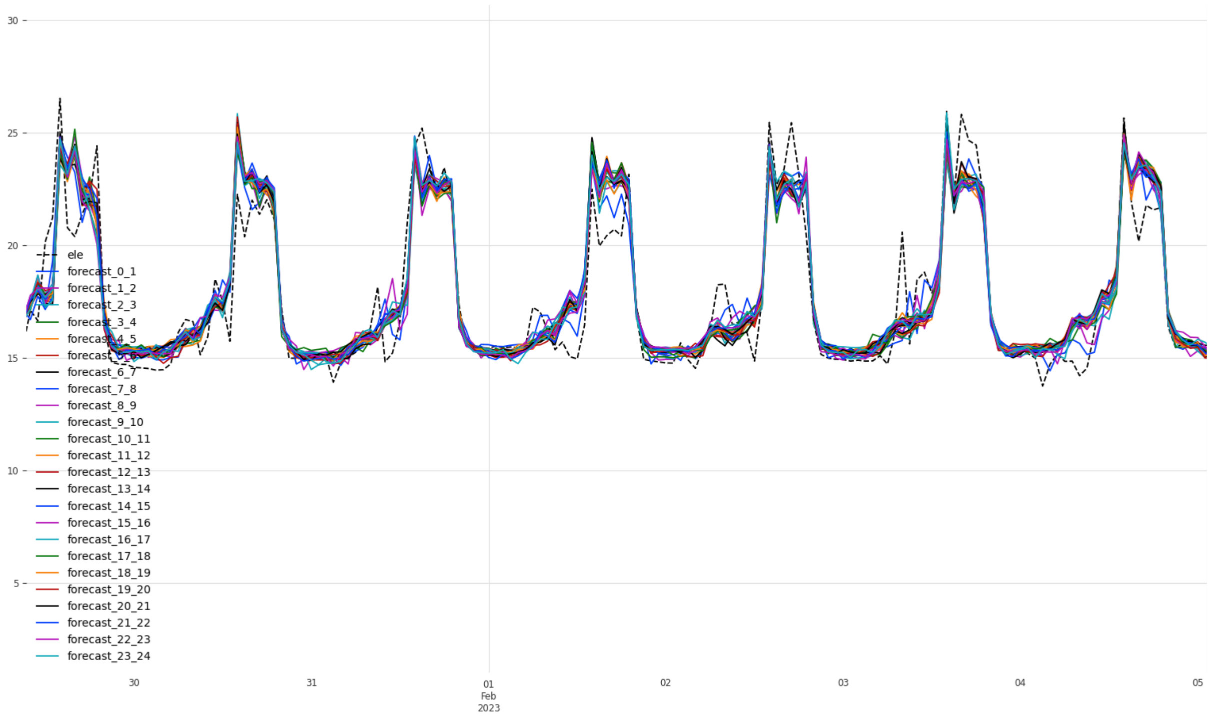


Figure 45: A random 7-day sample (subset of the 34-day sample above) of the electricity baseline forecast during from the test period. The different forecast periods are presented with different colours.

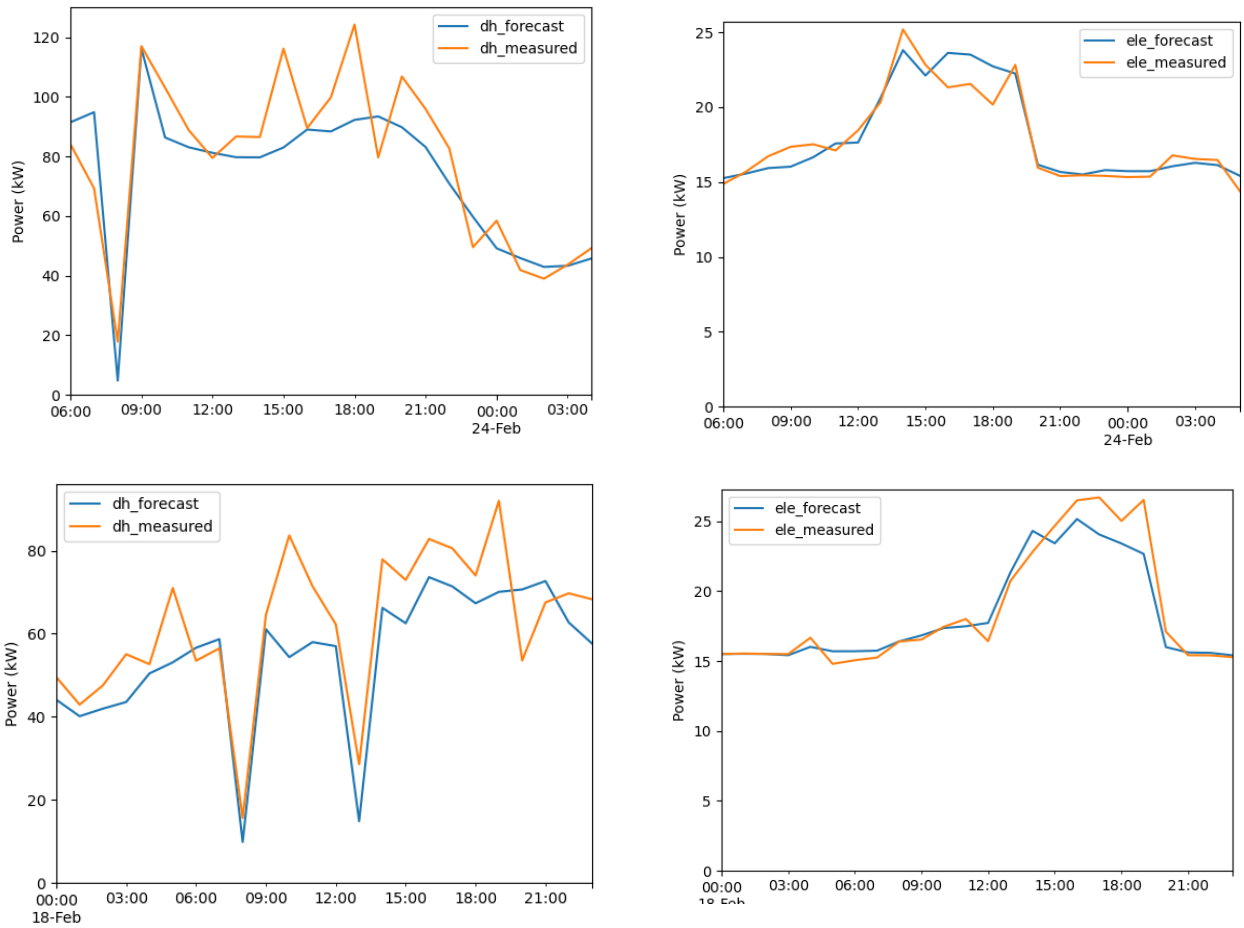
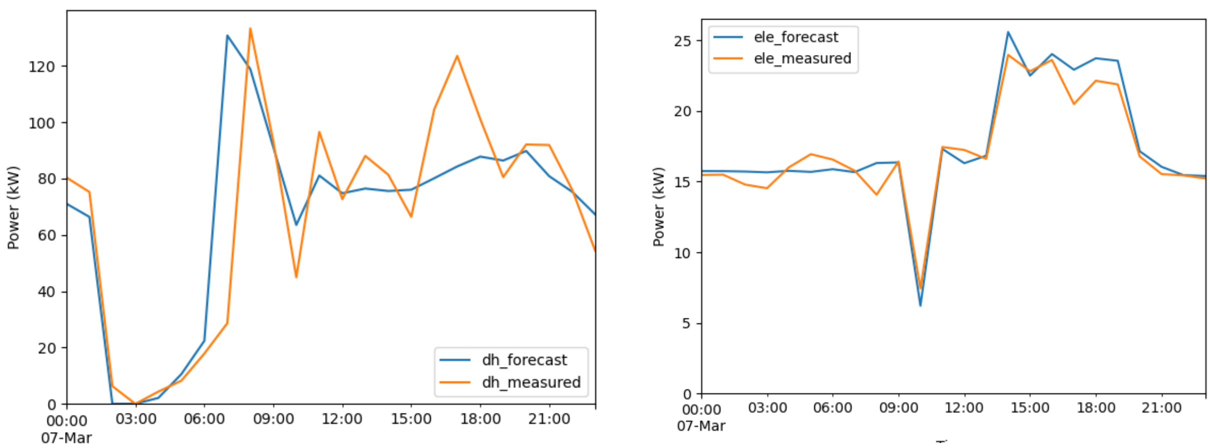


Figure 46: Individual forecast for district heating (left column) and electricity (right column). The samples were selected from periods where space heating was constrained during DR events.



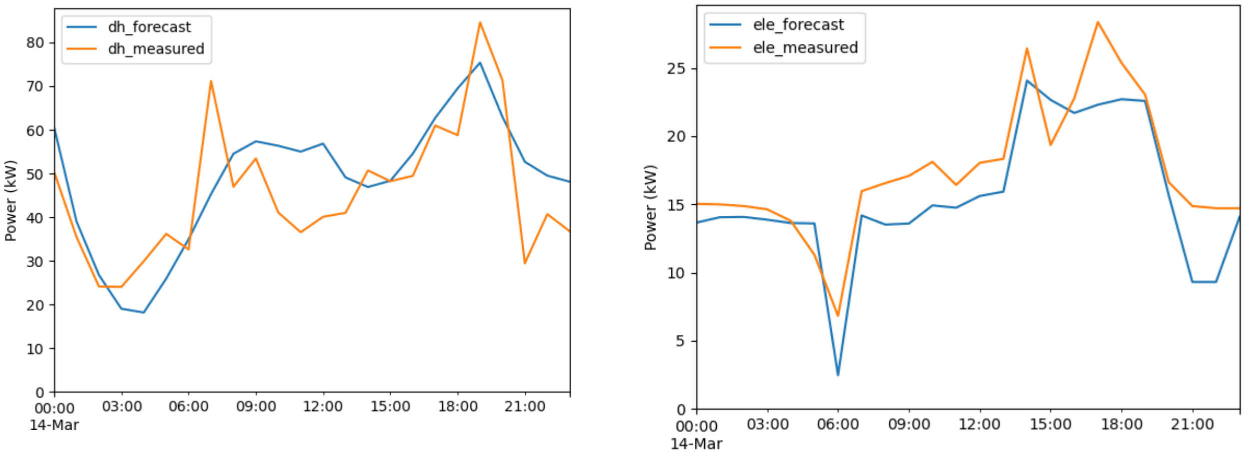


Figure 47: Individual forecast for district heating (left column) and electricity (right column). The samples were selected from periods where space heating and the heat pump was constrained during DR events.

3.3.2 Supermarket pilot with MakingCity co-operation

The Kaukovainio supermarket is ~2000m² single floor building located in Oulu, Finland. It is quite a new building, built in 2019, and contains a couple of rented spaces within. In total, there are 4 conditioned spaces, of which 2 are rent spaces. The floor heating does not reach the total area of the building, but mainly the rent spaces, social space and the hallway of the market, covering around half of the building.

Yearly electricity consumption of the building is roughly 430 MWh/year. This consumption is partly met by utilizing solar panels with 55kW of peak power. Around 30% of the electricity is used to run the heat pump system. This system produces both cooling and heating for the building energy needs. To achieve efficient operation, the building uses thermal storages to buffer its production: A hot water storage on the heating side, and ground wells on the cooling side. The heat pump system can produce heat for the district heating network as well.

Figure 48: The supermarket pilot building.

Multiple control experiments were conducted with the supermarket pilot, in which the heating of the building was restricted to minimum for 5 hours. These experiments were done during every other night between 23:00 and 04:00. An example is shown below in Figure 49.

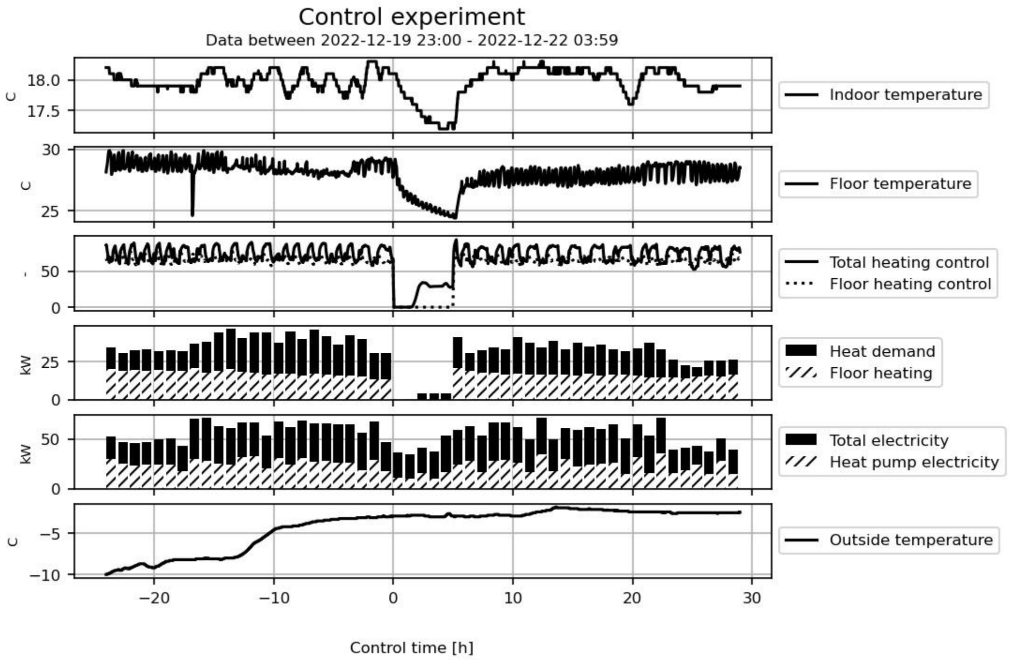


Figure 49: A control experiment in Kaukovainio pilot building.

The indoor and floor temperatures clearly decrease during the experiment. While heating of the main air conditioning and floor heating units are limited, some equipment are still consuming energy during the experiment, which is shown in the total heat demand. Total electricity consumption is also lower during the experiment, because of the reduced load of the heat pump system. These experiments were conducted during 2023 in the wintertime, and they provided reductions in energy consumption of the building. Results are shown in Figure 50.

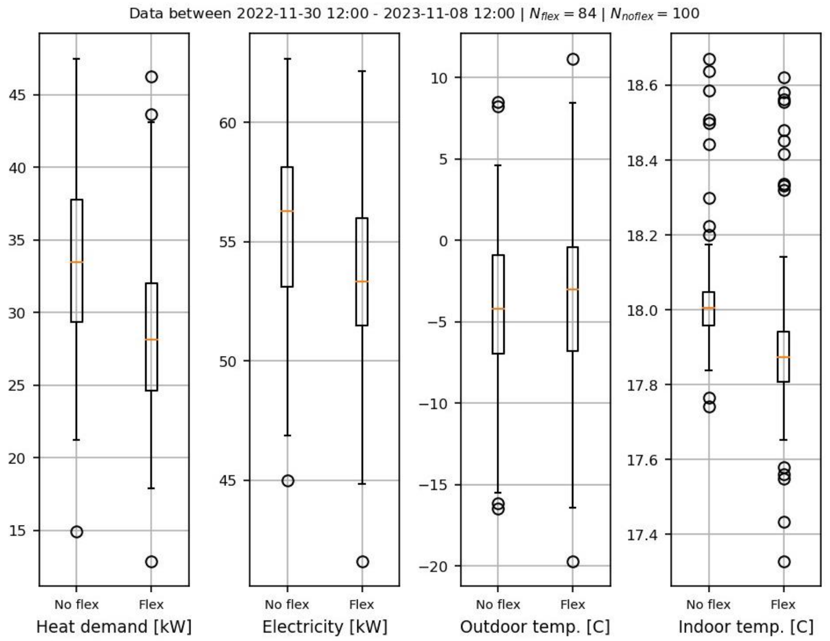


Figure 50: Analysis of control experiments performed during 2023 heating seasons. The figure presents distribution of daily means without control experiment (No flex) and with control experiment (Flex). The daily means were calculated with 12-hour offset starting from 12:00 noon.

The results show that ~20% less heat and ~10% less electricity is consumed during days when the control experiment was conducted (objective 3). The indoor temperature is also slightly lower during control experiment days. The results for days of no control and control are comparable because the outdoor temperature distribution is similar in both cases.

An RC-model was implemented in the iFLEX Assistant to predict indoor temperature, heat consumption and enable automated down-flexibility control in the pilot building. Figure 51 shows how realized indoor temperature compares with the simulation result.

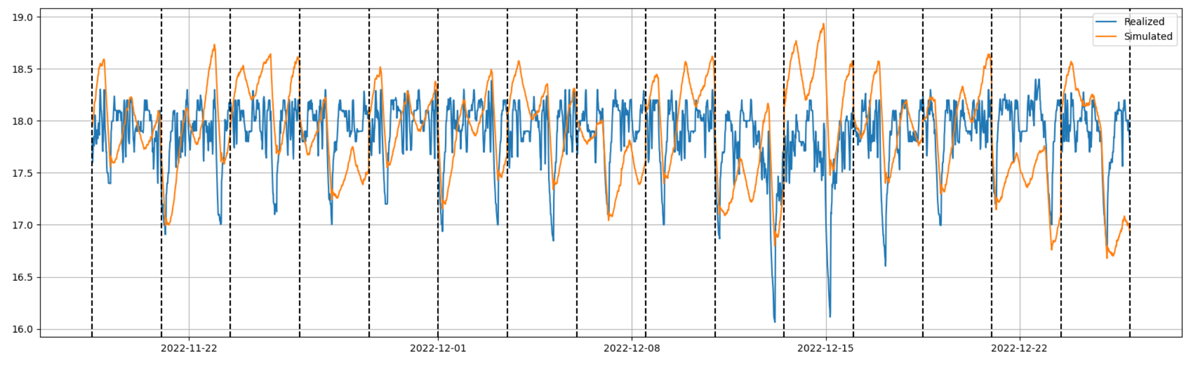


Figure 51: Train result of a trained RC-model. Dashed vertical lines separates train periods. Between each period the model is initiated. The length of prediction period for the model is 60h.

The trained model is used for simulating desired heating control. An example is shown in Figure 52.

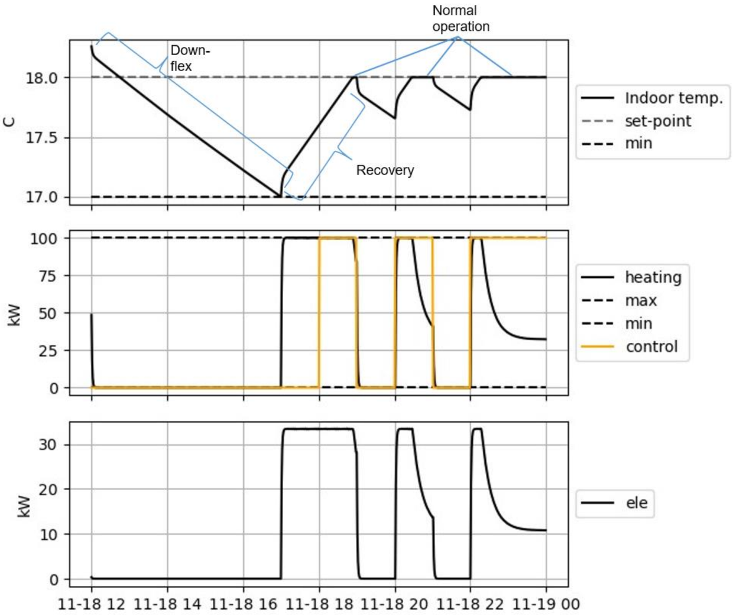


Figure 52: Demonstration of model control logic.

The model operates in 3 modes: Normal, down-flex and recovery. In normal mode, the model predicts normal heat consumption of the building. When control signal is set to 0, the model estimates down-flexibility by setting heat consumption to 0% and simulating cooling. When down-flex ends (control signal changes from 0 to 100), the model simulates first a recovery period, in which heat consumption is 100%. Recovery period ends, when set point temperature is reached.

This control model is implemented in iFLEX assistant to estimate available down-flexibility (objective 1). An example of the heating plan creation is shown in Figure 53, while Figure 54 shows heating plan implementation and comparison between the predicted and realized heat demand.

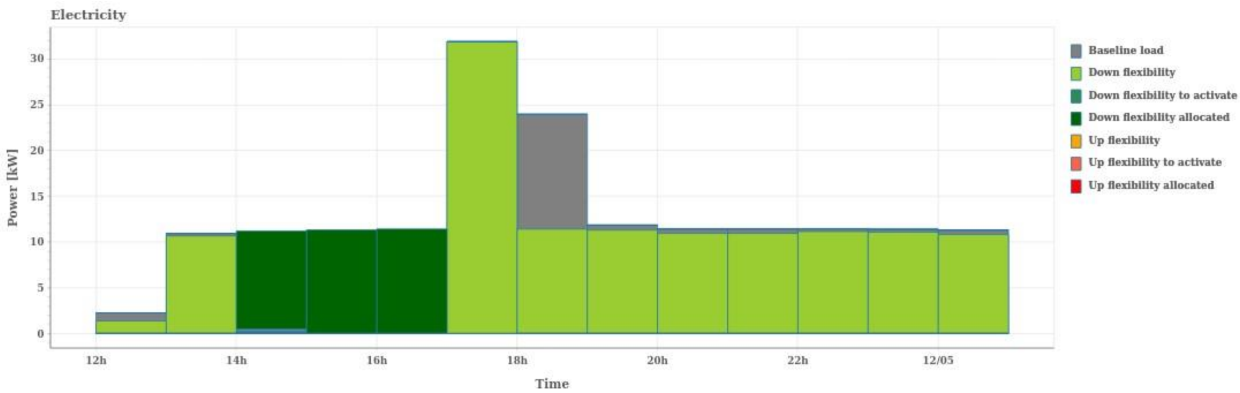


Figure 53: Demonstration of flexibility prediction in iFLEX Assistant with mock data. The figure present electricity used for heating.

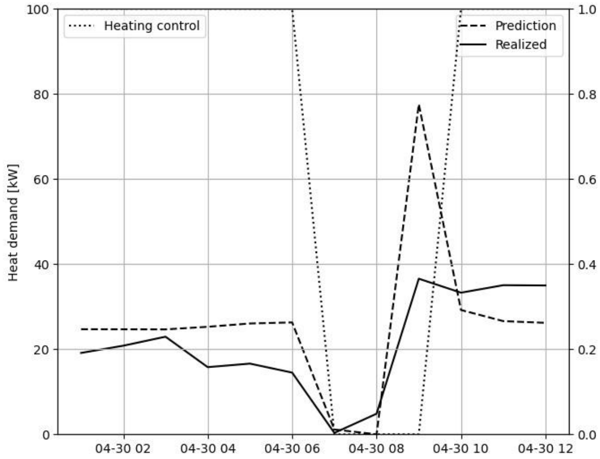


Figure 54: Flexibility control test with an online model. A control plan is created, which is then predicted with a 12-hour prediction. Realization of the control plan is shown for comparison.

The iFLEX Assistant has a capability to communicate its flexibility via MQTT to the aggregator. The architecture is the same as in HOAS pilot (objectives 2 and 6).

A study was conducted in coordination with S-group to find the potential savings if spot optimization were utilized in the Kaukovainio pilot (objective 4). The study is based on a linear optimization model, which uses an RC-model to predict the heat demand of the building. We used 4,5 month data period from a winter between 2022-2023 as the optimization period. The only forecasted parameters were outdoor temperature and day-ahead prices.

The results are based on simulation of two scenarios (energy minimization and cost minimization) and comparing them against each other. In the baseline case, heating consumption is the minimization target, while the other case minimizes electricity costs using day-ahead prices for electricity. Figure 55 shows how the price accumulates in both cases.

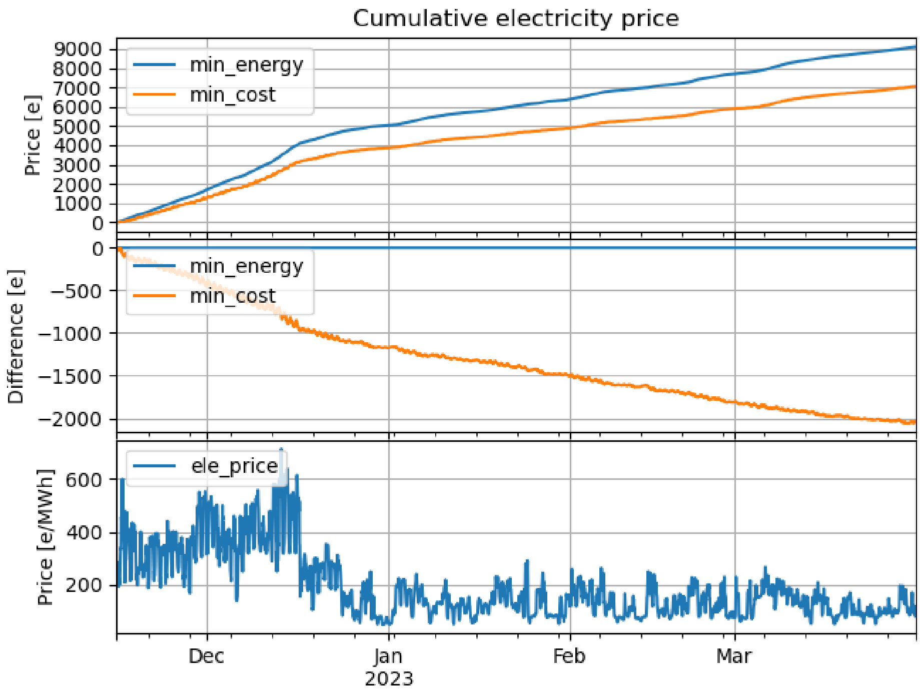


Figure 55: Spot optimization result for Kaukovainio S-market pilot.

After simulating the period, a difference of around ~2000e is found between cases. When spot optimization is utilized, electricity costs reduce approximately 22,4%. Key results are shown below in Table 14.

Table 14: Spot optimization key results for Kaukovainio S-market pilot.

Optimization cases		Total electricity	Electricity for heating
min-energy	Consumed electricity [kWh]	194 960	47 585
	Cost of electricity [e]	36 834	9 101
min-cost	Consumed electricity [kWh]	197 388	50 013
	Cost of electricity [e]	34 793	7 061
	Savings [e]	2 040	2 040
	Relative savings [%]	5,54	22,4

4 Validation plan for phase 3

The validation framework plan was originally developed in the beginning of the project, prior to pilot implementation, and presented D7.4 [1]. As a framework and plan, it would set the boundaries for the validation while being flexible to accommodate to changing shape and needs of the project (the iterative approach) and its end-users; it was not intended to be prescriptive or restrictive.

Validation in the iFLEX encompasses (see Figure 56):

- end-user validation,
- technical validation and
- business validation.

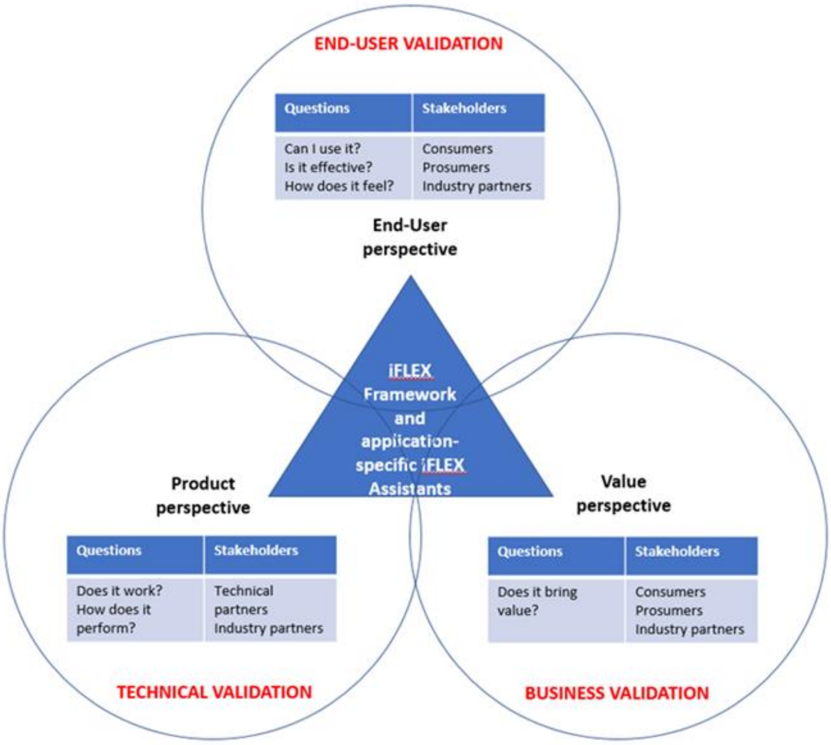


Figure 56: Validation aspects.

The key questions posed for each of the three aspects remain valid and have been assessed, however, as the pilots progressed, some of the originally planned methods and activities (described in D7.4 [1]) have been slightly modified to fit the specific pilot context, objectives and use cases. The following subsections present the relevant validation plans for each of the three aspects that have been used to guide the validation activities in this final phase of the project.

4.1 End user validation plan

End-user validation for phase 3 is a summative validation seeking to answer the question “Have we built the right system?”. End-user validation relates to the user experience and in the iFLEX we have focused on three intrinsically linked aspects affecting the user experience: i) user acceptance, ii) usability, and iii) satisfaction.[4] Specifically, the end-user validation plan was designed to validate the following:

- Functionality: Is it effective?
    - Do the functions and content solve my needs, is the assistant useful and will I use it?

[4] In ‘ISO/IEC 25010 for Quality of Use model for usability’, satisfaction is considered a property of usability. Thus, satisfaction is related to the user’s experiences of (or their evaluation of) usability.

- Usability: Can I use it?
    - Is it an effective and efficient tool that I am satisfied with?[5]
- Pleasure: How does it feel?
    - Does the presentation and interaction provide pleasure and value / is the assistant desirable / does it support the achievement of goals i.e., the motivation behind the interaction e.g., being independent, competent, etc.?

While the end-user validation plan is considered common to all three pilots in the project, the inherent differences across the three pilots with regards to end-user interaction with experiences with the iFLEX and the iFLEX Assistant mean that validation objectives (validation item) and methods have been designed to fit the pilot specific context.

The overall and common plan for end-user validation for phase 3 is presented in Table 15 below.

Table 15: End-user validation plan Phase 3.

ID	Validation Item	Validation Method	Success Criteria	Pilot
EUV 2	User experience & satisfaction	User Experience Questionnaire (UEQ)	>Good, compared to UEQ benchmark for each sub-item[6]	Greece
EUV 3	User acceptance	User Experience Questionnaire	>Good, overall result of UEQ (all items)	Greece
		Interviews with randomly selected users' data)	Principally positive feedback	Slovenia
EUV 4	Usability and user satisfaction for active participation in DR (usefulness, trust, please, comfort)	Pilot specific questionnaire	≥75% of respondents have not experienced significant effect on their thermal comfort	Finland
		Pilot specific questionnaire	>85% of respondents: score 5 or more on 6-point Likert scale use 3 or more functionalities in iFLEX App have used 2 or more functionalities often or every day.	Greece
		Interviews with randomly selected users	Principally positive feedback	Slovenia

[5] Linked to software usability tests (part of technical validation).

[6] UEQ Scores: Excellent = In the range of the 10% best results. Good =10% of the results in the benchmark data set are better than the result for the evaluated product and 75% of the results are worse.

		& Greece

The pilot specific details related to the validation plan in Table 15 are described in more details below.

4.1.1 Greek Pilot

The UEQ was administered to the Greek pilot participants once and thus used to cover both EUV2 and EUV3; for EUV2 the results for each of the 6 subitems or scales (i.e. attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty) was measured whereas for EUV3 it was the overall result of the UEQ that was measured. The UEQ analysis tool, which is freely available with the UEQ, was used to calculate the results. The UEQ was also integrated into the Greek pilot specific questionnaire so that the Greek pilot participants were only presented with one questionnaire to complete, see Annex A Greek pilot questionnaire.

The specially designed questionnaire enquires into all three aspects described above (functionality, usability, pleasure) using a 6-point Likert scale where possible, multiple choice (single answer), checkboxes (multiple answers), and comment fields (free text). In addition, data on frequency of use, duration and habit of use were collected to provide more context for interpretating the results.

The questionnaire was distributed online and answers were collected anonymously.

4.1.2 Slovenian Pilot

The interviews that were carried out with Slovenian pilot participants collected input to both EUV3 and EUV4. Interviews were conducted over the phone and followed a loosely structured interview guideline. This approach meant that while there were a set of predefined questions there was still room for allowing interviewees to bring up new additional aspects and for exploring or expand issues of particular interest that were brought up.

Inputs to EUV3 and EUV4 were collected also through a user interface test to evaluate the performance of the iFLEX Assistant application and the responsiveness of customers to direct messages that require their feedback. The purpose is primarily to test the usability of the application, the data overview within the application, how the customer interacts with the data they are searching for, how useful the data they are searching for is to the customer, and how responsive the customer is willing to be in exchange for achieving cost-effectiveness or improving the energy efficiency of the building.

The primary objectives during the user interface testing are including evaluation the usability of the iFLEX Assistant application, the usefulness of the data presented to users, ascertain whether users can interpret specific information provided by the application, gauge how willing users would be to actively participate in requests sent through the application, and determine users' willingness to trust the iFLEX Assistant in controlling their devices.

Interest was also in whether customers have any concerns before using such applications and which data points are most important for them to monitor on a daily basis for easier insight into the energy efficiency of their homes. It was considered whether end-users would be willing to dedicate their time to interacting with the application and following the advice that was provided.

To collect the results, the individual phone interviews with end-users was conducted. The purpose of this is to gain a better insight into the customers' thought process while using the application.

4.1.3 Finnish Pilot

The Finnish pilot differs from the other two pilot most significantly with respect to end-users and the characteristic of their interaction with the iFLEX. The targeted end-users for validation activities were the residents in the apartment building where the iFLEX was implemented to control the space heating of the apartments. In addition to general enquiry into perceptions and awareness of Demand Response and the Finnish iFLEX User Interface, a key object for assessment was comfort: a subjective assessment of any experienced changes in comfort during the testing period (see Annex D Finnish pilot questionnaire). As a highly subjective metric, the results are at best indicative in relation to the defined success criteria.

4.2 Technical validation plan

4.2.1 Requirements validation

The requirements management process was facilitated by JIRA, a tool enabling the consortium to model and monitor the full lifecycle of functional and non-functional requirements, from their definition up to their resolution. The detailed workflow of requirements management is presented in D7.4 [1].

During this last phase of piloting (Phase 3), the activities focused on minor fine-tuning of the already maturely formulated and prioritized project requirements. A detailed presentation of the results of technical validation based on the requirements modelled in JIRA on a pilot basis as presented in Chapter 6 of the current document. All requirements of the project have been resolved.

4.2.2 Internal verification activities

Internal verification activities continued in Phase 3, towards achieving an end-to-end fully integrated system in each pilot. Given the different maturity levels per pilot, the activity involved different intensities. The Finnish pilot had successfully completed all tests during the 2nd Phase, hence effort devoted in complementary final polishing activities. Main efforts during this period focused on unit and integration testing of the Greek and Slovenian pilots, successfully providing fully integrated systems towards the support of the demonstration phase. Some delays faced were addressed effectively through adaptations in the design of iFA instances and the prolongation of the project's duration.

4.2.3 Pilot validation of iFLEX Framework and application-specific iFLEX Assistants

The scope of this activity was to validate Functional, Security, Performance, and Acceptance aspects of the iFA and iFLEX framework. The instance of the iFA in the Finnish pilot has been validated regarding its functionality and security already by Phase 2, whereas during this period it focused on acceptance and performance. The other 2 pilots were fully validated during this period. A detailed presentation of the results of technical validation for functional, security and performance requirements on a pilot basis is presented in Chapter 6 of the current document. In terms of acceptance testing, during this period the end-users had provided feedback on the fully operational iFA instances, and all the reported bugs have been resolved.

4.3 Business validation plan

We followed a 3-step approach to evaluating the business potential of the iFLEX Assistant, which is shown in Figure 57.

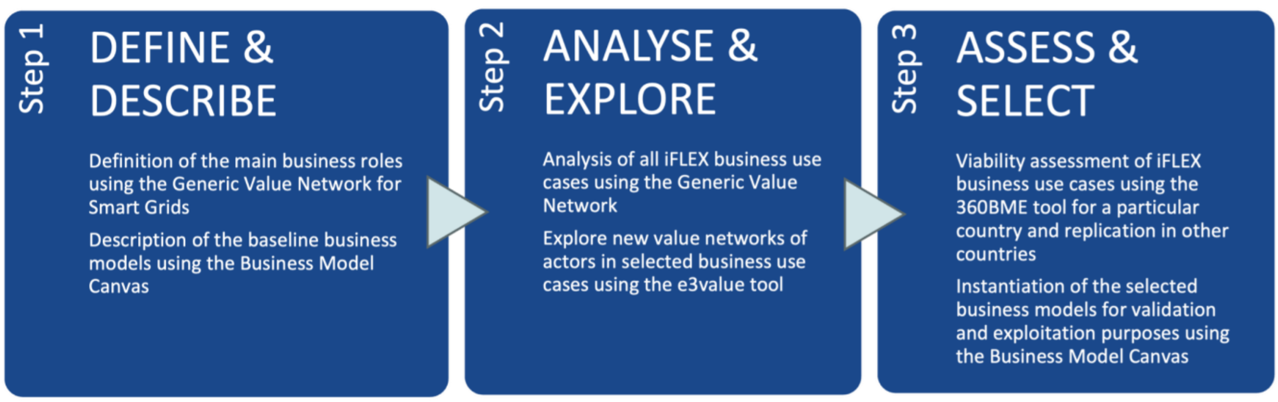


Figure 57: The overall approach for defining and assessing business models.

The first step involves the definition of baseline smart-grid business models by identifying key business roles and describing those via the Value Network and Business Model Canvas methodologies.

The second step proceeds to the definition of iFLEX-enabled business models that can realise the Business Use-Cases (BUC) of interest to the iFLEX consortium, as defined in D2.1 [2]. The candidate iFLEX-enabled business models emerge either by grouping different archetype business models or by introducing innovative ways for realising the main activities and the resulting value proposition. In particular, we analyzed the following candidate services as combinations of BUCs offered by an Independent Aggregator or an Energy Services Company (ESCO):

- An Independent Aggregator optimising the operation of a Balance Responsible Party (BRP) (BUC-1) by leveraging flexibility from consumers through Demand Response (DR) campaigns (BUC-8) based on accurate load profiles (BUC-5) in the Greek pilot cluster.
- An Independent Aggregator offering flexibility to relevant wholesale energy markets (BUC-2) by controlling or affecting the heating of a portfolio of community buildings (BUC-3), in the Finnish pilot cluster.
- An ESCO optimizing energy consumption for multi-vector energy system (building community) (BUC-4) based on the behaviour of consumers (BUC-5) and market price signals (BUC-7) in the Finnish pilot cluster.
- An ESCO supporting prosumers in better aligning their consumption profile (BUC-5) with the local production (BUC-6).
- An ESCO supporting consumers in better aligning their consumption profile (BUC-5) with market signals (BUC-7).

The third step aims to assess the viability and attractiveness of the iFLEX Business Use-Cases and associated business models by performing a techno-economic analysis. We start by modelling the costs and revenue streams of each actor and quantifying their magnitude in a baseline scenario, using data obtained from pilot members and custom simulations in the reference pilot country. By using the 360 BME Tool we individually analyze the profitability of the candidate services above in the reference pilot country. If some actors are identified as “bottleneck”, then we seek for alternative revenue sharing agreements that could lead to “all-win” service delivery. Then we perform a replication analysis of each business model to the rest pilot countries of the iFLEX project by scaling up or down appropriately the costs and revenues so that these reflect the local conditions. In doing so, we can formulate iFLEX-enabled business models for DSF Aggregator and ESCOs by combining one or more BUCs and eventually assess their economic attractiveness in the three pilot countries.

4.4 DoA KPIs validation plan

Table 16 lists the project KPIs that are validated after the phase 3 of the project and explains the success criteria, validation methods and inputs used for the validation.

Table 16: Project KPIs.

ID	Key performance indicator	Success criteria		Validation method	Validation input (data to be collected, documents, ...)
		Target	Validation measures		
KPI1	Number of different types of stakeholders contributing to the co-creation process.	6	Number of different stakeholders, including consumers, prosumers, DSOs, retailers, aggregators, technology providers represented and contributing to the co-design of iFLEX Assistant concept.	Quantitative method. Simple counting of different stakeholders that have contributed to the co-creation of iFLEX solutions.	D2.5 [12] documenting the type of stakeholders that have contributed to the design and development of iFLEX Assistants.
KPI2a	Increased accuracy of consumer load forecasting compared to state-of-the-art methods	20%	The results are compared to the state-of-the-art consumer load forecasting models and percentage decrease of forecasting error is calculated. Evaluation is performed using a variety of data sets (collected in the project),	Quantitative method is applied as described in validation measures.	Measurement and forecast data collected from the pilots and modelling described in D3.3 [11]

			data amounts and load forecasting lengths and average performance of the approaches is calculated.		
KPI2b	Increased accuracy of flexibility modelling compared to state-of-the-art methods	15%	The results are compared to the state-of-the-art flexibility modelling results and percentage decrease of forecasting error is calculated. Evaluation is performed using a variety of data sets (collected in the project), data amounts and flexibility forecasting lengths and average performance of the approaches is calculated.	Quantitative method is applied as described in validation measures	Measurement and forecast data collected from the pilots and modelling described in D3.3 [11]
KPI2c	Increased effectiveness of automated flexibility management compared to standard methods	10%	The results are compared to typical flexibility management algorithms in a wide variety of DR optimization targets and incentives. Percentage improvement of rewards (incentive-specific) is calculated. Evaluation is performed using a variety of data sets (collected in the project), and incentives, and an average performance of the approaches is calculated.	Quantitative method is applied as described in validation measures.	Measurement data collected from the pilots from reference (standard control methods are applied) and iFLEX Assistant optimized periods described in sections 3.3.1 and 3.3.2.
KPI3a	Level of interoperability (coverage of common standards)	100%	Compliance of the iFLEX Framework with connectivity, syntactic and semantic level interoperability standards.	Qualitative analysis. Interoperability demonstrated and evaluated in the pilots.	Documentation of the component interfaces presented in the relevant deliverables (i.e., D3.5 [13], D3.8 [14], D4.2 [15], and D4.5 [16])
KPI3b	Compliance with relevant EU privacy and data management regulation and standards	YES	Non-binding opinion regarding the project privacy and data management approach provided by one of the pilot countries Information Commissioners (IC) office.	Establish contact with IC office and request opinion. Update and implement privacy and data management as recommended by the IC office to ensure compliance.	Documentation of the opinion given by the IC office.
KPI4a	Return on Investment for prosumers in the base scenarios	>15%	Define a set of baseline scenarios related to the assumptions about key techno-economic parameters and compute	Perform a technoeconomic assessment using the iFLEX economic sustainability tool	Detailed quarter hourly data for a full year regarding consumption, production, environmental

			the Return on Investment for Prosumers.	from T5.4 and e3Value tool.	conditions, internal conditions and pricing information from Slovenian pilot site. Furthermore, real-world data from iFLEX trials, or assumptions will be utilised.
KPI4b	Internal Rate of Return for all commercial entities in the base scenarios	>15%	As above (see KPI4b), but for other commercial entities, such as Retailer, Independent aggregator, etc.	As above (see KPI4b) but tailored to the costs and revenues of the target commercial entities, as well as to the incentives for other participants (e.g., consumers, prosumers).	As above (KPI4b), but also considering data from wholesale markets, historical data about market conditions that could trigger Demand Response campaigns (e.g., imbalances) and information on cost items' list prices.
KPI4c	Monetary benefits to the consumer in the base scenarios	>8%	As above (see KPI4b), but for consumers that are examining whether new services (such as adoption of dynamic pricing schemes, etc.) are beneficial, or not and under what conditions.	As above (see KPI4b) but focusing on the annual net costs of consumers compared to current situation.	As above (see KPI4b and KPI4c)
KPI5a	Technology readiness of the iFLEX Framework and iFLEX Assistant prototypes	TRL 7	The iFLEX Framework and application-specific iFLEX Assistants, developed with the framework, have been demonstrated in operational environment.	Validate TRL 7 measures for pilot solution with stakeholders and pilot users. Questionnaire results confirming TRL7	Measures for TRL 7, Pilot solutions, Framework, Business model
KPI5b	Number of innovative demand response and holistic energy management services	5	Total number of new demand response and energy services, including holistic energy management services combining energy with non-energy benefits.	Count innovative DR services – DR services not available among project partners and in pilot sites when the project started.	Baseline DR services, List of new DR services in D2.1 [2] and D5.4 [4].
KPI6a	Number of consumers in the pilots	>600	Total number of consumers/prosumers in the iFLEX pilots.	Count customers involved into each pilot.	Consumer count/group (type) provided by each pilot.
KPI6b	Number of consumer groups targeted with novel demand response services	3	Total number of different consumer segments that have been engaged with demand response through the pilots.	Count customer groups involved into each pilot. Final count of all consumer groups involved in all pilots.	Consumer count/group (type) provided by each pilot.

KPI6c	Increased consumer flexibility for grid stability and RES integration	15%	The average flexibility of pilot participants that is validated in grid stability/RES integration cases is compared to relevant results reported in the literature.	The increase of flexibility available with iFLEX technologies is calculated as a linear combination of the improved baseline and flexibility forecast, and the improved effectiveness of the flexibility management algorithms.	Measurement and forecast (baseline and flexibility) data collected from the pilots. Measurement data collected from the pilots from reference (standard control methods are applied) and iFLEX Assistant optimized periods.

5 End user validation

The iFLEX project encompasses several pilot phases across different countries, each aimed at testing and refining the effectiveness of demand response strategies and energy management systems. In the Greek pilot, recruitment efforts targeted employees from HERON and GEK TERNA, resulting in 30 households with approximately 65 users. However, legal challenges related to electricity contracts and dwelling arrangements hindered the full installation of operational relays in most households. To address this, the pilot underwent a partial redesign, incorporating additional IoT devices like smart plugs to expand the flexibility pool. Despite these challenges, technical feasibility was validated through a lab testing, and by the end of the phase, 51 households had installed 75 meters and 134 plugs. Workshops and surveys gathered feedback on the iFLEX Assistant, revealing user interest in personalized advice and ease of use. Participants appreciated features like the Landing Page and tariff changes but showed less enthusiasm for the Auto Mode. Suggestions included the need for live cost estimations and options to provide reasons for inability to follow proposed actions. While participants favored small, certain monetary rewards for participating in Demand Response programs, they were less interested in comparisons with others. Overall, the survey findings provided valuable insights for refining the iFLEX platform to better meet user needs and preferences.

In the Slovenian pilot, extensive user recruitment and testing activities were conducted across three pilot phases. Initially targeting friendly users within specific companies, the project later expanded its outreach to include users with solar power installations and heat pumps. Various engagement activities, including participation in trade fairs and workshops, attracted more pilot users, demonstrating promising results in engaging users and testing the effectiveness of the Home Energy Management System (HEMS). End user interface (EUI) testing campaigns evaluated the usability and effectiveness of the iFLEX application, with most respondents expressing trust in digital assistants like the iFLEX application and willingness to engage with its features to optimize energy consumption. Feedback from interviews highlighted the importance of user-friendly interfaces and the need for clear instructions to enhance user experience. While some users encountered challenges with navigation and interpretation of data, suggestions for improvement included simplifying the overview of consumption and pricing. Overall, the Slovenian pilot phase demonstrated promising results in engaging users and testing the effectiveness of the HEMS system in optimizing energy usage.

In the Finnish pilot, user recruitment was conducted across all three phases, with emails sent to residents of the pilot building explaining the project's purpose and inviting registration. Prizes incentivized registration, resulting in ten registered users who signed informed consents for data collection. Apartment-specific sensors were installed for nine users to collect detailed data on temperature, humidity, and CO_2 levels. Control commands were executed during the official test period, intermittently cutting space heating for several hours every other or third day. Feedback collected through online surveys indicated high energy awareness among respondents, with interest in receiving more detailed information and advice on energy consumption. The user interface provided residents with access to collected data on district heating consumption, electricity usage, apartment temperature, CO_2 emissions, and potential savings. Survey results indicated positive feedback on data quality and usability, with residents expressing interest in receiving recommendations for energy-saving actions. While some noted changes in living conditions during the test period, overall, residents had a positive experience with the iFLEX project, appreciating the communication and gaining new knowledge about energy flexibility. In conclusion, despite challenges encountered in each pilot phase, the iFLEX project has demonstrated promising results in engaging users and testing the effectiveness of demand response strategies and energy management systems. Valuable insights gathered from user feedback have informed refinements to the iFLEX platform, aiming to better meet user needs and preferences. With continued development and implementation, the iFLEX project has the potential to contribute significantly to energy optimization and sustainability efforts in various regions.

5.1 Greek pilot

5.1.1 User recruitment

For the Greek pilot, recruitment was an ongoing effort throughout all iFLEX Phases. In the beginning of Phase 1, employees from HERON and its parent organization GEK TERNA where extensively surveyed leading to Phase 1 pool of prospective iFLEX end-users. This recruitment effort identified a critical legal challenge with the legal signatory of the electricity contract and the apartment / house dwellers given that in Greece there is a single legal signatory for utility (phone / electricity / heating) contracts due to tax and census reasons, with the legal signatory not necessarily being the consumer (parents paying on behalf of their children or couples dividing utility payments). Although the registration was quite rigorous requiring the consumer to approve their participation in three stages (i. acknowledge that they have read the privacy notice and have accepted the relevant terms and conditions of HERON Energy Control / EnergiQ, ii. give their consent for handling their data for HERON Energy Control / EnergiQ, iii. Give their consent for participating in iFLEX with additional provision iFLEX consent entailed), it had no legal validity when signed by the dweller and not the legal owner of the supply. This required a significant overhaul of HERON registration and consent process, halting the recruitment effort.

Addressing the legal challenges and stepping up the recruitment effort by fully utilizing iFLEX targeted user engagement activities (such as surveying users of the iFLEX Assistant from ICOM) led to successfully recruiting 30 households with ca. 65 users, boosted from the initial Phase 2 target of 15 households and the pool of 30 iFLEX users. Nevertheless, out of those 30 households, it turned out that it was not possible to install a smart meter in all of them due to the condition of the fuse box and that only 2 were capable of having fully operational relays installed. The lack of availability of water boilers was a significant challenge. Phasing out electric water boilers was a policy change due to the subsidising of the replacement of central heating which required the use of personal electrical water boilers, with apartment specific natural gas boilers.

The lack of water boiler users required a partial redesign of the Greek pilot so that more eligible end-users were recruited in order to increase the flexibility pool and validate iFLEX technical feasibility and impact. This was achieved by expanding HERON Energy Control to accommodate multiple type of IoT sensors such as smart plugs and movement sensors which in turn required additional iFLEX integration effort. By the end of the first testing period on 02/05/2024 the participation in the Greek pilot is illustrated in Table 17 and Table 18.

Table 17: Household participation in the Greek pilot.

#	Total
Households with smart meters	75
Households with smart plugs	51
Household dwellers (est. based on census)	180

Table 18: Smart assets inventory and status 02/05/2024.

Description	#	Offline (>24 hrs)	% active
Smart meters installed	75	21	72%
Smart boiler relay users	4	0	100
Smart plugs installed in heavy loads	80	31	61%
Average smart plugs per household	1.57		

From Table 18 it can be seen that smart plugs tend to be overlooked with end-users either choosing not to reconnect them or using the plug on-off feature.

5.1.2 Phase 3 Testing and End-User participation validation

From 1/4/2024 the green tariff service (% RES) was live with the users of EnergiQ given advice on when to reduce their consumption through push notification (Figure 58). This was a service for all iFLEX pilot participants equipped with an active smart meter for that day. The notification is issued at 21.00 of the previous day and contains the schedule for the next day (switching in 3 hours with the first interval 00.00 – 01.00).

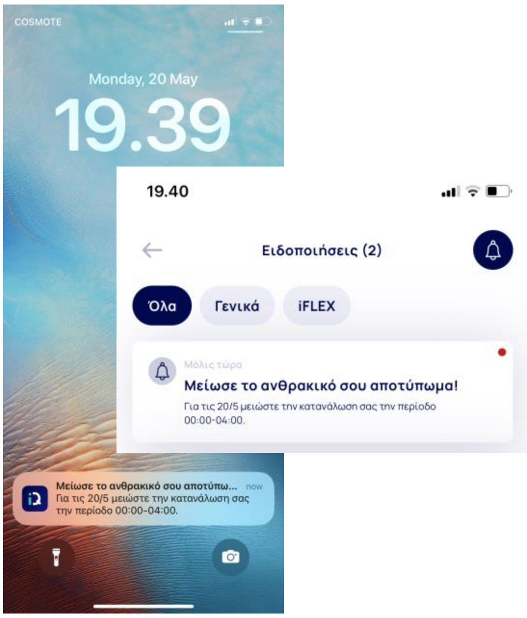


Figure 58: Notification of advice in home screen and in EnergiQ app.

For the electric water boiler users with an installed relay, April 2024 was designated as the live period for Demand Response control commands to be implemented following test of the independent components (remote ON/OFF of the boiler, communication between EnergiQ and iFA for scheduling and remote ON/OFF and triggering of ON/OFF based on OPTIMUS imbalances). During the live period, eligible users were asked to input their schedules and were issued DR suggestions based on OPTIMUS imbalances. Figure 59 shows the scheduling and the list of approved and disapproved DR actions and the reward points accumulated.

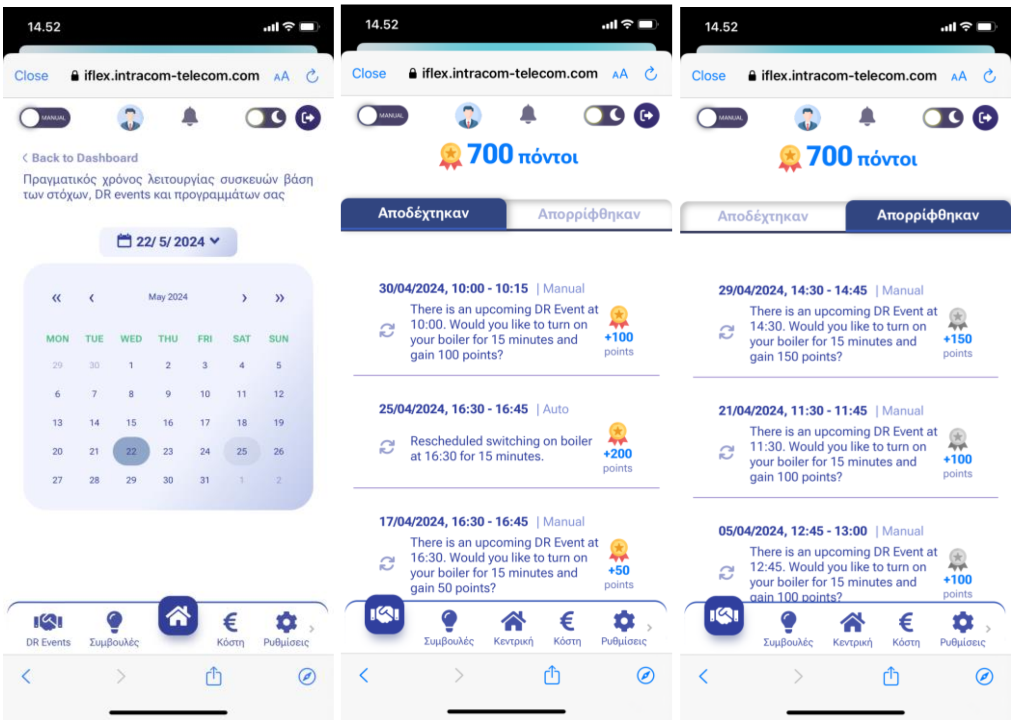


Figure 59: Boiler schedule and DR screens.

5.1.3 Phase 3 Testing and Demand Response validation

OPTIMUS owned asset remains actively involved in Phase 3 setup in which the end-user DR households' portfolio was called on to internally address and mitigate RES generation imbalances before the RES Aggregator needs to perform balancing through third parties in the relevant markets. This was enabled via the operation of ICOM's Demand Response Management System (DRMS) shown in Figure 60. The DRMS received regularly requests for flexibility provision by the RES Aggregator's system (managed by OPTIMUS), dispatched appropriate DR events to the iFA end-users to fulfil the request, and reported back to the RES Aggregator on the aggregated flexibility obtained.

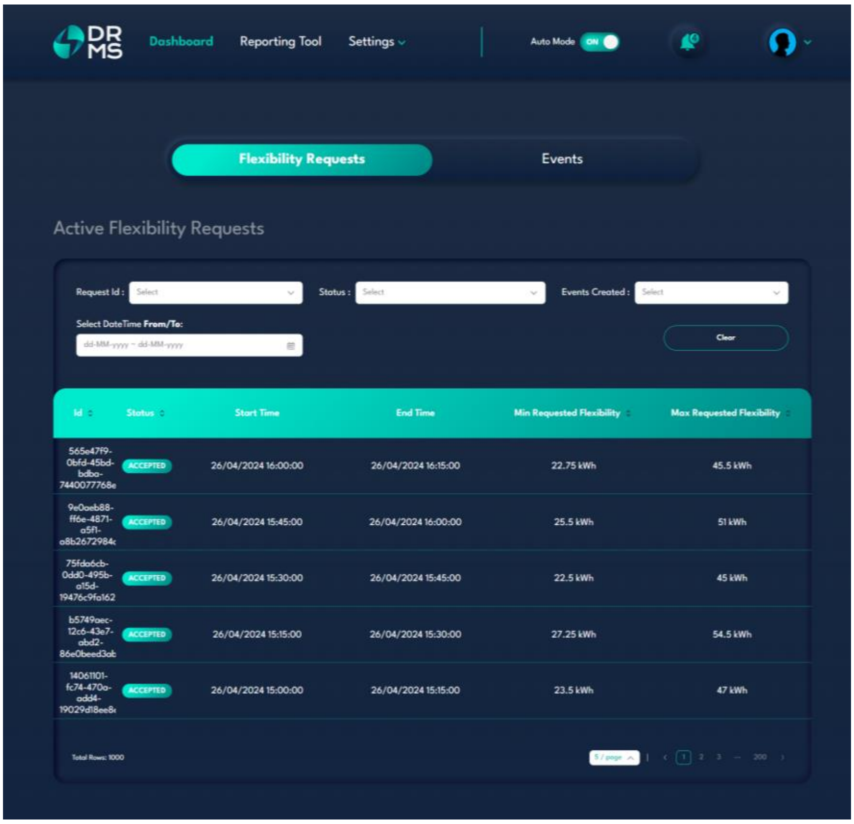


Figure 60: DRMS provided to the RES Aggregator / RES Owner.

5.1.4 End-User experience and satisfaction validation methodology

The validation of items EUV2 'User experience and satisfaction' and EUV3 'User Acceptance' was done using the User Experience Questionnaire (UEQ).

The validated UEQ is useful for assessing user's experiences of using the product itself. The UEQ consists of 26 items that are associated with 6 distinct quality aspects. It uses the Likert scale for scoring, i.e. respondents must answer to which degree they agree/disagree with each statement.

The UEQ comes with a unique scoring system which allows an automatic calculation of the scoring by using the provided Excel scoring sheet. It is possible to compare the results with a standard benchmark that allows conclusions about the relative quality of the evaluated product compared to other products. The UEQ data analysis tool also provides an Alpha-Coefficient analysis which is a measure for the consistence of a scale. The alpha value > 0,7 is considered as sufficiently consistent[7].

The UEQ contains 6 scales with 26 items:

- Attractiveness: Overall impression of the product. Do users like or dislike the product?

[7] https://www.ueq-online.org/

- Perspicuity: Is it easy to get familiar with the product? Is it easy to learn how to use the product?
- Efficiency: Can users solve their tasks without unnecessary effort?
- Dependability: Does the user feel in control of the interaction?
- Stimulation: Is it exciting and motivating to use the product?
- Novelty: Is the product innovative and creative? Does the product catch the interest of users?

The validation of EUV4 ‘Usability and user satisfaction for active participation in DR’ was done using a specially designed questionnaire consisting of 13 questions. This questionnaire was integrated into the UEQ and therefore presented as one questionnaire, with the UEQ placed at the end, see Annex A Greek pilot questionnaire.

The questionnaire was distributed online (using SurveyMonkey) to friendly users (primarily HERON employees) and a total of 30 responses were received (one respondent however did not answer the UEQ questions). The questionnaire was anonymous. The following subsections present the overall results. Individual results including illustrative graphs from the questionnaire are available in Annex B Greek pilot end-user questionnaire individual results.

5.1.5 EUV2 User experience and satisfaction & EUV3 user acceptance

EUV2 and EUV3 were both assessed using the UEQ. A total of 29 responses were received for the UEQ. The results from the UEQ show that the success criteria (see Table 19) for EUV2 and EUV3 were met.

For EUV2, the success criteria were to reach a result of >Good for each of the 6 scales (or subitems) in the UEQ against the benchmark. Two scales, Attractiveness and Efficiency, got a score of ‘Excellent’ compared to the benchmark. As all the items on the UEQ received a good or excellent score, the success criteria for EUV3 were also met. The results are presented in Figure 61 and Table 19 below. The Alpha-Coefficient value indicated sufficient consistency, however, as our sample was small this should of course be interpreted carefully (see Annex C UEQ Alpha-Coefficient (Greek Pilot)).

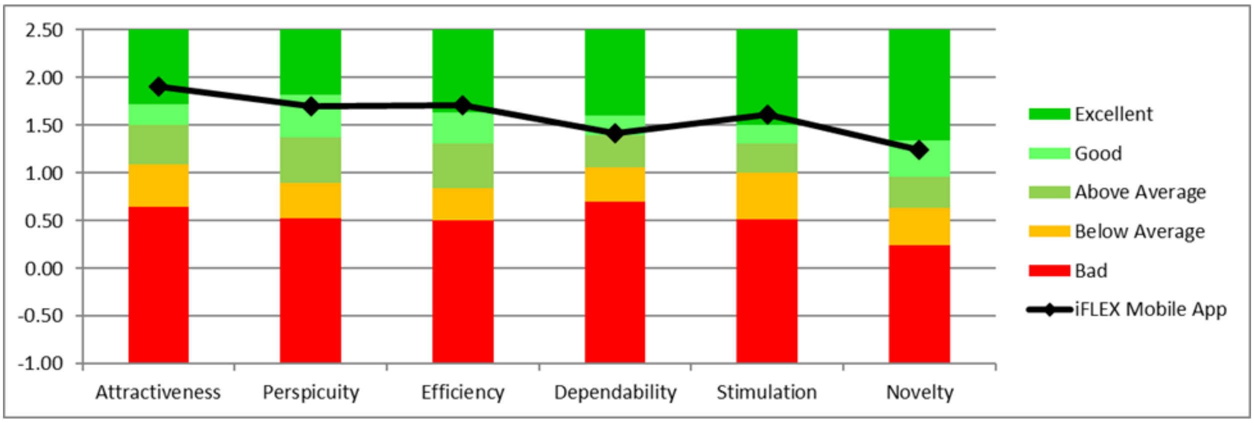


Figure 61: EUV2 Results (UEQ).

Table 19: EUV2 Results (UEQ).

Scale	Mean	Comparisson to benchmark	Interpretation
Attractiveness	1.90229885	**Excellent**	In the range of the 10% best results
Perspicuity	1.69827586	**Good**	10% of results better, 75% of results worse
Efficiency	1.70689655	**Excellent**	In the range of the 10% best results
Dependability	1.4137931	**Good**	10% of results better, 75% of results worse
Stimulation	1.61206897	**Good**	In the range of the 10% best results
Novelty	1.24137931	**Good**	10% of results better, 75% of results worse

5.1.6 EUV4 Usability and user satisfaction for active participation in DR

A total of 30 responses were collected for this part of the questionnaire. The questionnaire consisted of 13 questions. The success criteria for EUV4 were determined as follows:

- >85% of respondents:
    - score 5 or more on 6-point Likert scale,
    - use 3 or more functionalities in the iFLEX Mobile App,
    - have used 2 or more functionalities often or every day (in the last week).

Overall, the results were satisfactory although the success criteria were only partially met for item 1 and item 3 above. For the latter, when comparing answers in the entire questionnaire there were some ambiguities that could leave some issues open for interpretation.

5.1.6.1 EUV4 Item1: score 5 or more on 6-point Likert scale

For item 1, 2 of the four 6-point Likert scale questions were met, however, the two associated questions that did not the success criteria still got a satisfactory result with 73% of respondents giving a score of ≥5, and an average total of 81% (see Table 20 below).

More details on each item are given below.

Table 20: Likert Scale results.

Score 5 or more on 6-point Likert Scale	Result
Q1: How much do you like the iFLEX Mobile App overall?	87%
Q2: How easy has it been overall for you to use the iFLEX Mobile App?	90%
Q11: Would you be interested in using the iFLEX Mobile App in the future to participate actively in DR?	73%
Q12: Are you confident that the app has sufficient securement measurements installed to protect your personal data?	73%
Total Average	**81%**

Four questions used a 6-point Likert scale and for two questions more than 85% of the respondents gave a 5 or 6 score indicating that they were overall pleased with the iFLEX Mobile App and it was easy to use. In addition, 83% of the respondents reported that they had not experienced any technical issues/problems (Q9) with the remaining 17% indicating that they had experienced a few technical problems/issues with the iFLEX Mobile App which had affected their use of the app to a varying degree (Q10), see below.

Q10: If yes, how much would you say that it affected your use of the app?	NOT AT ALL 1	2	3	4	5	VERY MUCH 6
	0	1	1	2	1	0

For the other two questions related to item 1 above (Q11 and Q12 in Table 20), 73% of respondents gave a 5 or 6 score thus indicating a slightly poorer results with regards to using iFLEX to future active participation in DR. Comparing this result to the overall very positive rating of the two previous questions, the result for Q11 is likely to be an indication of a general hesitation to participate actively in DR based on various factors. With regards to confidence with the security measures (Q12), the result is still good but is nevertheless an indication of being able to communicate efficiently how the security measures work, including privacy policies and GDPR compliance, as well as of users' overall awareness and concern related to privacy and data protection.

5.1.6.2 EUV4 Item 2: use 3 or more functionalities in the iFLEX Mobile App

With regards to item 2, 87% of respondents (n26) said that they use 3 or more functionalities in the iFLEX Mobile App. The top 3 functionalities were Energy Consumption (n29), Advice, and DR Events and Push Notifications shared a 3rd place, see Figure 62.

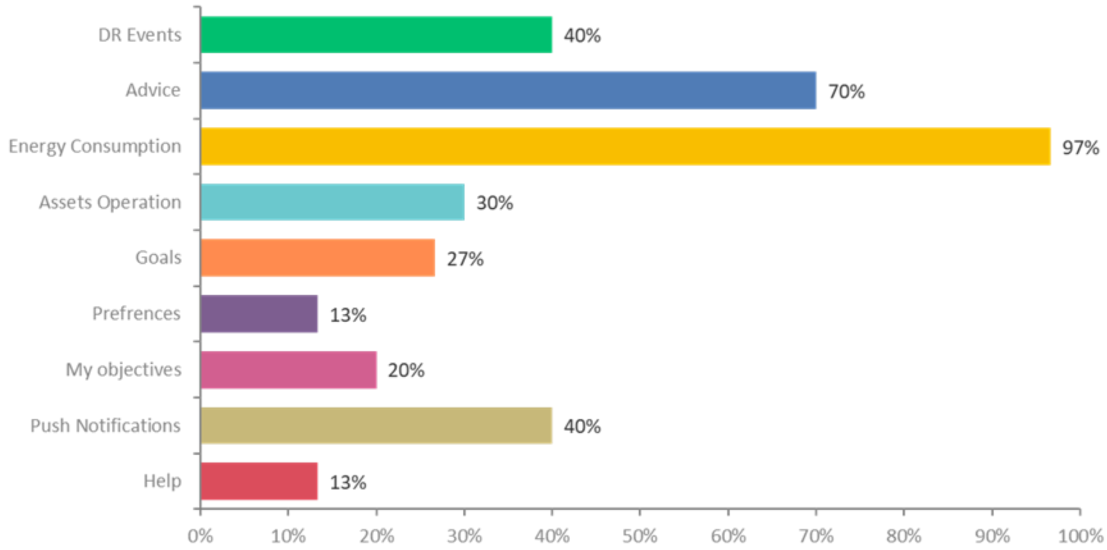


Figure 62: Q4 Which features/functions have you used? (tick all that applies).

5.1.6.3 EUV4 Item 3: have used 2 or more functionalities often or every day (in the last week)

Finally, with regards to item 3, 63% (n19) of respondents had used 2 or more functionalities every day or often. This result could have been better but still of the remaining 11 respondents, 3 indicated that they used the functionality (Energy Consumption) 'every day', 6 had replied 'often' (Energy Consumption (n5) and DR Events (n1)), and the final 2 respondents had answered 'rarely' and 'never'. Interesting, these two respondents were also the two people who had had the App for the longest time (6 months and 1 year respectively) and the fact that they had not been active the previous week (since presented with the questionnaire) can be seen as an indication of how challenging it is to continue to motivate users to be active, particularly in a pilot. On the other hand, these two individuals had also responded that they used 4 and 5 functionalities respectively, indicating that they had been active at one point.

5.2 Slovenian pilot

5.2.1 User recruitment

In the Slovenian part of the project, user recruitment activities were carried out in all three pilot phases. In the first pilot phase, only those friendly users (technical enthusiasts and users with a high fault tolerance) employed within the companies ECE and ELE were invited to the project, where the suitability of the HEMS system was first tested.

In the second phase of Slovenian pilot, the approach to engaging electricity consumers was tailored according to their subscription packages. Potential users were identified based on various criteria such as subscription package type and project requirements including geographical location, network stability, and distribution operator. Two main groups were targeted: those in the self-supply package, consisting of users with solar power installations, and those in the heat pump package, comprising users who utilize heat pumps for space heating or water heating purposes.

An initial pool of 2,300 potential users was compiled, which was then refined using data on electricity consumption and local weather conditions over a one-year period. Specifically, users whose electricity consumption exhibited dependence on local temperature conditions were prioritized. Within this group, 778 sites were identified where electricity consumption was linked to heating needs, suggesting electricity as their primary heating source.

Individual outreach efforts were made to these heat-dependent users through personalized mailings containing comprehensive information about the iFLEX project along with an accompanying questionnaire. The questionnaire aimed to gather details about the recipient's electrical consumer and generator technologies, such as the type of heat pump, hot water storage tank volume, and solar power plant specifics. Additionally, basic user data vital for the successful integration of developing technologies within the Slovenian iFLEX pilot project were also collected, including internet access, smartphone usage, willingness to participate in the iFLEX workshops, property ownership, and contact information.

Recipients were given multiple options to provide feedback: returning the completed questionnaire via mail, electronically through email, or by scanning a QR code that directed them to an online version of the questionnaire. Out of 119 returned questionnaires, 82 were deemed technically suitable potential users. All technically eligible candidates were then invited to participate in the iFLEX project. Participation confirmation involved agreeing to personal data processing and signing an informed consent, followed by the integration process into the iFLEX project.

In the Slovenian part of the project, numerous activities were carried out to attract a larger number of pilot users. These included participation in local trade fairs, where the iFLEX project was presented to a wider audience of interest. One such event was the local Celje fair (snapshot from fair are presented on Figure 63), which spans 5 days and attracts over 65000 visitors from 13 countries.

Figure 63: Presentation of the iFLEX project at the ECE company booth.

Workshops related to the project were also available to the broader interested public, where participants could learn more about the iFLEX project, contribute ideas, and actively engage by signing an informed consent form (snapshot from workshop are presented on Figure 64).

Figure 64: Presentation of use case examples for the Slovenian part of the project at the iFLEX workshop.

During the third pilot phase, there was a sharp increase in energy prices on the electricity market, leading to a steep demand among industrial users for the construction of their own solar power plants on the roofs of industrial buildings. Consequently, inquiries began to emerge within the Slovenian project segment for the inclusion of industrial users in the iFLEX project. The equipment being installed in the Slovenian part offers consumption monitoring on industrial DSO meters and production from large solar power plants. Equipped with this technology, industrial users gained complete visibility into their electricity consumption from the grid and solar power plants. Within their own team of energy experts, they adjusted production by increasing energy consumption within the industrial facility during hours when the solar power plant was generating electricity, and vice versa during hours when they drew electricity from the grid.

5.2.2 EUI piloting

The End User Interface (EUI) testing campaigns were aimed at evaluation of the EUI in general and at evaluation of some of the project core concepts. The users involved have been sent a number of notifications during few days' time-span encouraging them to involve with the iFLEX Application (iFA) and with the information and the capabilities the iFA provides.

The End User Interface campaigns started in April 2024. From all the users, 22 suitable users were invited to test the application. The suitability of the users was judged according to the user's configuration. Only households were invited, not the industrial installations. Out of 22, 11 users have responded and joined the testing.

The users and the results of the campaigns are presented in Table 21. The users are denoted with a part of their pseudonymous identifier in the column named User.

Table 21: iFLEX End User Interface campaigns.

Users	My settings	Change	Monitor my consumption	Set my objectives	Change	Set my goals	Change	Enegy advice
USC3	x	-	x	x	111	x	0/8	x
KOAD	x	2.2	x	x	111	x	0/8	x
D37F	-	-	x	x	000	x	3/8	x
4P67	-	-	x	x	110	x	2/8	x
FW88	-	-	x	x	000	x	0/8	x
P8EE	x	1.1	x	x	101	x	0/8	x
SSB5	x	1.1	x	x	000	x	1/8	x
VUBC	x	1.0	x	x	011	x	0/8	x
LJ77	x	1.0	x	x	000	x	1/8	x
HJE7	-	-	x	x	000	x	2/8	x
3Y69	-	-	x	x	000	x	0/8	x

Three campaigns were prepared, for each campaign the same set of notifications has been used. The campaigns have been organized in batches since the users have joined the testing at different times.

One campaign consists of a number of notification messages send to the user in a pace of a message or two messages per day. The following messages were considered, the order of the messages sent was the same as shown below:

- **Manage my preferences**: the user is invited to manage his/her preferences. It is expected that the user will change the preferences. The change could be followed through the EUI backend API and analyzed after the notification message is sent. The preferences to be managed were related to temperature settings of the user HVAC system. Only users with HVAC system have participated in the tests.
- **Monitor my consumption**: the user is invited to monitor his/her smart meter consumption and switch between different time horizons of the EUI monitoring view.
- **Set my objectives**: the user is invited to inspect his/her high-level goals and to change them to his/her preferences. The change can be followed through the EUI backend API and analysed after the notification message is sent.

- **Set my goals**: the user is challenged to check concrete goals regarding energy consumption and adapt them to his own preference. The change of the goals can be tracked through the EUI API and analysed after the notification message is sent.
- **Energy advice**: energy advice is sent to the user with an aim to support user goals and change in consumption patterns.

The first campaign duration was five days, the rest of the campaigns have been finished in two and a half or two days, with a pace of two messages sent to the user per day. The notifications were sent to the users in the afternoon, usually at 17:00. If two messages were sent per day the second message has been sent one hour later.

In the subsections below the messages sent are presented and their intent explained. Both the Slovenian and English versions of the messages are presented.

5.2.2.1 Manage my preferences

The message invites the user to set his/her preferences regarding heating devices - a HVAC or a thermostat, controlling to the HVAC. The notification directs the user towards a certain part of the application, like "the bottom right under 'Settings' and then 'My Schedules'". Most of the EUI messages have been translated to Slovenian for the testing purposes.

> Pozdravljeni! V poskusnem obdobju delovanja iFLEX asistenta se trudimo zagotavljati udobje in temperaturo prostorov po vaših željah. Prosimo če v aplikaciji nastavite želeno temperaturno območje. Nastavitev opravite v aplikaciji na ikoni domačega zaslona, spodaj desno "Nastavitve" in nato "Moji urniki".

The message translated to English is provided below:

> "Hello! During the trial period of the iFLEX assistant, we are striving to provide comfort and room temperatures according to your preferences. Please set your desired temperature range in the app. You can make this adjustment in the app by clicking on the home screen icon, located at the bottom right under 'Settings' and then 'My Schedules'."

The changes to the settings could be followed due to storage of the settings in the EUI back-end and access to the data through exposed interface. The preferences monitored are the upper, the preferred and the lower temperature settings the user accepts. The upper and the lower settings were considered during different testing scenarios of the pilot use cases.

Partial result of one of the user preferences is presented below. The before the event settings were stored just before the notification has been sent and then checked almost a day later for differences. From the example it can be seen the user has changed all three settings from the ones recorded before the notification.

```
- Before the event: 2024-04-19T17:00:56.028204 Device: Kronoterm KSM
 Preference Time start: 00:00:00, Time end: 23:59:00, Upper: 24.6,
 preferred: 22.9, lower: 21.7
- After the event at: 2024-04-20T02:13:14.462135 Device: Kronoterm KSM
 Preference Time start: 00:00:00, Time end: 23:59:00, Upper: 25.0,
 preferred: 23.0, lower: 22.0
```

5.2.2.2 Monitor my consumption

The monitor my consumption notification invites a user to check the consumption on hisr/her smart meter or any other device he/she has. The application presents the consumption in 15 minutes intervals for the day and also past weeks. The Slovenian message and its English translation are presented below.

> Pametni asistent omogoča spremljanje porabe energije v vašem gospodinjstvu. Prosimo če preverite gibanje porabe za današnji dan. To opravite v aplikaciji iz domačega zaslona in sicer v razdelku "Spremljanje porabe gospodinjstva", kliknete "Prikaži več", nato v izbirnem polju "Naprava" izberete "Distribucijski števec" in v izbirnem polju "Meritev" izberete "Active Power". Preverite grafični prikaz porabe oz. moči čez dan. Lahko izbirate tudi med drugimi možnostmi.

> The smart assistant enables you to monitor energy consumption in your household. Please check the consumption trend for today. You can do this in the app from the home screen by going to the 'Household Consumption Monitoring' section, clicking 'Show More', then selecting 'Distribution Meter' from the 'Device'

dropdown, and 'Active Power' from the 'Measurement' dropdown. Check the graphical representation of consumption or power throughout the day. You can also choose from other options.

5.2.2.3 Set my objectives

The set my objective notification has invited the users to specify their objectives regarding preferred objectives for their consumption optimisation. Available choices are energy costs, energy consumption and CO_2 emissions.

> Prosimo če si vzamete minuto in v aplikaciji nastavite vaše splošne cilje in ambicije glede porabe energije. Izberite kaj vam je najbolj pomembno (stroški energije, poraba energije ali zmanjšanje CO_2). Predlagamo 1 do 2 izbiri. Nastavitev opravite v aplikaciji na ikoni domačega zaslona, spodaj desno "Nastavitve" in nato "Moji cilji".
>
> Please take a minute to set your general goals and ambitions regarding energy consumption in the app. Choose what is most important to you (energy costs, energy consumption, or CO_2 reduction). We suggest 1 to 2 selections. Set this up in the app by clicking the 'Settings' icon at the bottom right of the home screen, then 'My Goals'.

The objectives can be followed through the EUI back-end API. In a similar manner as in the case of notification for the "Manage my preferences" the change of user objectives can be followed. The before and after the notification settings for one of the users are presented below:

```
- Before the event: 2024-04-21T17:01:36.756385 {'min_cost': True,
 'min_consumption': True, 'min_co2': False}
- After the event at: 2024-04-21T22:20:40.241245 {'min_cost': True,
 'min_consumption': True, 'min_co2': False}
```

One of the users has changed the objectives from default all false setting to selection of minimal consumption and minimal cost. The notification seemed not to stimulate any change in the user preferred values.

In the campaigns figure the change from the defaults is indicated in the column Change right to Set my objectives column. The defaults are presented as three 0s (000) and if the value is changed from the default, it is presented as 1. The user with pseudo identifier PW88 has the values set to 101, so the user’s preferences are minimal costs and minimal CO_2 emissions.

5.2.2.4 Set my goals

To set my goals notification encourage a user to provide some concrete goals regarding his/her whole consumption at peak level or on a weekly basis.

The settings that can be controlled to the weekly or monthly periodicity are the following: CO_2 Emissions, Instant power consumption, Max Energy Consumption and Self Consumption Ratio.

> Prosimo če si vzamete trenutek in razmislite kakšne konkretne cilje porabe energije želite doseči v roku enega tedna. Lahko nastavite največjo trenutno porabo (npr. 10kW) ali porabo energije za cel teden (npr. 50kWh) ter tudi druge cilje. Brez skrbi, iFLEX asistent vam ne bo izklopil naprav če boste presegli nastavljene vrednosti. Nastavljene vrednosti nam bodo pomagale optimizirati delovanje iFLEX asistenta v poskusnem delovanju.
>
> Please take a moment to consider what specific energy consumption goals you want to achieve in the course of a week. You can set a maximum current consumption (e.g., 10 kW) or total energy consumption for the week (e.g., 50 kWh), as well as other goals. Don't worry, the iFLEX assistant will not turn off devices if you exceed the set values. The set values will help us optimize the operation of the iFLEX assistant during the trial run.

The general results are presented among the other notifications in Table 21. In the table, reaction to the notification is denoted with the number of limits set or modified by the user. It can be seen that five out of eleven users have modified the default settings. More detailed results are provided in Table 22 below.

Table 22: Set my goals notification results.

	USC3	KOAD	D37F	4P67	FW88	P8EE	SSB5	VUBC	LJ77	HJE7	3Y69	Sum
CO2 Emissions/weekly	0	0	1	0	0	0	0	0	0	0	0	1
CO2 Emissions/monthly	0	0	0	0	0	0	0	0	0	0	0	0
Instant Power Consumption/weekly	0	0	0	1	0	0	0	0	0	0	0	1
Instant Power Consumption/monthly	0	0	0	0	0	0	0	0	0	0	0	0
Max Energy Consumption/weekly	0	0	1	1	0	0	0	0	1	1	0	4
Max Energy Consumption/monthly	0	0	1	0	0	0	0	0	0	0	0	1
Self Consumption Ratio/weekly	0	0	0	0	0	0	1	0	0	1	0	2
Self Consumption Ratio/monthly	0	0	0	0	0	0	0	0	0	0	0	0

The table presents changes done by each user at a combination of category and periodicity. In the end, Sum column, the overall results are provided. The most changes have been done on "Max Energy Consumption/weekly" limit, which is in line with the notification message sent. There have been changes in other categories as well, in particular in weekly self-consumption ratio.

5.2.2.5 Energy advice

An energy advice was given to the piloting participants with an aim to provide them some information how to change consumption patterns or usage of their devices. The advice have been given per configuration of the household in the following order. If the household configuration included an HVAC, the HVAC advice has been sent. Households without the HVAC, but with the solar power plant have been sent a PV advice. If the household had none of the HVAC and the PV a general advice have been provided. In this way the testing had demonstrated that the advice can be fine-tuned to the needs of the customers. Example pieces of advice, per device category, or general, are given below, first in Slovenian and then repeated in English:

- HVAC advice: Stroške ogrevanja lahko znižate z znižanjem nastavljene temperature na termostatu ogrevanja. Znižanje za 1 stopinjo Celzija lahko zmanjša vaše stroške ogrevanja tudi do 6%.
- PV Advice: Samoporabo proizvedene električne energije lahko povečate, če v času največje proizvodnje povečate lastno porabo: pripravite sanitarno vodo, perete ali sušite perilo, pomivate posodo ali zvišate nastavitve termostata ogrevanja.
- General advice: Spremljajte porabo po posameznih priključnih fazah vašega lokalnega omrežja ter poizkusite uravnotežiti bremena po posameznih fazah. Porabo lahko spremljate po tokovih po posamezni fazi na vašem števcu - Poglejte na Dashboard/Spremljanje porabe/Prikaži več/naprava - %s[8].
- HVAC advice: You can reduce heating costs by lowering the set temperature on your heating thermostat. A decrease of 1 degree Celsius can reduce your heating costs by up to 6%.
- PV advice: You can increase self-consumption of produced electricity by increasing your own consumption during peak production times: heat sanitary water, wash or dry laundry, wash dishes, or increase the settings of your heating thermostat.
- General advice: Monitor consumption across individual phases of your local network and try to balance the loads across phases. You can monitor consumption by currents on individual phases on your meter - Check the Dashboard/Consumption Monitoring/Show More/device - %s.

5.2.3 End User Interviews

To attract as many participants as possible, we reached out to 19 customers who were deemed suitable based on their installed devices and had conversations with them about the process of the UI test. After the first call, we sent customers a message with instructions on how to download the application to their mobile phone. We provided them with some time to download the application at their smart phones. The vast majority of customers we deemed suitable for participation in the testing unfortunately did not proceed with installing the application, as it operates in a test environment, and they were deterred by the security aspect of installing an unverified application. Throughout this period, we were available on the contact number provided in the instructions message to assist customers with the installation process.

In the following days, we sent daily notifications to customers through the application. After the notification period ended, we conducted interviews with the customers. In the end, the application was installed by eleven

[8] Python string modifier, in the code replaced with the name of the device in the configuration.

users, three of whom were testing experts, so we conducted the final interviews with eight customers. These interviews were conducted via telephone conversations. To guide the conversation, we used twelve questions aimed at addressing the objectives set for the test (see Table 23).

Table 23: Questions used in the interview with end-users.

	Questions we used to navigate the conversation during the interviews:
Q1	Did you learn about demand flexibility options for your household through the iFLEX project or before that?
Q2	Did you find the handling of the application easy and straightforward, or did you encounter any difficulties?
Q3	Were the instructions in the notifications clear enough for you to navigate the application, or did you face challenges during review or adjustment of the required functionalities?
Q4	Is the range of parameters for monitoring consumption adequate or too extensive? Is there any specific data you would like to see displayed that you haven't found when using the application?
Q4	How would you prioritize the goals you can set in the application: 1. Reducing cost 2. Reducing energy consumption 3. Reducing CO_2 emissions Would you like to add any other goals that could be achieved with the help of the iFlex Assistant?
Q5	Which capability of the iFLEX Assistant would be most beneficial to you? • Overview of energy consumption for the day and month and comparisons with previous days and months • Detailed overview of consumption throughout the day using a graph • Detailed overview of consumption for specific devices • Warning about excessive consumption (peak) for the entire household or specific devices
Q6	Do you see digital assistants like iFLEX helpful in adjusting consumption, and would you trust a certain level of automation in consumption adjustment to a digital assistant?
Q7	Would you trust the iFLEX Assistant to automatically turn on and off major appliances in your household based on solar energy production, if you were rewarded from €3 to €10 per month for this?
Q8	Would you trust the iFLEX Assistant to automatically turn on and off major appliances in your household to avoid additional costs when exceeding grid usage during upcoming changes in the tariff structure?
Q9	Do you find personalized advices by the iFlex assistant sensible, and would you follow them to achieve your desired savings and increased energy efficiency goals?
Q10	Do you use a heat storage tank as part of your heat pump system? If yes, do you have information on how much you can save in winter months by charging the tank at a lower tariff? Would you trust the optimization of the tank charging to the iFLEX Assistant?
Q11	Are you aware that your building's mass can act as a heat storage tank, which you can leverage through smart management to save on heating costs? Would you adjust the operation of your heat pump if it would me turned off during peak hours between 4 pm and 10 pm, allowing you to save on network fees and heating costs?
Q12	If the temperature dropped by 1°C during this time due to the object's persistence, would you be concerned that reheating to the desired temperature would increase heating costs?

Interviews were conducted to gather feedback on the iFLEX project regarding ease of app usage, clarity of instructions we provided, monitoring parameters, goal prioritization, preferred iFLEX Assistant capabilities, trust in digital assistants, willingness to trust the iFLEX for appliance control, acceptance of personalized advice, trust in the iFLEX for heat pump optimization, concerns about reheating costs, and any suggestions for improvement.

Most respondents learned about demand flexibility options through the iFLEX project. Participants particularly highlighted how higher electricity prices had contributed to their increased interest in monitoring consumption and seeking insights into household appliances.

The majority of respondents found the app usage easy, indicating a user-friendly interface. However, there were some suggestions for improvement, particularly regarding data accuracy and clarity of instructions. One particular participant pointed out that he was a bit confused because some data differs from what is provided by Solar Edge Application. The reason for this was most likely due to the time difference in data synchronization or as he said himself, »it was hard to compare the graphs, as those displayed in the SolarEdge application are more user-friendly and couldn't find his way around the graphs in the iFLEX Assistant.

One of our goals was also to recognize the value of such DR events, and the clients have welcomed them. While most respondents found the instructions, we sent clear, some suggested improvements such as an archive for notifications to avoid missing important information, or that the already read messages could be checked off instead of disappearing.

Feedback on the range of consumption monitoring parameters was mixed, with some finding them sufficient but unclear, and others suggesting additional specific data for better tracking such as daily, monthly, and weekly totals. Three participants highlighted that the range of measuring devices or parameters in the dropdown menu is too extensive, and they struggle to read the content from the graphs. As an improvement, data could be streamlined, and the display made more user-friendly.

At the question about the functionality, they would most like to monitor, we provided participants with pre-prepared options. The results of their responses are as follows:

- Overview of energy consumption for the day and month and comparisons with previous days and months: (50%).
- Detailed overview of consumption throughout the day using a graph: (12,5%).
- Detailed overview of consumption for specific devices: (12,5%).
- Warning about excessive consumption (peak) for the entire household or specific devices: (25%).

Our main focus was to assess the customers' willingness to engage in DR events with us and determine how various requests could benefit them. Due to an error in the application, they did not receive personalized advice. However, after discussing with us and explaining what kind of advice they would receive, they welcomed the idea. Everyone expressed their willingness to respond to and follow the advice given. One of the tasks we assigned to participants was setting goals. They all highlighted two objectives: reducing costs and decreasing energy consumption. While they found goal setting to be a good idea, they expressed a desire for a more detailed overview of how they are progressing towards their goals and their success in achieving them. However, they liked the idea of receiving advice based on the goals they set for themselves.

All respondents expressed trust in digital assistants such as iFLEX Assistant, for adjusting consumption, indicating confidence in automation technology, even when controlling major appliances. One of the participants expressed concern about remotely turning the heat pump on and off, fearing that such events should not occur too frequently as they could do some harm to the heat pump.

We also presented them with the concept of energy storage, achievable through the use of a water tank or by leveraging the thermal inertia of the building. Participants responded positively to this idea. Only one of the participants had a water storage tank and would be willing to entrust the management of the tank. The use of a water storage tank for such a scenario, especially since the customer had oversized tank regarding their own needs, seemed like a very good solution to them. As mentioned earlier, all of the participants were open to let the iFLEX Assistant optimize the heat pump by turning it on and off remotely. None of the participants expressed concern about the temperature dropping too low while the heat pump was off, or that reheating the building would result in increased energy consumption. They found the displayed cost savings satisfactory as well.

Feedback on the app's usability was generally positive, but there were instances where respondents found certain aspects of the app confusing or lacking in clarity. Suggestions for improvement included providing more specific data for monitoring consumption and simplifying navigation among graphs.

Here are some random customer observations from the conversations:

- Difficulty navigating through the graphs.
- Desire for a simpler overview for users; many graphs were unclear to a layman user
- Difficulty in installation; some parts are still in English, struggled with interpreting the graphs, found it a bit overly complex.
- Request for a simpler overview of consumption and pricing.

» I need an application that will combine everything: monitoring the performance of the solar power plant, heat pump, charging station, and at the same time the entire consumption of the building; in it, I will also see my electricity bills, past consumption, my prices. For now, I'm combining three applications. «

5.3 Finnish pilot

5.3.1 User recruitment

In the Finnish pilot, the end-user recruitment was implemented in all three phases. An e-mail was delivered to all residents of the pilot building that introduced the iFLEX project, described the purpose of the pilot, and invited the residents to register. The e-mail was delivered with the help of the pilot building owner; HOAS (a non-profit foundation providing rental housing for students). To motivate the residents to register, prizes were promised for those who had registered and answered to the surveys.

During the first pilot phase, four residents registered in the pilot. In pilot phase two, five more residents were registered. In the third phase, one more resident registered. All the registered users signed informed consents, with which they agreed on participating in the pilot and allowing the (private) data collection from their own apartment. The data protection description document was also made available for them.

One registered user had moved out during the third phase. The data collection was terminated immediately from the apartment from which the resident had moved out.

5.3.2 Sensor installation

In phase two, apartment-specific sensors were installed for 9 registered users to collect more accurate measurement data from the apartments. This also enabled the registered residents to monitor their apartment-specific data: temperature, humidity and CO_2 measurements. In phase three, these sensors were installed for the one new registered user.

5.3.3 Test periods

Control commands were implemented during the official test period in the winter 2022 - 2023 (1.12.2022 – 20.3.2023). During this time, the space heating of the apartment building was cut for several hours (2-12h) every other day or every third day. After that, some occasional control commands have been implemented, mostly in April 2023 and January-February 2024.

5.3.4 Feedback collection

The feedback was collected from the registered residents in all three phases with an on-line survey.

In the first phase, the starting point and the current status of the residents was examined with the help of the collected data about resident's living comfort preferences, energy awareness, engagement to energy conserving actions, data needs, and demand flexibility potential. The first survey was open 15.12.2022 - 5.2.2023.

In the second phase, feedback was collected about the provided data, project actions and their impacts, and the project itself, and to detect the possible changes caused by the data visualization. The second survey was open 3.4.2023 - 14.4.2023.

In the third phase, feedback was collected on the data and its impact on awareness and consumption habits of the residents, the control commands and their impact on living conditions, detected changes in residents' consumption habits, user interface, and feedback on the iFLEX project itself. The third survey was open 13.3.2024 – 24.3.2024.

During the pilot, users have also been able to provide feedback regarding the thermal comfort of the building, and registered users also apartment-specific feedback on thermal comfort.

5.3.5 User interface

All the residents of the building are provided with the user interface (see Figure 65), using which they can monitor the collected data from the building: district heating consumption, electricity consumption, average temperature of the apartments, CO_2 emissions and possible savings. For the registered users, also the apartment-specific data is visualized, including apartment's temperature, humidity and CO_2 (see Figure 66). Users can also provide feedback with the help of the interface.

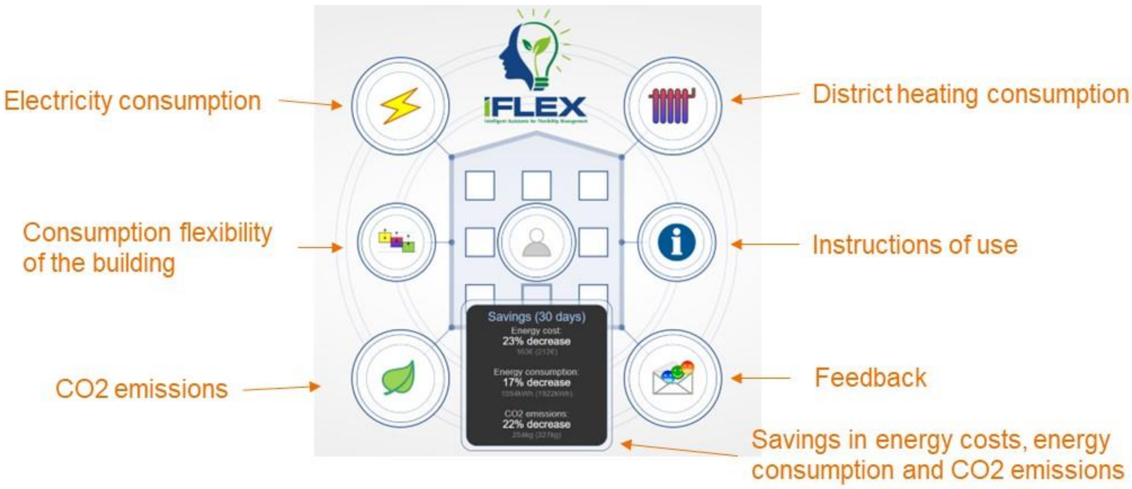


Figure 65: User interface for all end-users in the Finnish pilot.

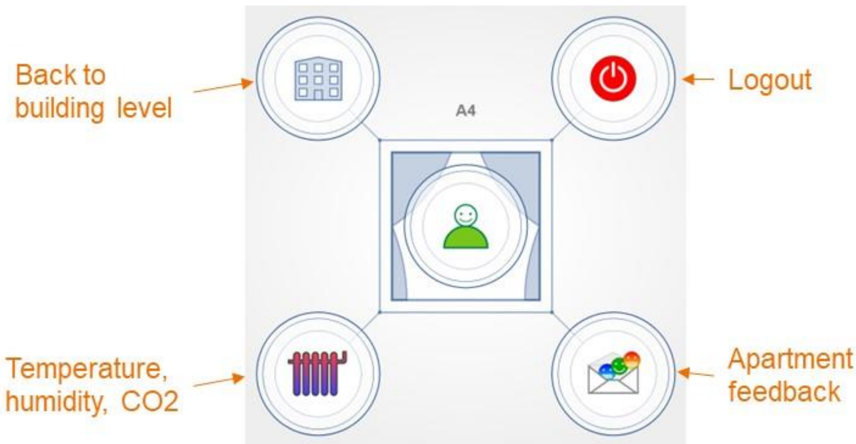


Figure 66: User interface for registered end-users.

5.3.6 Surveys results

<u>The first survey:</u>

Characterization of the respondents: Number of respondents: 7. Gender: 6 men, 1 woman. Age: 5 of the respondents are 30-40 years old, and 2 respondents are 20-30 years old. Majority lives in a 2-persons household, only one of the respondents lives alone.

Living comfort: Living comfort was important to all respondents. Still, their energy consumption habits were good (turning off lights, saving hot water, etc.). The recent fluctuations in electricity prices have affected consumption for 3 respondents. All the respondents were satisfied with the air quality of their apartment. 2 of the respondents were unsatisfied with the room temperature in general, and one with the air humidity and the amount of the energy bill. The energy efficiency of the current home devices divided the most opinions: some were satisfied, some very unsatisfied.

Satisfaction & main concerns: The respondents were asked to identify things of which they are satisfied or worried. The following positive issues were identified: The aim towards energy self-sufficiency, the easy monitoring of stock exchange electricity, and the drive towards organic/green forms of energy production. The main concerns included the development of electricity prices, large and unexpected price fluctuations, and the dependence on entities outside the EU as energy producers.

Energy awareness: 5 of the respondents follow the energy market and are aware of energy prices. 4 of the respondents were aware of the content of their own energy bill (including heat & electricity) and the environmental impact of their own energy consumption. 3 could identify the functions that consume the most energy in the whole residential building.

Data needs: Everyone considered the topic of the project as important and intended to follow the information presented to them in the project. The majority (except one) were interested in the suggested consumption-related information: 6 of the respondents would like to receive more detailed information about own energy consumption, and to receive suggestions and advice to chance own consumption to save. In addition, 6 respondents would like to see the environmental effect of their own consumption and to see the benefits that have been achieved through the demand flexibility of the building.

Engagement in energy saving: Saving energy and natural resources was important to all the respondents. Financial savings were the biggest motivation for changing one's energy consumption. Energy savings came closely as the second. A clean environment was the third biggest motive, after which came rewards. Social motives divided the most opinions. 5 of the respondents would be willing to change the daily routines to different time to provide flexibility, 4 could go to sauna at different time than usual, 3 could lower the water temperature or heating in wintertime, and to invest smart devices and sensors. The building's energy consumption and CO_2 emissions influence the choice of a (rental) apartment only for one respondent.

Demand flexibility: 3 of the respondents understand what energy flexibility means, and, in addition, 3 of the respondents are aware of the ways in which household consumers can offer energy flexibility. All the respondents agreed that the energy flexibility of an individual person has an effect. 4 of the respondents thought that it was important that the residential building is involved in energy flexibility. 4 would allow the energy supplier to regulate certain common energy functions in their apartment building against the benefits, even if it could affect their own living comfort. Up to 6 of the respondents were interested in energy flexibility and believed that they could offer flexibility in the future against benefits.

The second survey:

Characterization of the respondents: Number of respondents: 8. Gender: 7 men, 1 woman. Age: 5 of the respondents are 30-40 years old, and 3 respondents are 20-30 years old. Majority lives in a 2-persons household, two of the respondents live alone and one in a household with three or more persons.

Feedback on data: The respondents have been following the data visualized to them using phones and computers. Most of them followed the data a few times in a month, one a few times in a week, one once a day and one several times a day. The data quality (real-time, correctness, accuracy) was estimated to be good, and usability of the data quite good. All the residents considered the visualized data as interesting. 5 of the residents wanted to receive recommendations and advice in order to save, and 7 wanted to more detailed information about the control commands. 5 respondents would like to receive the same kind of data after the iFLEX project has ended. All the respondents were interested in the benefits that have been achieved from the building's participation in demand flexibility (saved energy, reduction of emissions, financial savings).

Feedback on project actions: Some of the respondents had detected changes in living conditions in their apartment during the test period: change in temperature: too cold (2 respondents), too warm (4 respondents), change in humidity (2 respondents), and change in air quality (1 respondent). However, it was impossible to say have those occurred due to the control commands, since the control commands were not executed every day. The controls during the test period had not affected to the adequacy of the hot water.

Detected changes in awareness and behaviour: The respondents were asked to estimate the changes in their awareness and consumption behaviour over the past weeks when they have been able to monitor information through the iFLEX user interface. 5 of the respondents pay now more attention to their own energy consumption habits, and 4 residents follow more energy-related news and events in the energy market. 3 of the residents agreed that their awareness of energy consumption and environmental effects of energy consumption has increased, and one agreed that his/her own energy consumption has decreased. 6 residents are now better aware of the ways in which the household consumer can provide energy flexibility.

Feedback on user interface: The usability, appearance of graphics and the logic of the interface was estimated to be good by 5 of the respondents, and the informativeness was estimated to be good by 6 of the respondents. Security was considered as good by 2 of the respondents, the rest could not evaluate the security. Furthermore, half of the respondents could not evaluate the ease of providing feedback, which tells that probably they haven't used the opportunity.

Feedback on iFLEX project: All the respondents considered the topic of the project to be important and their experiences with the iFLEX project have been positive. They all also agreed that they have been contacted to an appropriate amount as the project progresses and the communication in the project has been smooth and clear. 6 of the residents have gained new information about energy flexibility during the iFLEX project and for 5 of the residents the willingness to participate in consumption flexibility has increased.

The third survey:

Characterization of the respondents: Number of respondents: 4. Gender: all the respondents were men. Age: 3 respondents are 20-30 years old, and one 30-40 years old. Three respondents live alone, and one lives in a household with three or more persons.

Feedback on data: Three of four respondents evaluated that the data visualized through user interface is clear and in an understandable format, the amount of data is sufficient, and that the data has been interesting. Only one agreed that the data has provided a comprehensive picture of their energy consumption and its impact on the environment (one disagreed, 2 couldn't say), and also only one agreed that the data has helped to understand how benefits can be achieved with demand flexibility (2 disagreed, one couldn't say). The respondents didn't have any requirements for additional data.

Feedback on project actions: Three of four respondents agreed that the control commands haven't affected on their living comfort (one couldn't say). However, according to two respondents, there has been occasionally too cold in their apartments during the last months. It is impossible to say whether this is because of the control commands. One of the respondents was interested in the control commands and would have required more information about them.

Changes in awareness: Three of four respondents follows now more energy-related news and events in the energy market and is better aware of energy prices than in the beginning of the iFLEX pilot. Two respondents have paid more attention to their consumption habits and would like to receive recommendations or advice to change energy consumption in order to save money. Only one respondents agreed that his own awareness of the environmental effects of energy consumption has increased during the pilot, and two respondents disagreed on this.

Feedback on user interface: The usability, informativeness, appearance of graphics, and the ease of providing feedback was estimated to be good by two respondents, and satisfactory by one respondent (one respondent couldn't say). Two respondents estimated the visual appearance of the user interface to be good, one estimated it bad, and one couldn't say.

Feedback on iFLEX project: All of the respondents considered the topic of the project to be important. Two respondents understand now better why energy flexibility is important and would also be interested in services with which an individual household can participate in demand flexibility. In addition, two respondents also agreed that participating in the project has been interesting, while one respondent disagreed on this. Three respondents agreed that their experience with the iFLEX project has been positive, and one didn't agree or disagree. Furthermore, three respondents agreed that the participation in the pilot has been effortless, and that they have been contacted to an appropriate extent as the project progressed. One respondent disagreed on both of these.

5.3.7 Conclusions

The participants of the Finnish pilot live in an apartment building connected to district heating, and therefore their possibility to influence on demand flexibility by their own energy consumption behavior is quite small. The implemented surveys examined the participants' energy awareness, consumption habits and the willingness to support demand flexibility, and collected participants' feedback on the iFLEX project and its actions. Although the number of the respondents in the surveys was small, the following trends could be detected:

- The pilot participants considered the topic of the project to be important.
- The energy awareness of the pilot participants has increased and many of them pay now more attention to their own consumption habits.
- The participants are willing to receive more energy related information and advice how to save energy.
- The participants have gained new knowledge about demand flexibility during the pilot and are more aware of how they could participate in it.
- Participants' experiences with the iFLEX project were positive.

6 Technical validation

Technical validation of the iFLEX Assistant (iFA) is presented in this section on a pilot basis, focusing primarily on the implemented requirements in each one of the iFA instances.

6.1 Greek pilot

Technical validation of the Greek pilot by the end of the project concerns functional and unit testing of the iFA components or external systems, which are presented in Figure 67, as well as integration testing between these components and systems. Furthermore, system tests have been conducted to demonstrate the interoperability between all the components and validate the required functionalities in the pilot end-to-end. It is noted that due to implementation issues, it was eventually decided to host the RAI of the Greek pilot in Heron's server. More details on the scope and deployment of the Greek pilot in Phase 3 are presented in Section 3.1.

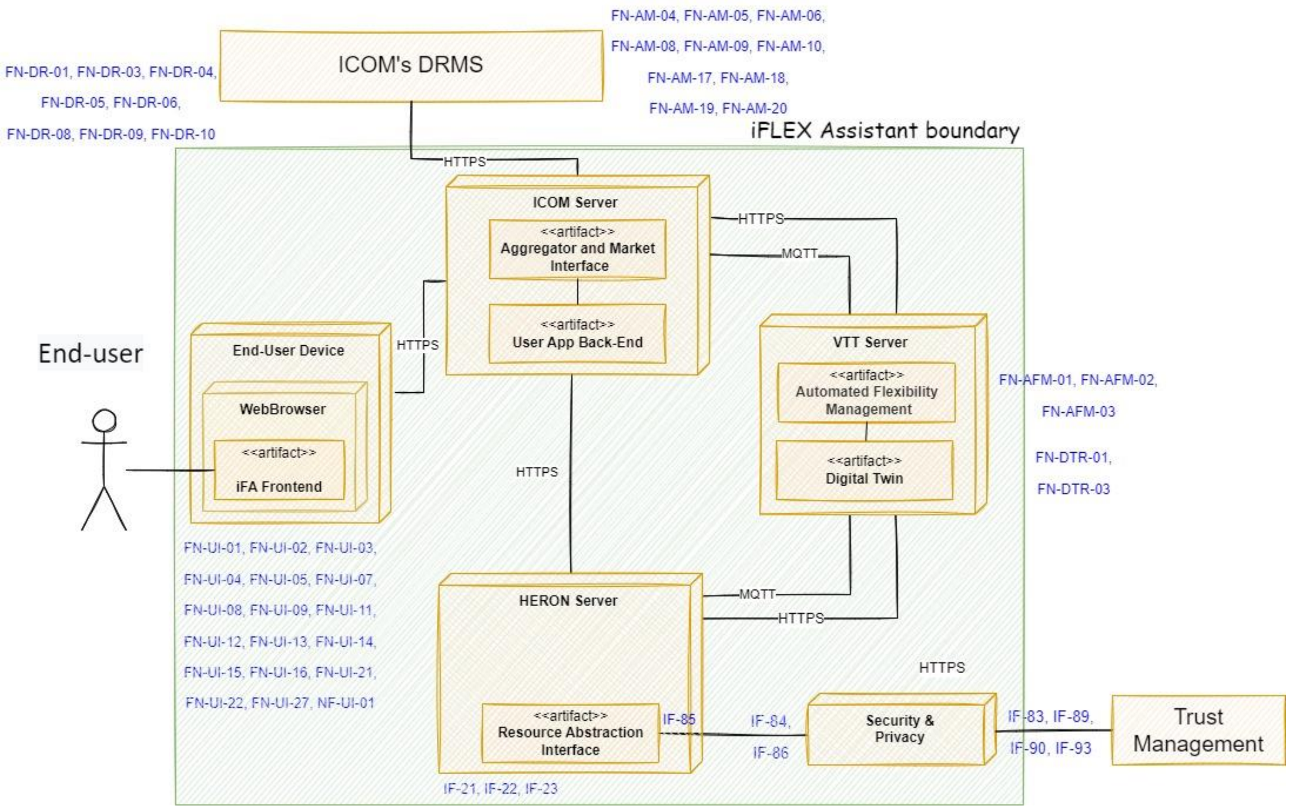


Figure 67: Deployment diagram of the Greek large-scale pilot.

The validated requirements concern the iFA's components and external systems that are shown in Figure 67 above. These requirements are summarised in Table 24, while their complete documentation can be found in the deliverables of WP3 and WP4.

Table 24: Implemented requirements in the Greek large-scale pilot.

Code	Title	Component/ System	Source
FN-UI-01	Operation mode customisation	UI	PUC-1
FN-UI-02	User-defined time and operational constraints	UI	PUC-1
FN-UI-03	End-user feedback	UI	PUC-1
FN-UI-04	Optimisation policy selection	UI	PUC-1
FN-UI-05	Automation level customisation	UI	PUC-1

FN-UI-07	Supported system interface languages	UI	PUC-1
FN-UI-08	Provision of consent for the schedules of dispatchable assets	UI	PUC-9, PUC-10
FN-UI-09	DR notification policy	UI	PUC-1
FN-UI-11	Real-time energy data	UI	PUC-7
FN-UI-12	Past energy data	UI	PUC-7
FN-UI-13	DR reports	UI	PUC-4
FN-UI-14	Insights into energy efficiency	UI	PUC-7
FN-UI-15	Customised alerts	UI	PUC-1, PUC-7
FN-UI-16	Energy advising service	UI	PUC-1, PUC-5
FN-UI-21	DR event notification	UI	PUC-1, PUC-8
FN-UI-22	Presentation of DR event history	UI	PUC-4
FN-UI-27	Actual schedules of assets	UI	Greek pilot discussions on iFA
NF-UI-01	The iFA UI of the Greek pilot should be integrated in the existing Mobile App	UI	Greek pilot discussions on iFA
FN-AM-04	Information on participation in explicit DR actions	A&M	PUC-4
FN-AM-05	Communication of Flexibility Potential	A&M	PUC-8
FN-AM-06	Access to flexibility reports to end users	A&M	PUC-4
FN-AM-08	Receiving Flexibility Signal	A&M	PUC-8
FN-AM-09	Communication of Flexibility Signal	A&M	PUC-8, PUC-9
FN-AM-10	Response to Flexibility Signal (explicit DR)	A&M	PUC-9
FN-AM-17	Access of flexibility validation data from the RAI (explicit DR)	A&M	PUC-4
FN-AM-18	Communication of flexibility validation data (explicit DR)	A&M	PUC-4
FN-AM-19	Assessment of end user participation in a DR event (explicit DR)	A&M	D2.4 [17]
FN-AM-20	Communication of participation assessment data (explicit DR)	A&M	D2.4 [17]
FN-DR-01	iFA end-users' flexibility potential	DRMS	PUC-8
FN-DR-03	Sending Flexibility Signal	DRMS	PUC-8
FN-DR-04	Response to Flexibility Signal (explicit DR)	DRMS	PUC-9
FN-DR-05	Information on participation in explicit DR actions	DRMS	PUC-4
FN-DR-06	Access of flexibility validation data from the iFA (explicit DR)	DRMS	PUC-4
FN-DR-08	Response to flexibility request	DRMS	Pilot-specific
FN-DR-09	Flexibility dispatch	DRMS	Pilot-specific
FN-DR-10	Provide activated flexibility report	DRMS	Pilot-specific
FN-AFM-01	Provide baseline forecasts	AFM	PUC-8, PUC-9
FN-AFM-02	Flexibility potential	AFM	PUC-8, PUC-9
FN-AFM-03	Activate offered flexibility	AFM	PUC-9
FN-DTR-01	Household electricity model	DTR	HLUC-1, PUC-4, PUC-6, PUC-8, PUC-10

FN-DTR-03	Household flexibility model	DTR	PUC-4, PUC-5, PUC-6, PUC-8, PUC-10
IF-21	Sensor data	RAI	PUC-2
IF-22	Flexible assets control	RAI	PUC-1, PUC-9
IF-23	Flexible assets constrain	RAI	PUC-1
IF-83	Trust management	TM	/
IF-84	Authentication, Authorization and Accounting	S&P	/
IF-85	Communication security	RAI	/
IF-86	Confidentiality, integrity and availability of the data (CIA)	S&P	/
IF-89	User consent	TM	/
IF-90	Explicit data flows	TM, S&P	/
IF-93	Apply need to know principle	TM, S&P	/
IF-95	Right to be forgotten	TM, S&P	/

6.2 Slovenian pilot

In the Slovenian pilot the main iFA components have been gradually provided through the phase two and phase three of the pilots. The components of the iFA were validated in the large-scale pilot in particular through piloting in 2024 as is described in Section 3.2. The addition of the new users and updates to technical HEMS solution is reported in Section 3.2.1. Parametrization of the smart meters and their inclusion in the RAI is reported in Section 3.2.2. The End User Interface (EUI) is reported in Section 3.2.3. The RAI updates are reported in Section 3.2.4. The components were tested and validated in use cases experimentation as are presented in Section 3.2.5 and the result of experimentation reported in Section 3.2.6. Experimental results have been compared to classical methods in Section 3.2.7. The Automated Flexibility Management (AFM) experiments are reported in Section 3.2.8. Overall, the requirements related, implemented and validated in the Slovenian pilot are more detailed in Table 25.

Table 25: Implemented requirements in the Slovenian large-scale pilot.

Code	Title	Component/ System	Source
FN-AFM-01	Provide baseline forecasts	AFM	PUC-8, PUC-9
FN-AFM-02	Flexibility potential	AFM	PUC-8, PUC-9
FN-AFM-03	Activate offered flexibility	AFM	PUC-9
FN-AFM-04	Optimize flexibility based on prices (e.g. implicit demand response)	AFM	PUC-9, PUC-10
FN-AFM-05	Optimize flexibility locally (self-consumption, consumer load reduction)	AFM	PUC-1, PUC-9, PUC-10
FN-DTR-01	Household electricity model	DTR	HLUC-3, PUC-8, PUC-10
FN-DTR-02	Household thermal model	DTR	HLUC-3, PUC-8, PUC-10
FN-DTR-03	Household flexibility model	DTR	HLUC-3, PUC-6, PUC-8, PUC-9, PUC-10
IF-65	Household occupant behaviour model	DTR	HLUC-3, PUC-8, PUC-10

IF-21	Sensor data	RAI	PUC-2
IF-18	Weather data	RAI	PUC-10, PUC-5
IF-19	CO_2 emissions	RAI	PUC-3
IF-22	Flexible assets control	RAI	PUC-1, PUC-9
IF-23	Flexible assets constrain	RAI	PUC-1
FN-UI-01	Operation mode customisation	UI	PUC-1
FN-UI-02	User-defined time and operational constraints	UI	PUC-1
FN-UI-03	End-user feedback	UI	PUC-1
FN-UI-04	Optimisation policy selection	UI	PUC-1
FN-UI-05	Automation level customisation	UI	PUC-1
FN-UI-07	Supported system interface languages	UI	PUC-1
FN-UI-09	DR notification policy	UI	PUC-1
FN-UI-11	Real-time energy data	UI	PUC-7
FN-UI-12	Past energy data	UI	PUC-7
FN-UI-14	Insights into energy efficiency	UI	PUC-7
FN-UI-15	Customised alerts	UI	PUC-1, PUC-7
FN-UI-16	Energy advising service	UI	PUC-1, PUC-5
FN-UI-17	FN-UI-17 Inspection of energy tariffs	UI	PUC-9, PUC-10
FN-UI-23	User Feedback on Satisfaction from DR/Flexibility Event	UI	/
FN-UI-27	Actual schedules of assets	UI	Greek pilot discussions on iFA
FN-AM-11	Communication of network tariffs from external system	A&M	PUC-9, PUC-10
FN-AM-12	Access to network tariffs to end users	A&M	PUC-9, PUC-10
FN-AM-13	Communication of electricity tariffs from external system	A&M	PUC-9, PUC-10
FN-AM-14	Access to electricity tariffs to end users	A&M	PUC-9, PUC-10
IF-83	Trust management	TM	/
IF-84	Authentication, Authorization and Accounting	S&P	/
IF-85	Communication security	S&P	/
IF-86	Confidentiality, integrity and availability of the data (CIA)	S&P	/
IF-89	User consent	TM	/
IF-90	Explicit data flows	TM, S&P	/
IF-93	Apply need to know principle	TM, S&P	/
IF-95	Right to be forgotten	TM, S&P	/

6.3 Finnish pilot

In the Finnish pilot, all the main components of the iFLEX Assistant were already in the place after phase 2, and in the phase 3 the supermarket was added to the large-scale pilot. This iFA was validated via demonstrations in operational environment at an apartment building in phase 2 and in the phase 3 demonstrations were done with supermarket pilot. In the phase 3 the focus in the apartment building has been improving the modelling accuracy as described in the 3.3.1. System tests involving also ENERIM's Aggregation Platform (i.e., DR solution) have been run successfully in phase 2, validating the DR-related functionalities of the apartment building iFA. The demonstrated use cases are described in more detail in section 3.3 and further elaborated in D8.5 [7].

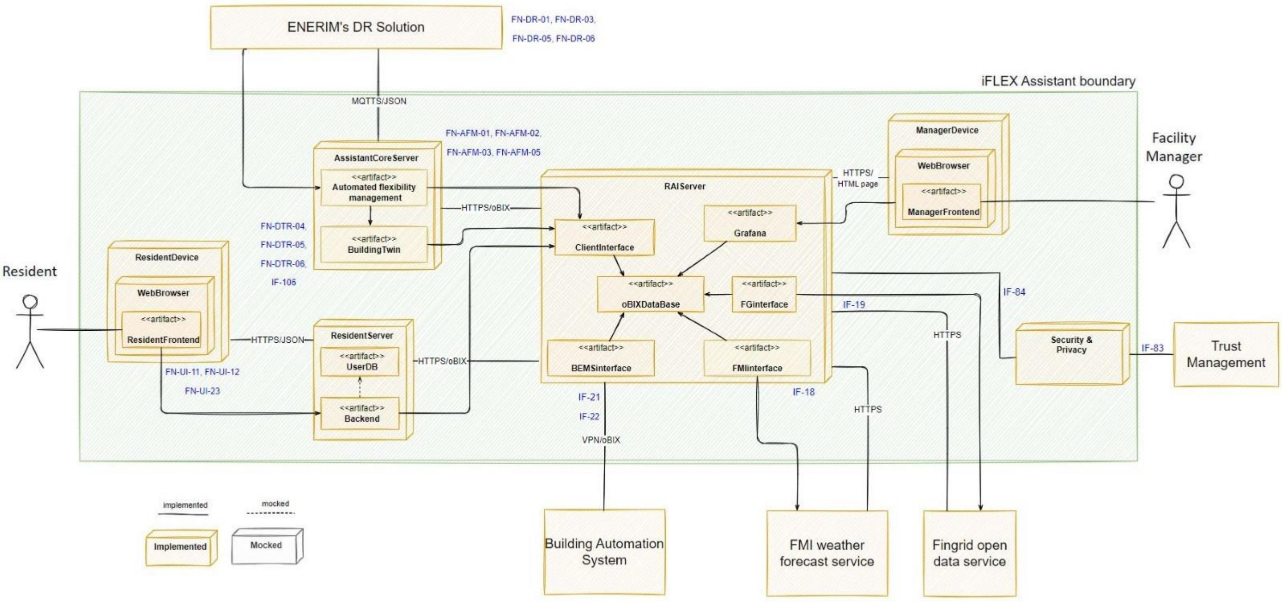


Figure 68: Deployment diagram of the Finnish large-scale pilot.

The requirements which were implemented in Phases 1,2 and 3 of the Finnish pilot concern all the iFLEX components, as shown in Figure 68, and are presented in more details in the Table 26.

Table 26: Implemented requirements in the Finnish large-scale pilot.

Code	Title	Component/ System	Source
FN-AFM-01	Provide baseline forecasts	AFM	PUC-8, PUC-9
FN-AFM-02	Flexibility potential	AFM	PUC-8, PUC-9
FN-AFM-03	Activate offered flexibility	AFM	PUC-9
FN-AFM-04	Optimize flexibility based on prices (e.g. implicit demand response)	AFM	PUC-9, PUC-10
FN-AFM-05	Optimize flexibility locally (self-consumption, consumer load reduction)	AFM	PUC-1, PUC-9, PUC-10
FN-DTR-04	Apartment building district heating model	DTR	HLUC-3, PUC-8, PUC-10
FN-DTR-05	Apartment building electricity model	DTR	HLUC-3, PUC-8, PUC-10
FN-DTR-06	Apartment building flexibility model	DTR	HLUC-3, PUC-6, PUC-8, PUC-9, PUC-10
FN-DTR-07	Supermarket baseline model	DTR	HLUC-3, PUC-8, PUC-10
FN-DTR-08	Supermarket flexibility model	DTR	HLUC-3, PUC-6, PUC-8, PUC-9, PUC-10
IF-106	Machine learning based apartment building district heating and electricity flexibility models	DTR	HLUC-3, PUC-8, PUC-9, PUC-10
IF-21	Sensor data	RAI	PUC-2
IF-18	Weather data	RAI	PUC-10, PUC-5
IF-19	CO_2 emissions	RAI	PUC-3

IF-22	Flexible assets control	RAI	PUC-1, PUC-9
FN-UI-12	Past energy data	UI	PUC-7
FN-UI-11	Real-time energy data	UI	PUC-7
FN-UI-23	User Feedback on Satisfaction from DR/Flexibility Event	UI	/
IF-83	Trust management	TM	/
IF-84	Authentication, Authorization and Accounting	S&P	/

7 Validation progress monitoring (KPIs)

Table 27 presents the current values of the project KPIs obtained during the final round of validation. The methodology, validation data and success criteria for the validation is presented in section 4.4.

Table 27: Current values for KPIs monitored after each pilot phase.

ID	Key performance indicator	Current value	Target	Remarks on the validation process
KPI1	Number of different types of stakeholders contributing to the co-creation process.	10	6	The following stakeholder types contributing to the co-creation process were identified and actively contributing to co-creation process: household consumers, household prosumers, DSOs, retailers, aggregators, technology providers, business prosumers (small-medium enterprise, Slovenia), business consumers (shop, Finland), energy community – apartment building residents (Finland), apartment building management (Finland) More details on methodology and results in D2.6 [18]. Report on user engagement and co-creation activities.
KPI2a	Increased accuracy of consumer load forecasting compared to state-of-the-art methods	22%	20%	The results are calculated by comparing the new hybrid models, documented in D3.3 [11], to the state-of-the-art feed-forward machine learning models in the pilots and calculating the improvement in baseline load forecast accuracy (mean squared error). Please refer to section 3.3.1 for further details on the KPI2a validation.
KPI2b	Increased accuracy of flexibility modelling compared to state-of-the-art methods	32%	15%	The improvements are obtained by comparing the novel hybrid model, documented in D3.3 [11] with SotA machine learning methods. The accuracy improvement is calculated during DR events with MSE. Please refer to section 3.3.1 for further details on the KPI2b validation.
KPI2c	Increased effectiveness of automated flexibility management compared to standard methods	16%	10%	The current results are validated based on the results collected from the apartment building and supermarket pilots. The validation was executed by comparing the results obtained with the automated flexibility management algorithm with the default methods applied in the pilot building. In the apartment building the average savings were as follows: CO_2 emission reduction by 10,72% and cost savings 9,42%. We balanced these savings equally and the average result for the apartment building is thus 10,1%. For the supermarket the costs savings were 22 %. The average savings are thus 16 %. Please refer to sections 3.3.1 and 3.3.2 for further details on the results and evaluation.

KPI3a	Level of interoperability (coverage of common standards)	100%	100%	Contrary to proprietary solutions, the interfaces of iFLEX functional components, both towards other components and towards external systems, are fully based on open/standard communications protocols and serialisation formats, most notably 1) the JSON format for data encoding, 2) the HTTPS/REST (including standardized RESTful APIs for the energy domain such as oBIX), MQTT, OpenADR2.0 for communications among software entities, 3) RS-485 and ModBus in HEMS/BEMS systems with either serial (ModBus RTU) or ethernet (ModBus ETH) physical layer for interactions with energy smart meters, appliances, and PV inverters; when existing appliances used in pilots did not support ModBus, a bridge/gateway was installed for converting to ModBus other low level protocols, such as M-Bus, EMS and OCPP, and 4) data formats and protocols for secure communications, such as JWT and TLS.

KPI3b	Compliance with relevant EU privacy and data management regulation and standards	YES	YES	The Slovenian Information Commissioner has reviewed the project's privacy and data management approach, specifically the Joint Controller Agreement. A set of recommendations were given which align with the implemented policies and protocols. Overall, GDPR compliance requirements and their implications for the project has been analysed (see D1.10 [19]). In addition, the national regulations in the three pilot countries (Greece, Slovenia and Finland) have been analysed to assess if there are any additional legal requirements or provisions with respect to the processing of personal data that must either be adhered to or that may affect the project/pilot. While there are no additional requirements, there are some provisions related to the power given to the Data Protection Officer in each of the three pilot countries. The continuous monitoring of legal and ethical requirements is documented in annual compliance monitoring reports (WP1). **Privacy Policy and Informed consent** A project privacy policy, information sheets and informed consent forms in pilot languages are in place and in compliance with the GDPR. Consent is obtained prior to the collection of personal data. When given digitally, it is a prerequisite for enrolling into the pilot and becoming an active participant. When collected on paper, a signed copy must be returned (a free return envelope is provided) before registering and enrolling the individual into the pilot. All consent forms are stored securely with restricted and monitored access. The project website contains a GDPR compliant privacy and cookie policy. **Joint Controller Agreement** All project partners have entered into a Joint Controller Agreement (JCA). Data subjects are informed hereof. The Slovenian Information Commissioner (IC) has reviewed the JCA and provided a non-binding opinion hereof. The JCA (and information given to data subjects) are in line with IC recommendations. **Data Subject Rights** A set of project protocols (with defined procedures) are in place to protect data subjects' rights (enable them to exercise these rights) with regards to their personal data. This includes a data breach notification protocol, an incidental findings protocol as well as forms and procedures for exercising rights (Subject Access Request). A project Ethical Checklist is used to check that ethical and regulatory requirements have been met. **Data Protection Impact Assessment (DPIA)** DPIAs per pilots were completed for phase 1 pilots and have since been monitored and updated as necessary. **Ethics Advisory Board** The iFLEX Ethics Advisory Board (EAB) is active and has regular annual meetings. The EAB

				monitors and advises on ethical and legal requirements and aspects of the project/pilots and how to deal with these and resolve any potential ethical issues. **Data Security** Measures and procedures for data security are in place, including anonymisation and pseudonymisation techniques and secure data sharing mechanism. Classic security protocols are used to provide data integrity, authentication and confidentiality services.
KPI4a	Return on Investment for prosumers in the base scenarios	57%	>15%	According to Section 8.2 of D5.6 [20], the average Return on Investment (RoI) for prosumers across the 3 pilot countries is 57%, even though in Finland the expected RoI is 13% and assumes that the ESCOs decide to subsidise BUC-6 (see relevant discussion in KPI4b below for ESCOs) from BUC-4 and BUC-7(or achieve a higher customer base compared to the one assumed in baseline scenario).
KPI4b	Internal Rate of Return for all commercial entities in the base scenarios	48% on average	>15%	According to Section 8.1 of D5.6 [20], the average Internal Rate of Return (IRR) for the proposed Aggregator business model, in the baseline scenario, across the three pilot countries is 48%, which is higher than the target values. Note, however that only the Aggregators in Greece will be offering the complete service portfolio (all relevant BUCs), while BUC-1 will not be offered in Finland and Slovenia. Similarly, the average Internal Rate of Return for the proposed Energy Services Company (ESCO) business model, in the baseline scenario across the 3 pilot countries, was estimated at 49% (Section 8.2 of D5.6 [20]). These ESCOs can offer the complete service portfolio, even though the BUC-6 service would be cross-subsidised by the rest services in Finland for the baseline scenario (it requires 5x more customers to be self-sustainable).
KPI4c	Monetary benefits to the consumer in the base scenarios	10,25% on average	>8%	The average annual monetary benefits to consumers across the 3 pilot countries was found to be 10,25%. These benefits involve cost savings from BUC-4 and BUC-7. Similarly, based on the preliminary results documented in Section 7.2 (D5.6 [20]), a Slovenian residential consumer with Heat Pump will be able to reduce annual electricity costs by 17,8%, which means that the target of 8% can be obtained after taking into account the cost for the iFLEX Assistant.
KPI5a	Technology readiness of the iFLEX Framework and iFLEX Assistant prototypes	TRL 7	TRL 7	A full-scale prototype of an iFLEX Assistant was demonstrated in operational environment in the pilots (TRL 7).

KPI5b	Number of innovative demand response and holistic energy management services	5	5	The project has developed and demonstrated in the pilots following services (exploitable results) supporting the uptake of DR and holistic energy management solutions: iFLEX framework for energy & flexibility management, Resource Interface Module & Security Data Management Service, Hybrid Modelling and Flexibility Management Service, End-user Interface Services for households, residents and building owners and Aggregator/Market Interface Services. The exploitable results are further elaborated in D9.6 [21].
KPI6a	Number of consumers in the pilots	990	>600	For the KPI6a we were focusing on consumers that took part in the pilots in Slovenia, Greece, or Finland (with direct or indirect involvement according to KPI6a definition). We have engaged 990 consumers which is above our base target value (600 consumers): • Finish pilot: 144. • Slovenian pilot: 636. • Greek pilot: 210. More details on methodology and results in D2.6 [18]. Report on user engagement and co-creation activities.
KPI6b	Number of consumer groups targeted with novel demand response services	6	3	We have following consumer groups in the iFLEX pilots that were targeted with novel demand response services: 1. Residential Consumers – House owners (owned property) 2. Residential Consumers – Apartment owners (owned property) 3. Residential Consumers – Apartment residents (rented property) 4. Residential Prosumers – House owners 5. Business Consumer – commercial or industrial 6. Business Prosumer – commercial or industrial More details on methodology and results in D2.6 [18]. Report on user engagement and co-creation activities.

KPI6c	Increased consumer flexibility for grid stability and RES integration	15,3%	15%	The increase in consumer flexibility is challenging to validate in a scientifically rigorous manner as it depends heavily on the type of flexible assets available in the pilots' sites. The iFLEX solutions cover assets such as HVAC systems that have very high flexibility potential. Therefore, it is not fair to compare the results directly to research such as [22] where the flexibility is harnessed from other type of assets. To address this problem, we decided to estimate the increase in a situation where we have identical flexible assets (e.g. the HVAC system). In this case the increase in the flexibility comes from the more accurate models and control algorithms provided by the iFLEX Assistant. I.e., with more accurate forecasts and control algorithms more of the available flexibility can be used to improve grid stability and RES integration. The actual increase is calculated by multiplying the increased accuracy of the baselines, with the increased flexibility forecast and the increased effectiveness of the flexibility management (i.e., 1,0 * 1,142 * 1,097).

8 Conclusion

The deliverable D7.7 presents a comprehensive overview of the outcomes derived from the third pilot phase conducted across three distinct clusters: Greece, Finland, and Slovenia. These pilots serve as integral components of the iFLEX project, aimed at exploring the integration of renewable energy sources and demand response (DR) aggregators to address energy imbalances and enhance energy efficiency.

In the Greek pilot cluster, focused on optimizing a 500 kW PV plant owned by OPTIMUS, the third phase built upon lessons learned from previous phases, necessitating partial redesign to overcome identified challenges. The deployment and testing of HERON's energy monitoring infrastructure facilitated a deeper understanding of the interaction between RES and DR aggregators.

The Slovenian pilot expanded its scope by incorporating additional households and industrial clients during the large-scale deployment phase. Utilizing home energy management systems and end-user interfaces (EUI), the pilot aimed to enable remote control, data collection, and resource abstraction. Noteworthy improvements were made to the resource abstraction interface, enhancing its functionality and usability.

In Finland, the iFLEX project introduced the iFLEX Assistant, which provided personalized energy-related recommendations to users. Deployed in various settings including apartment buildings and supermarkets, the pilot demonstrated the efficacy of demand flexibility in alleviating bottlenecks within the energy distribution network. Collaboration with the OneNet project highlighted the potential of demand response to enhance grid stability and efficiency.

The validation plan outlined in D7.4 [1] encompassed end-user, technical, and business aspects across all pilot clusters. End-user validation varied in methodology, with Greece employing a User Experience Questionnaire, Slovenia conducting interviews and interface tests, and Finland assessing comfort alongside user perceptions. Technical validation focused on requirements and pilot testing, while business validation utilized a structured approach to evaluate iFLEX's commercial viability. Post-phase 3, Key Performance Indicator validation ensured alignment with project objectives and specific contexts.

In each pilot cluster, user engagement and feedback were integral to refining the iFLEX solutions. In Greece, positive responses to the iFLEX Assistant were garnered through workshops and surveys, highlighting user interest in personalized advice and ease of use. Slovenian participants expressed willingness to engage in demand response events, emphasizing the importance of clear instructions and concise data presentation in the EUI app. Finnish users demonstrated increased energy awareness and a positive perception of the iFLEX project, indicating the effectiveness of demand flexibility initiatives.

Overall, the third pilot phase of the iFLEX project underscored the significance of user-centric design and iterative refinement in deploying innovative energy solutions. By addressing technical challenges, engaging stakeholders, and evaluating business potential, the project aims to facilitate the transition towards a more sustainable and efficient energy landscape.

9 List of figures and tables

9.1 Figures

9.2 Tables

10 References

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11 Annex A Greek pilot questionnaire

iFLEX End-user survey 2024

The purpose of the survey is to collect your feedback on your experiences with using the iFLEX Mobile App. Please answer all the questions and remember to click "Done" at the end to submit your answers.

The survey is anonymous.

1. How much do you like the iFLEX Mobile App overall?
   [Not at all 1 – 2 – 3 – 4 – 5 – 6 Very much]

2. How easy has it been overall for you to use the iFLEX Mobile App?
   [Very difficult 1 – 2 – 3 – 4 – 5 – 6 Very easy]

3. For how long have you used the iFLEX Mobile App (when did you install the app?)
   [One week or less – 2 weeks – 3 weeks – 4 weeks – 5 weeks – 6 weeks – 6 weeks or more (please specify)]

4. Which features/functions have you used? (tick all that applies)
   [DR Events – Energy Consumption – Advice – Assets Operation – Goals – Preferences – My objectives – Push Notifications – Help]

5. Which features/functions were particularly important for you? (tick all that applies)
   [DR Events – Energy Consumption – Advice – Assets Operation – Goals – Preferences – My objectives – Push Notifications – Help]

6. How often have your checked/used the iFLEX Mobile App in the past week?
   [Once a week – Twice a week – Three times a week – Four times a week or more – Once a day – Twice a day or more – Not at all – Other (please specify)]

7. During this past week indicate how often you've used the following features
   [DR Events – Energy Consumption – Advice – Assets Operation – Goals – Preferences – My objectives – Push Notifications – Help]

   [Never – Rarely – Sometimes – Often – Every day]

8. Thinking about how often you've used the iFLEX Mobile App, do you consider this time expenditure (i.e. the amount of time you needed to invest, such as responding to a DR event, checking your energy consumption etc.) as:
   [Appropriate – Too high – I would be ok with spending more time]

9. Have you had any technical problems/issues with the iFLEX Mobile App?
   [Yes, a few – Yes many – No, none at all]

10. If yes, how much would you say that it affected your use of the app?
    [Not at all 1 – 2 – 3 – 4 – 5 – 6 A lot]

11. Would you be interested in using the iFLEX App in the future to participate actively in DR?

[No, not at all 1 – 2 – 3 – 4 – 5 – 6 Yes, definitely]

12. Are you confident that the app has sufficient securement measurements installed to protect your personal data?
    [No, not at all 1 – 2 – 3 – 4 – 5 – 6 Yes, definitely]

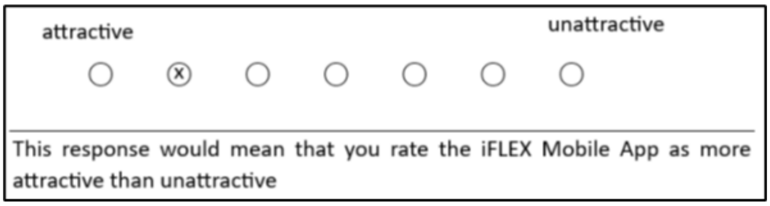
13. Have your expectations from participating in the pilot/using the app been fulfilled?
    [Yes – No]

    [Please specify]

QUESTIONS ABOUT OPERATION AND SURFACE (DESIGN) OF THE iFLEX MOBILE APP

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:



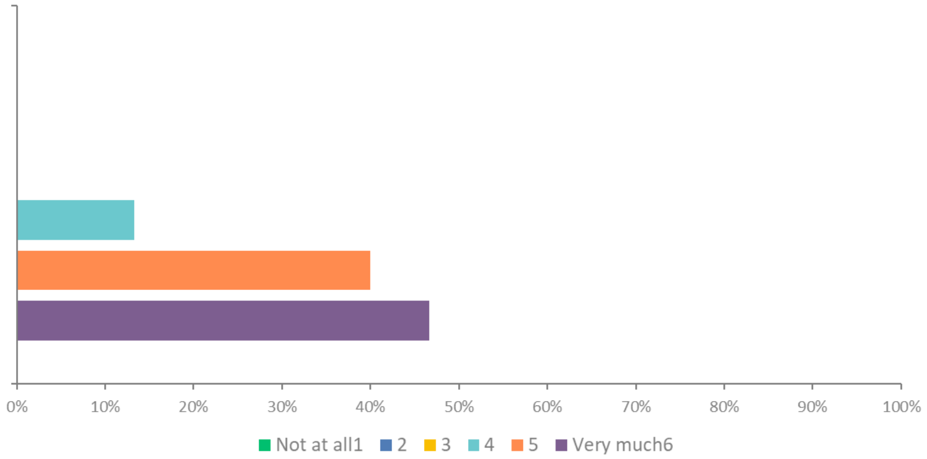
Please decide spontaneously. Don’t think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

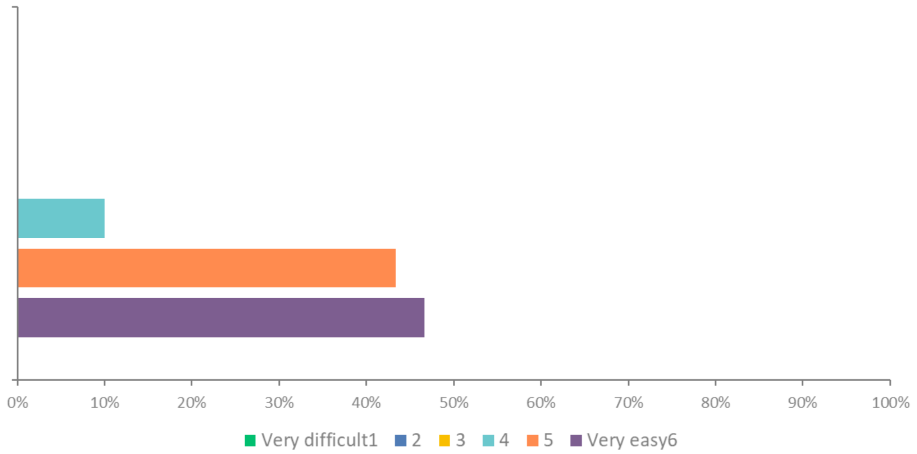
It is your personal opinion that counts. Please remember: there is no wrong or right answer!

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
not understandable	○	○	○	○	○	○	○	understandable
creative	○	○	○	○	○	○	○	dull
easy to learn	○	○	○	○	○	○	○	difficult to learn
valuable	○	○	○	○	○	○	○	inferior
boring	○	○	○	○	○	○	○	exciting
not interesting	○	○	○	○	○	○	○	interesting
unpredictable	○	○	○	○	○	○	○	predictable
fast	○	○	○	○	○	○	○	slow
inventive	○	○	○	○	○	○	○	conventional
obstructive	○	○	○	○	○	○	○	supportive
good	○	○	○	○	○	○	○	bad
complicated	○	○	○	○	○	○	○	easy
unlikable	○	○	○	○	○	○	○	pleasing
usual	○	○	○	○	○	○	○	leading edge
unpleasant	○	○	○	○	○	○	○	pleasant
secure	○	○	○	○	○	○	○	not secure
motivating	○	○	○	○	○	○	○	demotivating
meets expectations	○	○	○	○	○	○	○	does not meet expectations
inefficient	○	○	○	○	○	○	○	efficient
clear	○	○	○	○	○	○	○	confusing
impractical	○	○	○	○	○	○	○	practical
organized	○	○	○	○	○	○	○	cluttered
attractive	○	○	○	○	○	○	○	unattractive
friendly	○	○	○	○	○	○	○	unfriendly
conservative	○	○	○	○	○	○	○	innovative

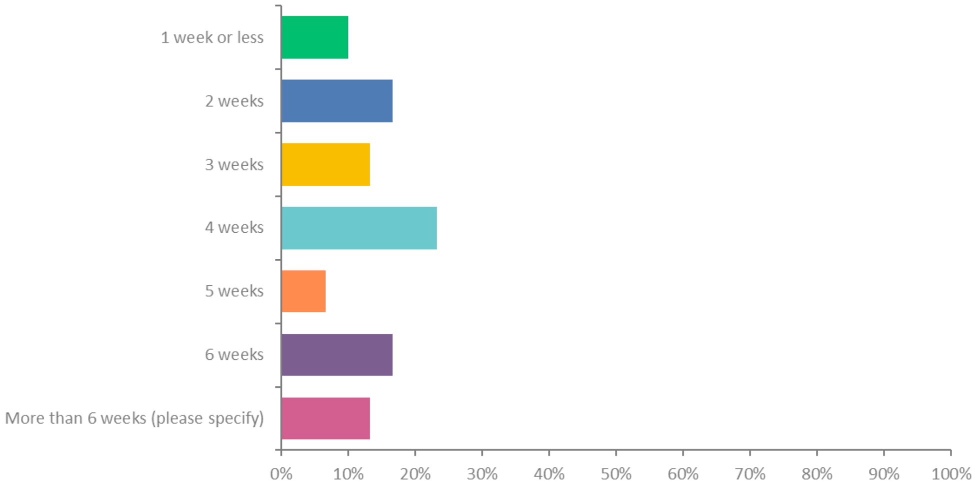
12 Annex B Greek pilot end-user questionnaire individual results



Q1 How much do you like the iFLEX Mobile App overall?

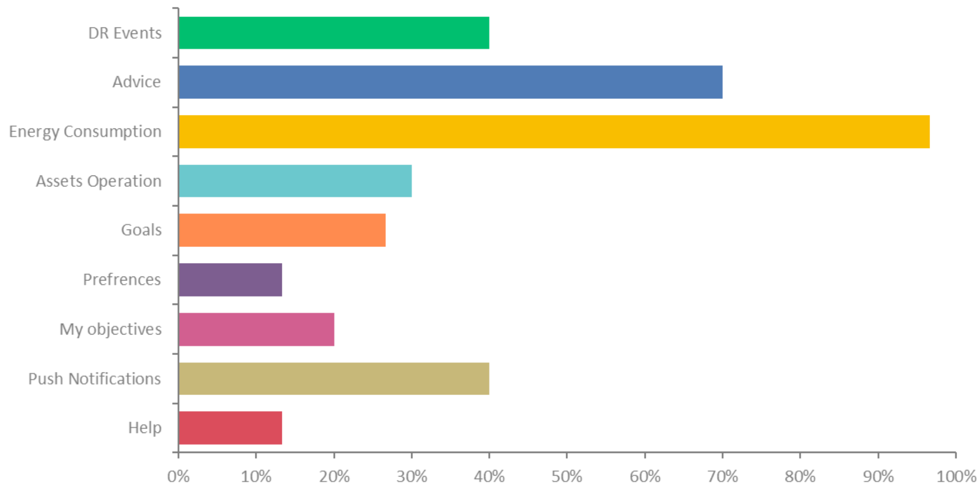


Q2 How easy has it been overall for you to use the iFLEX Mobile App?

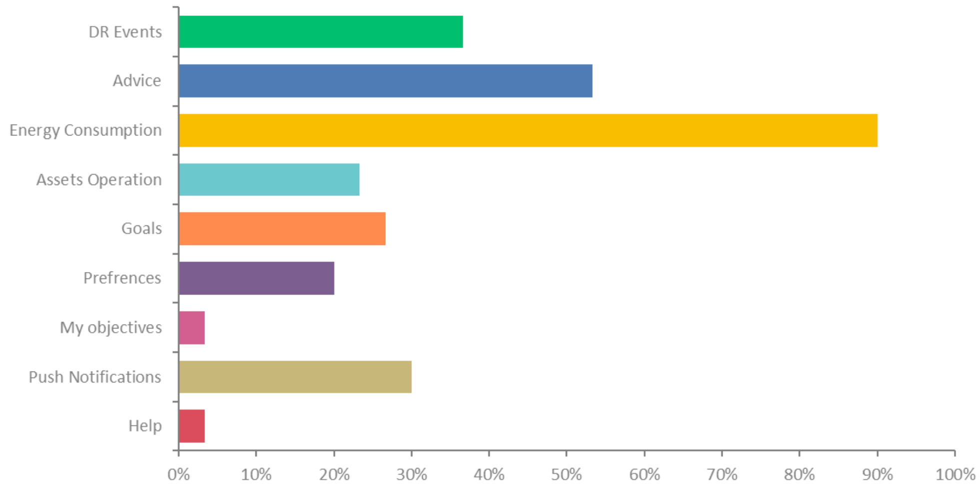


Q3: For how long have you used the iFLEX Mobile App (when did you install the app?)

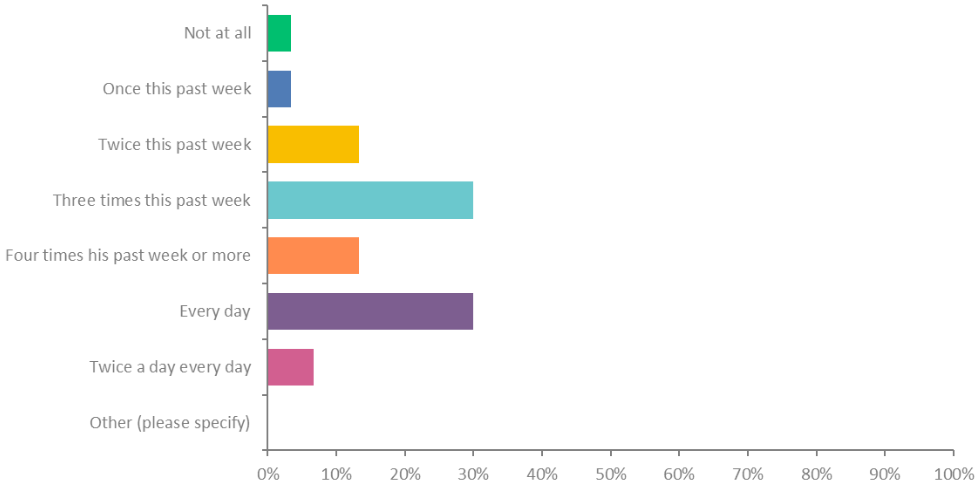
The four respondents who answered “more than 6 weeks”, had indicated that they had had the app for 2 months, 3 months, 6 months and 1 year.



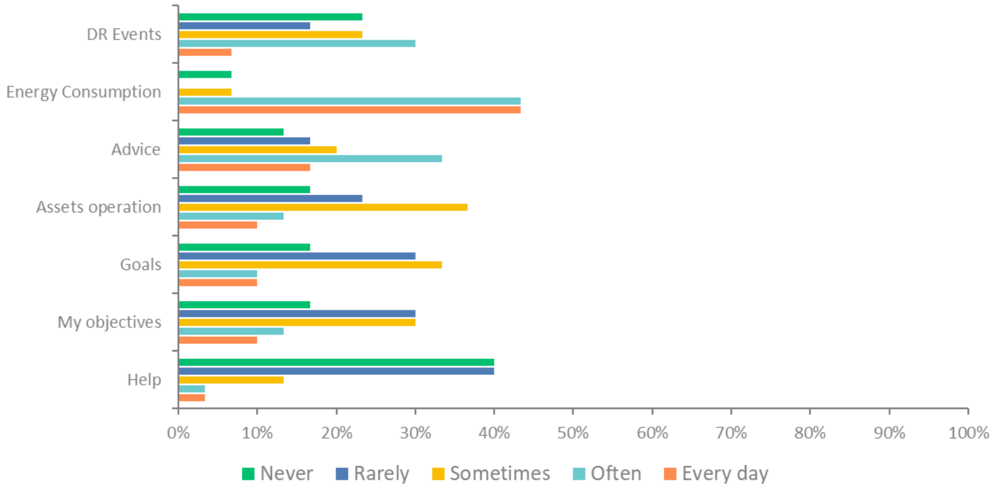
Q4 Which features/functions have you used? (tick all that applies).



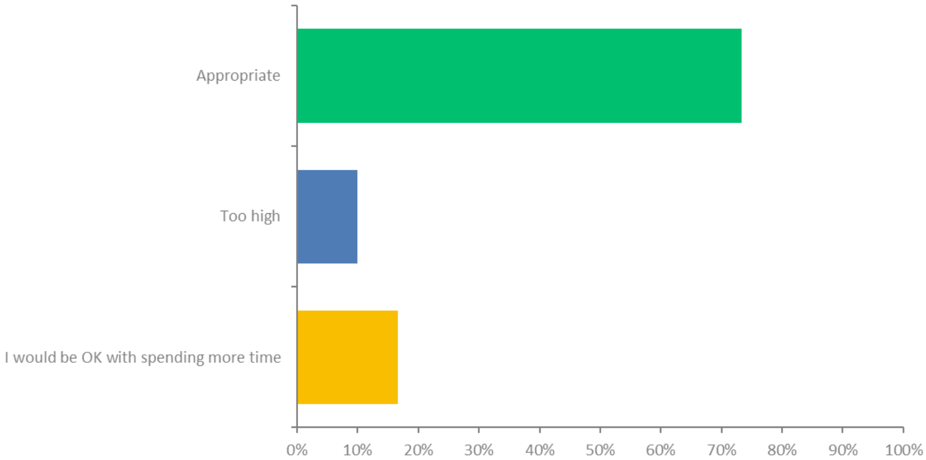
Q5 Which features/functions were particularly important for you? (tick all that applies).



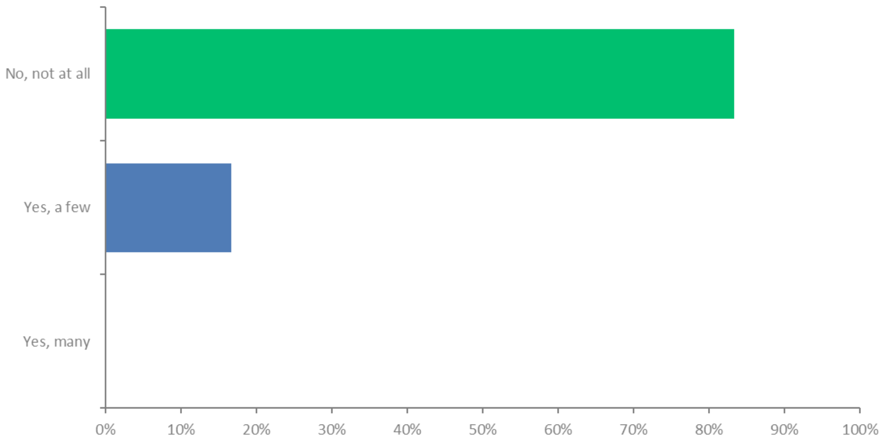
Q6 How often have your checked/used the iFLEX Mobile App in the past week?



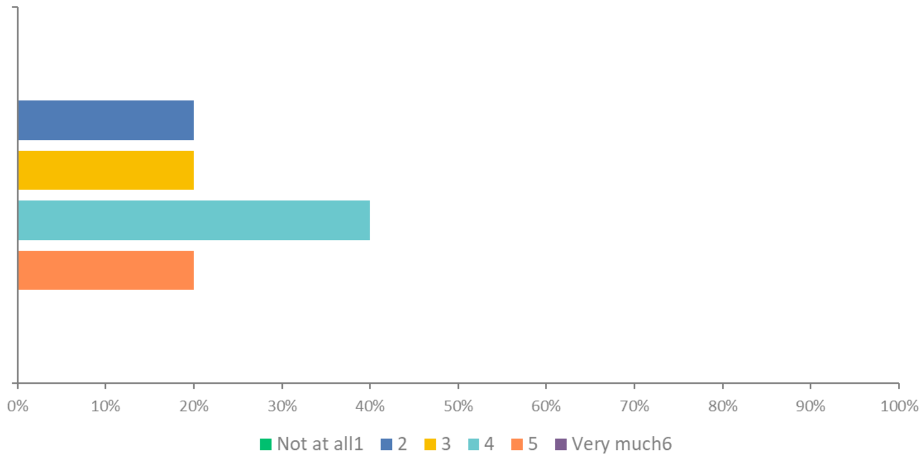
Q7 During this past week indicate how often you've used the following features.



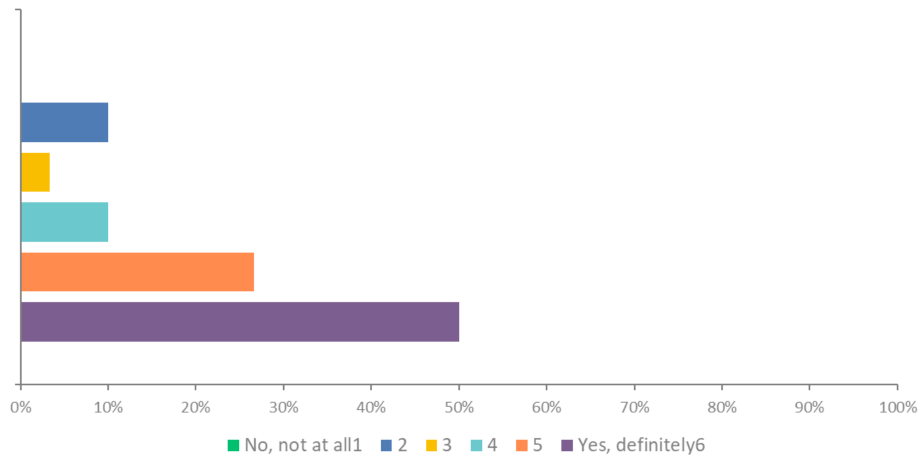
Q8 Thinking about how often you've used the iFLEX Mobile App, do you consider this time expenditure (i.e. the amount of time you needed to invest, such as responding to a DR event, checking your energy consumption etc.) as i) Appropriate, ii) Too high, iii) I would be OK with spending more time.



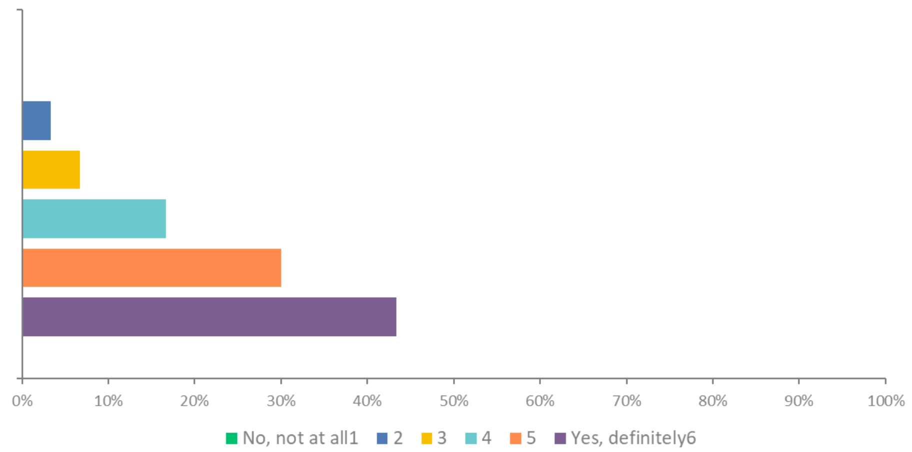
Q9 Have you had any technical problems/issues with the iFLEX Mobile App?



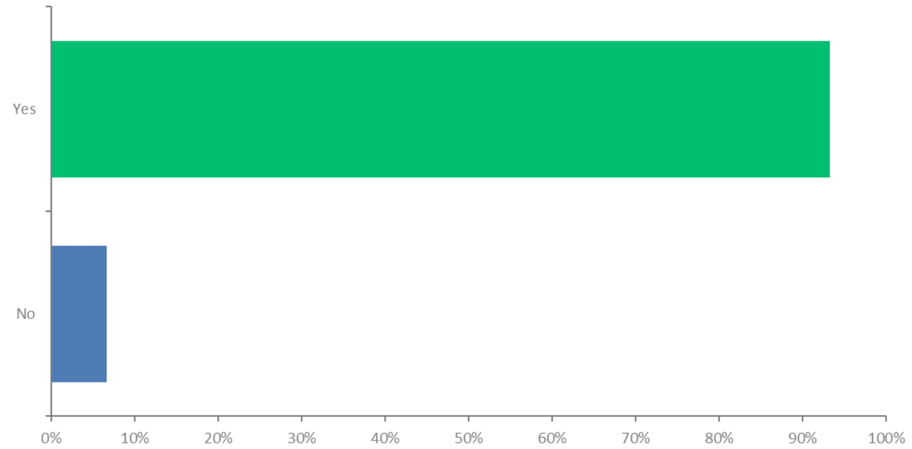
Q10 If yes, how much would you say that it affected your use of the app?



Q11 Would you be interested in using the iFLEX Mobile App in the future to participate actively in Demand Response?



Q12 Are you confident that the app has sufficient securement measurements installed to protect your personal data your personal data is stored securely in the app?



Q13 Have your expectations from participating in the pilot/using the app been fulfilled?

13 Annex C UEQ Alpha-Coefficient (Greek Pilot)

Attractiveness	
Items	**Correlation**
1, 12	0.46
1, 14	0.50
1, 16	0.64
1, 24	0.42
1, 25	0.29
12, 14	0.43
12, 16	0.47
12, 24	0.81
12, 25	0.80
14, 16	0.85
14, 24	0.53
14, 25	0.53
16, 24	0.49
16, 25	0.50
24, 25	0.79
DK	0.57
Alpha	**0.89**

Perspicuity	
Items	**Correlation**
2, 4	0.38
2, 13	0.65
2, 21	0.38
4, 13	0.49
4 , 21	0.54
13, 21	0.27
DK	0.45
Alpha	**0.77**

Efficiency	
Items	**Correlation**
9, 20	0.25
9, 22	0.53
9, 23	0.60
20, 22	0.44
20, 23	0.34
22, 23	0.72
DK	0.48
Alpha	**0.79**

Dependability	
Items	**Correlation**
8, 11	0.56
8, 17	0.45
8, 19	0.40
11, 17	0.50
11, 19	0.48
17, 19	0.71
DK	0.52
Alpha	**0.81**

Stimulation	
Items	**Correlation**
5, 6	0.50
5, 7	0.49
5, 18	0.72
6, 7	0.43
6, 18	0.48
7, 18	0.46
DK	0.51
Alpha	**0.81**

Novelty	
Items	**Correlation**
3, 10	0.12
3, 15	-0.05
3, 26	0.12
10, 15	0.47
10, 26	0.40
15, 26	0.68
DK	0.29
Alpha	**0.62**

14 Annex D Finnish pilot questionnaire

Final survey for participants in the iFLEX pilot

You have participated in the iFLEX project, and have been able to monitor your own apartment's data for a few month, as well as the entire building's electricity and district heat consumption, carbon footprint and the effect of participating in demand flexibility.

With the following questions, we are collecting feedback about the project.

By answering the questions, you will be entered into the prize draw (S-group gift card, 50€)!

Background information about you:

1) * Your age

- ◯ Under 20 years
- ◯ 20 - 30 years
- ◯ 30 - 40 years
- ◯ 40 - 50 years
- ◯ Over 50 years

2) * Gender

- ◯ Male
- ◯ Female
- ◯ Other / I don't want to tell

3) * Size of your household

- ◯ I live alone
- ◯ 2 persons
- ◯ 3 or more persons

4) * How often have you followed the information presented through the iFLEX user interface?

- ◯ Several times in a day
- ◯ Once in a day
- ◯ A few times in a week
- ◯ A few times in a month
- ◯ Never

5) * Evaluate the following things about the information you receive through the user interface:

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	Can't tell
The information has been clear and in an understandable form.	◯	◯	◯	◯	◯	◯
The amount of information is adequate.	◯	◯	◯	◯	◯	◯
I have found the information interesting.	◯	◯	◯	◯	◯	◯

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	Can't tell
The information has given me a comprehensive understanding of my home's energy consumption and its impact on the environment.	◯	◯	◯	◯	◯	◯
The information has helped me to understand how benefits can be achieved with demand flexibility.	◯	◯	◯	◯	◯	◯

6) What other information would you like to receive, or would be useful / interesting?

7) * Some control commands have been carried out in your apartment building, with which the house's energy consumption (heating, water heating) has been transferred to a more favorable time. Evaluate the following statements:

	Yes	No	Cannot say
There has been a temporary change in temperature in the apartment over the past 3 months: too cold.	◯	◯	◯
There has been a temporary change in temperature in the apartment over the past 3 months: too warm.	◯	◯	◯
The hot water has run out at least once in the last 3 months.	◯	◯	◯
The effect of the control commands has been unnoticeable on my living comfort.	◯	◯	◯
I would like to receive more detailed information about control commands.	◯	◯	◯

8) Here you can leave more detailed feedback about your living conditions. We appreciate all feedback.

9) * Please estimate any changes in your awareness over the past months when you have been able to monitor information through the iFLEX user interface:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Nowadays, I follow more energy-related news and events in the energy market.	◯	◯	◯	◯	◯
I have paid more attention to my own energy consumption habits.	◯	◯	◯	◯	◯
I am more aware of energy prices.	◯	◯	◯	◯	◯
My awareness of the environmental effects of energy consumption has increased.	◯	◯	◯	◯	◯
I would like to receive recommendations or advice to change my own energy consumption in order to save.	◯	◯	◯	◯	◯

10) * Next, evaluate the iFLEX user interface itself. What is the user interface's...

	Excellent	Good	Not good but not bad either	Satisfactory	Bad	Cannot say
Usability / ease of use	◯	◯	◯	◯	◯	◯
Informativeness / amount of information	◯	◯	◯	◯	◯	◯
Visual appearance	◯	◯	◯	◯	◯	◯
Clarity and comprehensibility of graphics (pictures and diagrams)	◯	◯	◯	◯	◯	◯
Ease of providing feedback	◯	◯	◯	◯	◯	◯

11) You can help us develop the user interface by giving suggestions for improvement, or feedback on what works or doesn't work in the user interface.

12) * Finally, evaluate the iFLEX project as a whole.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I consider the topic of the project to be important and topical.	◯	◯	◯	◯	◯
I think participating in the project has been interesting.	◯	◯	◯	◯	◯

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I understand better why energy flexibility is important.	○	○	○	○	○
I would be interested in services with which an individual household can participate in demand flexibility.	○	○	○	○	○
I could participate in a similar project again.	○	○	○	○	○

13) * Your experience of participating in the iFLEX project

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
My experience with the iFLEX project has been positive.	○	○	○	○	○
Participating in the project has been effortless.	○	○	○	○	○
I have been contacted to an appropriate extent as the project progresses.	○	○	○	○	○
Communication in the project has been smooth and clear.	○	○	○	○	○
My privacy has been well taken care of in the project.	○	○	○	○	○

14) You can freely leave your thoughts on the topic or feedback about the iFLEX project here. We really appreciate all the feedback we receive.

Prize draw

If you want to participate in the prize draw (S-group gift card, 50€), you can leave your contact information here. Contact information is used only for the prize draw.

If you do not want to participate in the draw, press the "Send" button directly.

15) Your contact information for the draw:

Name:

E-mail: