Intelligent Assistants for Flexibility Management
(Grant Agreement No 957670)

D7.6 Small-scale pilot deployment and validation

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1 Executive summary

Delivery document D7.6 serves as the second consecutive validation document that provides a summary of the outcomes from the second 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. During Phase 1, challenges such as the lack of availability of water boilers and legal issues with electricity contracts and apartment dwellers were identified. To address these challenges, the pilot underwent partial redesign, including changes to the consent process and the inclusion of additional IoT devices like smart plugs. The pilot successfully recruited 30 households and around 65 users, with 2 fully operational relays installed.

The Slovenian pilot aimed to establish a pilot area with residential and small business users equipped with home energy management systems (HEMS) for data collection and remote control of user devices. The first phase focused on selecting suitable pilot endpoints and conducting a needs assessment. Based on the assessment, HEMS devices were deployed, and advanced modules like MQTT communication bridge, enrolment, digital twin, and trust, security, and privacy interfaces were integrated. The pilot successfully implemented measurement and control signals for various devices, provided an application for end-users to monitor energy performance, and offered incentives to users in the form of reduced electricity costs.

The Finnish pilot focused on the iFLEX Assistant, which aimed to provide users with personalized energy-related recommendations. The pilot integrated the iFLEX Assistant into existing home devices and systems, such as HVAC and solar power plants, and developed interfaces for controlling and collecting measurement data. The pilot also implemented the Resource Abstraction Interface (RAI) module, trust, security, and privacy interfaces, and weather and tariff interfaces. The iFLEX Assistant provided users with graphical and numerical data on energy consumption and enabled them to make informed decisions and optimize their energy usage.

Furthermore, the end user validation process was conducted separately in each pilot region to gather comprehensive feedback from end users. Various methods were employed, including usability testing of the iFA application, workshops, and end-user surveys.

The usability test conducted on the iFLEX Assistant App, focusing on specific screens. The study involved 12 participants from Greece and Slovenia with varying levels of domain knowledge. Participants were asked to complete 11 scenarios while their actions and comments were recorded. A questionnaire adapted from the System Usability Scale (SUS) was also administered. The results revealed certain challenges and areas for improvement. The most complex scenario involved checking schedules and understanding flexibility, while scenarios related to tariffs and DR events also posed difficulties for participants. However, the Advices, Notifications, and Preferences pages were generally clear. The SUS questionnaire indicated positive user perceptions overall, with the need for some learning highlighted. Based on the findings, recommended UI changes include rephrasing text, clarifying asset flexibility, improving DR event information on the Costs page, enhancing the Tariffs page, increasing scroll bar contrast, adding information buttons, and incorporating an app walkthrough.

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 iFLEX pilot project conducted workshops, surveys on installations, gathering valuable feedback from end-users. The main key findings were that participants prioritize cost reduction, reliable grid operation, and increased self-supply/consumption. Relevant use cases include grid optimization, energy consumption optimization, load profile analysis, self-balancing, and flexibility through demand response programs. Participants provided feedback on the iFLEX Assistant application, highlighting issues with contrast, font size, and language options. Key features desired are optimization related to price, consumption, and device efficiency, as well as consumption monitoring. Participants mentioned incentives such as cash prizes, lower bills, and environmental contributions. Collective benefit as a community was prioritized over comparing performance with other users. End-users expressed satisfaction with the installation process, appearance, and information provided. Improvement suggestions focused on coordination between electricians and installers, program support, and additional device integration.

The Finnish pilot for the iFLEX Assistant successfully engaged and validated end-users. Participants displayed interest in energy conservation, were willing to adapt behaviours, and expressed satisfaction with the project. The pilot involved user registration, surveys, installation of apartment sensors, and a test period with control commands. The residents followed visualized data, desired recommendations, and showed increased awareness of energy consumption and environmental effects. The user interface received positive evaluations, and communication throughout the project was smooth and clear.

Moreover, the technical validation in the iFLEX project was enhanced by the adoption of the JIRA tool, which facilitated the requirements validation process. This tool enabled efficient categorization of requirements by component and pilot, streamlining the monitoring process. Through discussions and user feedback, new requirements were identified, documented, and existing ones were updated. In Phase 3, the consortium made final decisions on open requirements, conducted integration tests in specific pilots, and validated the functionality, security, performance, and acceptance of pilot-specific instances of the iFLEX Assistants.

Furthermore, the comprehensive business analysis conducted for the pilot project assessed the commercial viability and economic feasibility of implementing energy management systems on a larger scale. The analysis considered factors such as pricing, consumer behaviour, market demand, and potential revenue streams. The findings provided valuable insights for developing a detailed pricing strategy and marketing plan, ensuring the long-term success of the project.

The document also summarizes the current values for various key performance indicators (KPIs) after each pilot phase. The KPIs include 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 for prosumers and commercial entities, technology readiness, number of demand response services, number of consumers in the pilots, and number of consumer groups targeted.

2 Introduction

2.1 Purpose, context and scope

The document presented, D7.6, serves as a validation report for the second 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 D7.6 is structured into six main chapters, each focusing on different aspects of the iFLEX project and its pilot deployments in phase 2. These chapters provide valuable insights and information regarding various stages of the project:

- Small Scale Pilot Deployment in Phase 2:
  This chapter details the progress made in integrating the iFLEX Framework for end-users during the small-scale pilot deployment. It highlights the advancements and developments made in implementing the framework within the pilot regions.
- Validation Plan for Phase 2:
  In this chapter, the validation procedures employed during phase 2 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 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 the cost aspect of each individual pilot. It provides a comprehensive breakdown of costs in various categories such as maintenance, equipment purchase, development costs, and more. This analysis offers insights into the economic feasibility and commercial viability of the iFLEX project.
- 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 the second pilot phase, providing a snapshot of the project's overall progress.

Through these chapters, Document D7.6 offers a comprehensive and structured overview of the iFLEX project's pilot deployments, validation processes, and progress monitoring.

3 Pilot deployment phase 2 (small-scale pilot)

3.1 Greek small-scale pilot deployment

The Greek pilot aims to demonstrate the interaction between RES and DR Aggregators as a means of mitigating the imbalances in the generation of 500 KW PV plant owned by OPTIMUS. During Phase 1, a pool of employees from HERON and its parent organisation GEK TERNA where extensively surveyed in order to identify the pool of iFLEX end-users. During this process several challenges were identified; most notably the lack of availability of water boilers due to the replacement of central heating which required the use of personal electrical water boilers, with apartment specific natural gas boilers. In addition, legal challenges with the legal signatory of the electricity contract and the apartment / house dweller were identified.

All these challenges, required partial redesign of the Greek pilot to first, address legal challenges so that more end-users are recruited for the pilot, and second, to increase the flexibility pool. The first issue was addressed by a thorough redesign of the consent process for HERON's platform and of the specific iFLEX forms. The second issue was addressed by extending HERON's platform to include additional IoT devices such as smart plugs.

In terms of other technical developments, the technical feasibility of the relay solution was validated in a lab environment prior to home installations, and tests with remote control of the boiler were conducted.

Overall, the initial planning for Phase 2 was to install smart meters in 15 households creating a use base of 30 users. However, continuous recruitment efforts, in conjunction with iFLEX specific user engagement activities (such as surveying users of iFLEX Assistant from ICOM) have been successful in recruiting 30 household and around 65 users, with 2 fully operational relays installed.

3.2 Slovenian small-scale pilot deployment

The Slovenian pilot project aimed to establish a pilot area comprising at least ten residential and small business users, equipped with HEMS devices to collect measurement data and enable remote control of user devices. The project successfully achieved this target, and it was instrumental in advancing their understanding of energy management systems in real-world settings.

During the first phase of the pilot project, the team focused on selecting suitable pilot endpoints and conducting a thorough needs assessment for the pilot area. They identified a range of potential pilot endpoints, taking into consideration factors such as building type, energy usage, and geographical location. They also conducted extensive user surveys to gain insights into user preferences, habits, and behaviors regarding energy consumption and management.

Based on assessment of their needsand user surveys, the team equipped the selected pilot points with HEMS devices to collect measurement data and enable remote control of user devices. The devices were carefully selected to ensure compatibility and reliability, and they provided extensive training and support to users to ensure they were comfortable with using the devices.

During the second pilot phase, the team focused on developing and implementing an MQTT communication bridge, enabling two-way communication with individual endpoints and secure transmission of measurement and control signals to and from end-user devices. They also integrated RAI, Enrollment, and Digital Twin modules to provide advanced functionality and analytics capabilities. These modules allowed to monitor and analyze energy usage patterns in real-time, identify areas for improvement, and provide customized recommendations based on user specific energy consumption patterns.

Furthermore, they deployed a Trust, Security, and Privacy interface to ensure the confidentiality and integrity of user data. This interface provided users with full control over their data and ensured that sensitive information was protected from unauthorized access or tampering.

Overall, the Slovenian pilot project was on the right track, and the team learned a lot about the challenges and opportunities of deploying energy management systems in real-world settings. They're confident that the insights they gained from this project will inform future efforts to develop sustainable and efficient energy systems for the benefit of society as a whole.

3.2.1 HEMS installations and interfaces

In the second pilot phase of the project, the Slovenian partners focused on equipping household, small, and large business customers with flexible energy solutions. The pilot activities for household users were continued by identifying devices that can provide the greatest impact in ensuring flexibility, particularly heating systems and systems for the production of electricity. The Slovenian partners also provided support for connecting new devices, and successfully integrated a heat pump from local manufacturer Kronoterm (Figure 1), as well as distribution meters from Iskraemeco and Landis+Gyr, by transferring data via wired and wireless connection (Figure 2).

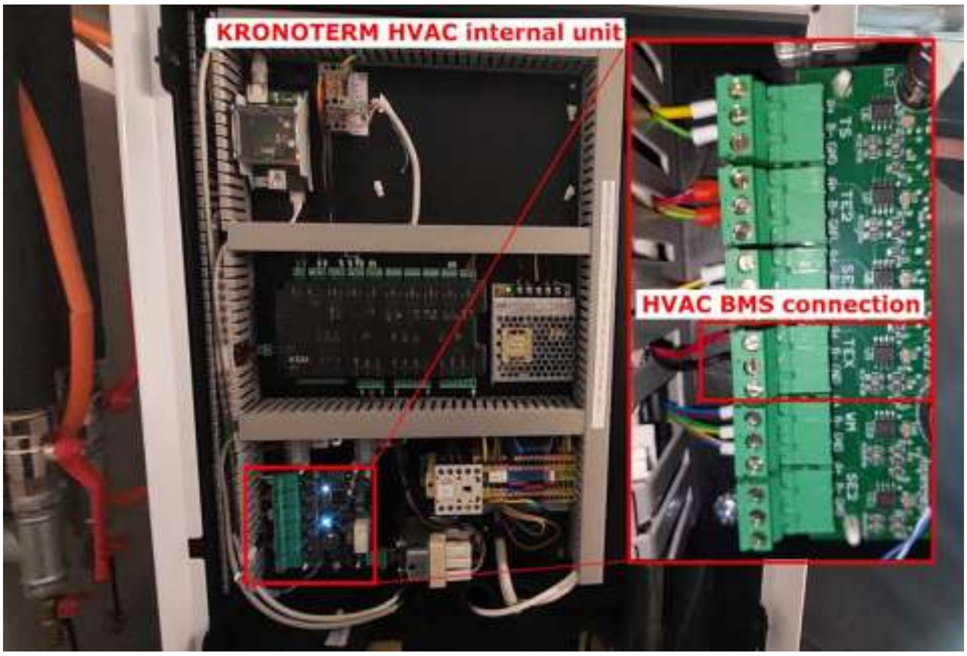

Figure 1: Kronoterm HVAC BMS/HEMS connection point

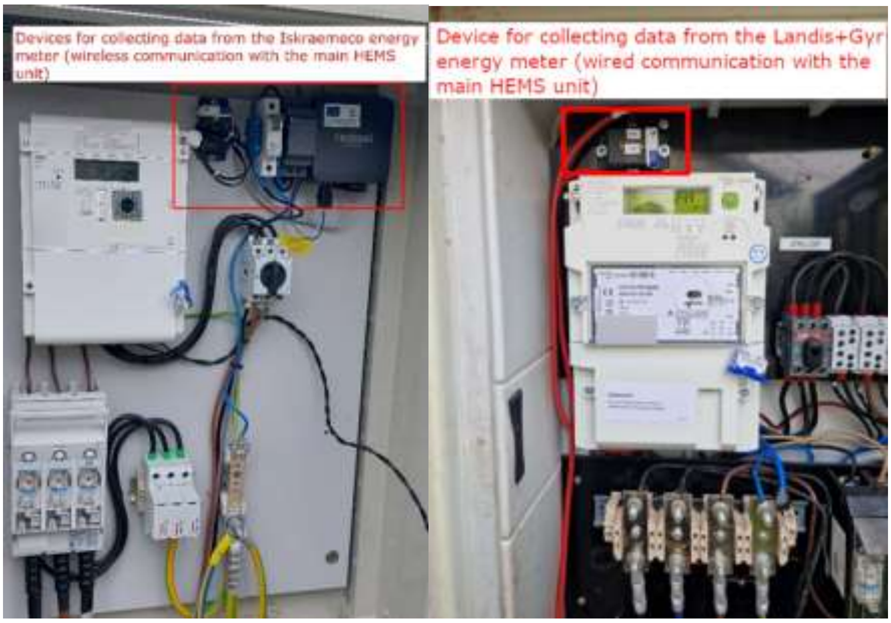

Figure 2: Iskraemeco and Landis+Gyr connection to P1/I1 user interface

To further enhance the HEMS system for the iFLEX project, the Slovenian partners added support for iFLEX MQTT with secure socket layer (SSL) (Figure 3) over wired or wireless Ethernet connection to local network or over UMTS/GSM telecommunication data transport. By introducing a wider range of communication channels with the internet, it is possible to cover a wider range of iFLEX users who will be equipped in the third pilot phase.

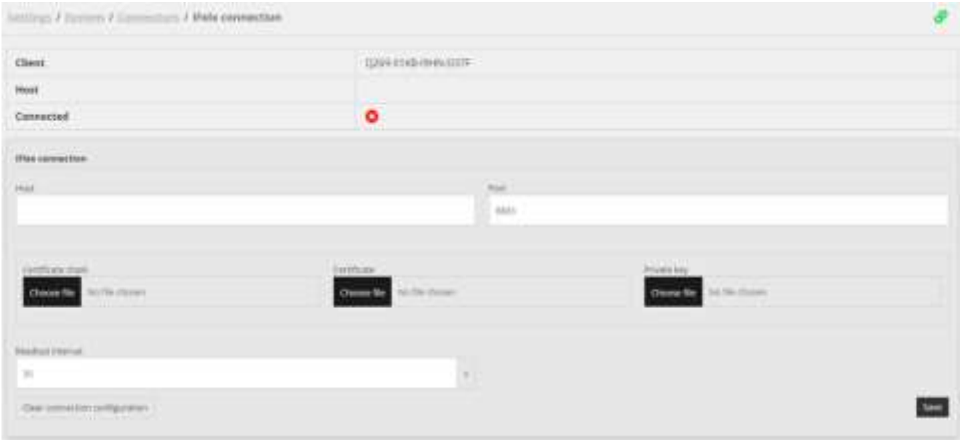

Figure 3: iFLEX MQTT SSL GUI remote configuration

As part of the Slovenian pilot project, test equipment was purchased which is an EV charging station manufactured by Etrel (model Inch Pro) and installed for an end user who had an electric vehicle. The iFLEX project's equipment (HEMS with external gateways) was integrated into the user's existing devices: a solar power plant, HVAC, a connection to a distribution meter, and a connection to an electric charging station.

To control these devices, communication protocols were implemented and tested, including a heat pump, solar power plant, and distribution meter. Equipment for controlling and collecting measurement data from the EV charging station was planned for integration in the third pilot phase.

The flow diagram was created based on the integrated equipment at the end user's location. It was shown in Figure 4 to help understand the process better.

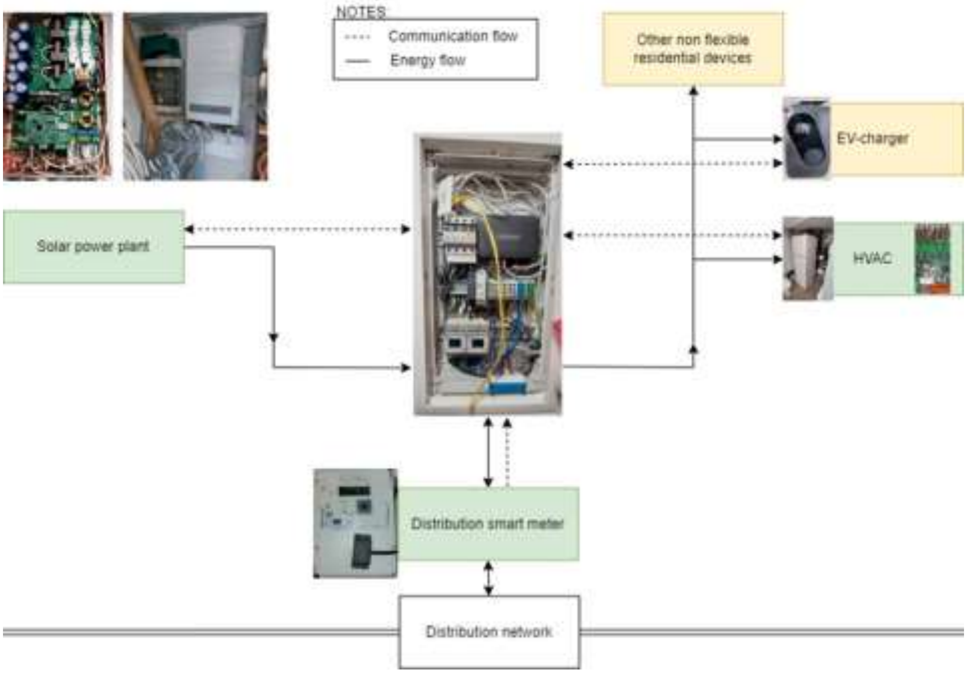

Figure 4: Flow chart on the existing end user

During the implementation of new devices in the second pilot phase, the Slovenian partners tested and successfully implemented measurement and control signals for control and measurement from the heat pump, solar power plant, and other measuring equipment for measuring the consumption and production of electricity.

As part of the iFLEX project, a preliminary application was developed for end users to monitor the energy performance of devices assigned to management. The application enabled users to view data in graphic and numerical form, either for all devices or for each device separately.

An example of the application display (Figure 5) was provided for a user who used a Kronoterm Adapt heat pump to heat their apartment and sanitary water (Figure 6), a SolarEdge PV power plant to produce electricity (Figure 7), an Etrel EV charger with a nominal power of 22 kW (Figure 8), and an Iskraemeco AM550 smart distribution meter for measuring electrical energy (Figure 9).

With the application, the user could monitor the performance of each of these devices on a single dashboard. The dashboard provided clear and comprehensive information on the energy usage of each device, allowing the user to make informed decisions and optimize their energy consumption.

Figure 5: Graphical display of total building consumption and individual device consumption

Figure 6: Numerical data display from the Kronoterm Adapt HVAC

Figure 7: Numerical data display from the SolarEdge solar power plant inverter

Figure 8: Numerical data display from Etrel charging station

Figure 9: Numerical display of the total building consumption from the Iskraemeco AM550 distribution meter

During the second pilot phase, the host of the Slovenian pilot project (ECE d.o.o.) provided incentives to end-users in the form of a monthly reduction in their electricity costs. Every active end-user was rewarded with a reduction in their monthly electricity bill, up to a maximum value of 3 € (including VAT). A real example of a monthly payment is shown in the Figure 10 below, where the user received a reduction of 3 € on their electricity bill.

Figure 10: The iFLEX bonus and the invoice stub received by every active user in the iFLEX project

3.2.2 Project services in Slovenian pilot

A number of pilot services has been implemented and deployed in the Slovenian pilot. The services and interfaces have been specified in the deliverable D2.4 – Revised architecture of iFLEX Framework [1], deliverable D4.2 – Revised Resource Abstraction Interface [2] and D4.8 – Secure data management module [3]. The following services have been deployed: the RAI module, Trust, security and privacy module, end user Enrolment module, Weather module, Tariffs module and Digital Twin module. All the services have been deployed in a cloud environment operating at JSI premises. The services are implemented in the Python programming language, the deployment operating system is Linux, Ubuntu 22.04, using LXC Linux virtualisation. The services will be shortly discussed in the next sections.

3.2.2.1 RAI module

The RAI module enables on the Southbound (SB) interface data collection from the HEMS installations as were described in Section 3.2.1. The MQTT protocol is used to collect the data from the HEMSes: measurements, devices' configurations and devices' state. An example of the measurements available at the Northbound (NB) RAI module interface is presented in Figure 11. In the figure import and export active power is presented. It can be seen that the most consumption happens during the day (green, blue and orange lines) and generation during the day (red, violet and brown line).

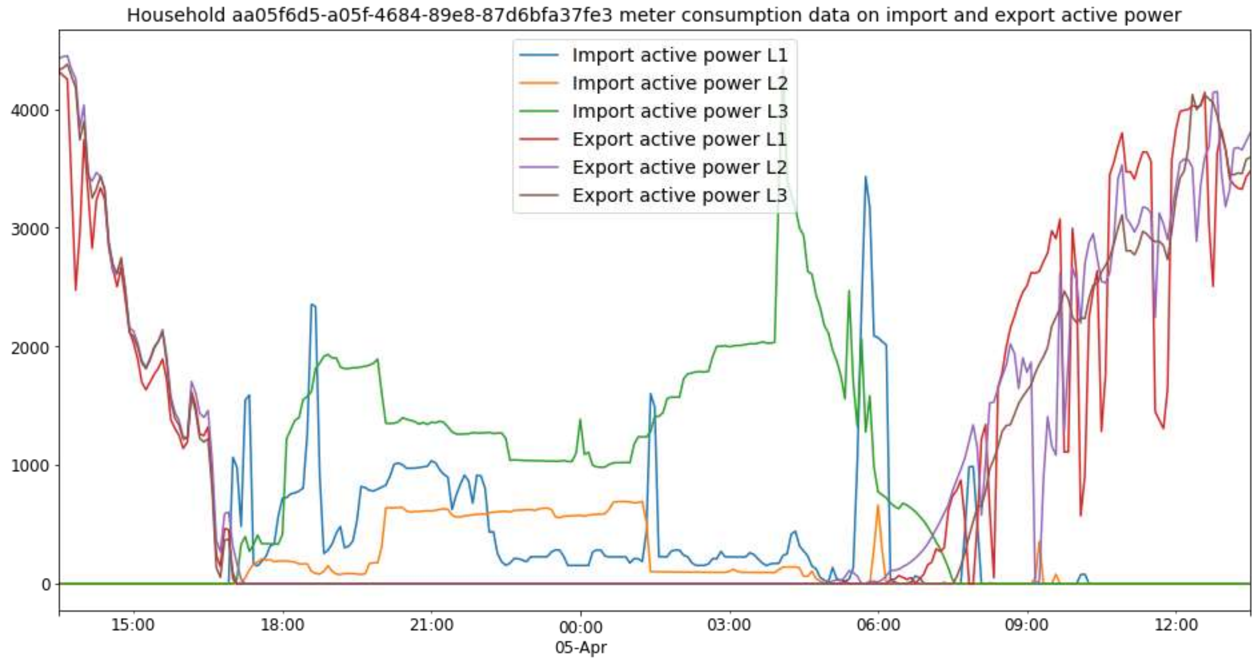

Figure 11: Typical smart meter household measurements

The devices' configuration at the NB interface provides all needed data for the rest of the iFLEX Framework modules and guides the RAI interfaces and capabilities. An example of a household devices' configuration is presented in Figure 12. Only a part of the configuration is shown: the SolarEdge solar power plant and HVAC, the smart meter (device 2) and boiler (device 3) are omitted. Every device configuration has sensors and can have a control section. Two control sections are presented, the solar power plant has the power limiter exported and the HVAC has exported a number of temperature set-points.

3.2.2.2 Enrolment module

The Enrolment module implementation and deployment has been simplified from initial plan as was described in the D4.8 [3]. To be accessible to as broad set of end users the consent has been collected manually and the digital registration replaced by simple procedure controlled through an Excel file shared between the partners controlling the pilot deployment (ECE and JSI). At the file updates the RAI and Trust, security and privacy interfaces have been used to create new user accounts and accounts' related credentials. The credentials are then installed in the end user HEMS device as is presented in Figure 3 by the pilot host. The same Excel file interface has been used to boost the Digital Twin data structures as is presented in Section 3.2.2.4.

3.2.2.3 Trust, security and privacy interfaces

The Trust module is implemented as a X.509 Certification Authority. The module is deployed in the JSI cloud and is instantiated when needed only for security reasons. When the file controlling the enrolment is updated and new users are added the Trust module is used to issue new certificates for the end user HEMSes. The security and privacy interfaces are deployed alongside the RAI module as is described in Section 3.2.2.1. The RAI module provides an authorization engine as well that is used by eternal protocols, like MQTT, or other project components to assess if one entity has access to the RAI resource or not.

```
{
  "elements" : [
    0 : {
      "device_id" : 144
      "device_name" : "SolarEdge"
      "device_category" : "SOLAR_POWER_PLANT"
      "device_type" : "SOLAR_SOLAREDGE"
      "control" : [
        0 : {
          "control_type" : "setValue"
          "actuator_id" : 266
          "control_name" :
          "Export power limit in Watt (negative value)"
        }
      ]
      "sensors" : [...]
    }
    1 : {...}
    2 : {...}
    3 : {
      "device_id" : 156
      "device_name" :
      "EMS Bus - Thermostat - RC300/RC310/Moduline 3000/1010H/CW400
      /Sense II/HP"
      "device_category" : "HVAC"
      "device_type" : "EMS_THERMOSTAT"
      "control" : [
        0 : {
          "control_type" : "setValue"
          "actuator_id" : 728
          "control_name" : "Defines HC_1 temperature"
        }
        1 : {
          "control_type" : "setValue"
          "actuator_id" : 732
          "control_name" : "Defines HC_2 temperature"
        }
        2 : {
          "control_type" : "setValue"
          "actuator_id" : 736
          "control_name" : "Defines HC_3 temperature"
        }
        3 : {
          "control_type" : "setValue"
          "actuator_id" : 740
          "control_name" : "Defines HC_4 temperature"
        }
        4 : {
          "control_type" : "setValue"
          "actuator_id" : 744
          "control_name" : "Defines HC_5 temperature"
        }
        5 : {
          "control_type" : "setValue"
          "actuator_id" : 748
          "control_name" : "Defines HC_6 temperature"
        }
      ]
      "sensors" : [...]
    }
  ]
  "hems_id" : "7458-FCV1-0FIK-K0AD"
  "ts" : "2023-04-06T17:55:18.267000"
}
```


Figure 12: Example households devices configuration

3.2.2.4 Digital Twin

The Digital Twin module provides interfaces for accessing the household predicted data. The twin basic input data is shown in Figure 13. It contains the household data with basic parameters, the building data providing information for the household heat demand model, the geolocation (intentionally covered) and PV data used to estimate the household generation, the heat pump data used to model the heat pump and the heat storage data used to model the heat storage. The building data is sufficient to build the heat demand model according to ISO 13790 standard [4].

Household data:

	Parameters
id	ecf42183-8f43-45
bt	2023-04-04T13:2
connection_type	3.0
current_limit	25.0
hems_id	7458-FCV1-0FIK-I
household_type	None
p_id	ece-1
power_limit	17.0
tariff_type	None

Building data:

	Parameter
id	ecf42183-8
air_ventilation	0.35
bt	2023-04-04
floor_area	213.2
floor_height	2.4
temperature_set_point	22.0
thermal_capacitance_pe	165000.0
u_walls	2.0
u_windows	1.2
ventilation_efficiency	0.0

Geolocation

	Parameters
latitude	
longitude	

PV data:

	Parameters
pv_orientation	JZ
pv_power	15.58
pv_power_limit	13.6
pv_tilt	30.0

Heat pump data:

	Parameters
model	Bosch Compr
inlet temperature	38.0
cop diff temperature	6.0
Pmax	3600.0

Heat storage data:

	Parameters
model	Bosch AT400/3bar
capacity	406.0
loss	2200.0
Tmax	95.0
Tmin	

Figure 13: Example household digital twin configuration

An example of a heat demand model with a heat storage activation is shown in Figure 14. The heat demand is calculated according to the heat pump model, data about the pump COP, solar and internal household gains and outside temperature forecast. We can see that the heat demand is high during the night when the temperatures are the lowest. An example how the storage boiler can be used to store the energy and release it later is shown in Figure 15. The storage boiler starts filling the energy storage at 14:00. The storage inlet temperature is set to 50 °C. the energy is released at 18:00. The price is paid for the action in a form of lower COP at higher temperatures and the energy needed to fill the boiler.

A flexibility estimation for a static heat demand model is presented in Figure 16. The estimated flexibility is calculated according to the set-point temperature of 22 °C. The positive flexibility is expected if the set-point temperature is lowered (example shown for temperature of 21, 20 and 19 °C) and negative if the set-point temperature is raised (example shown for 23 °C).

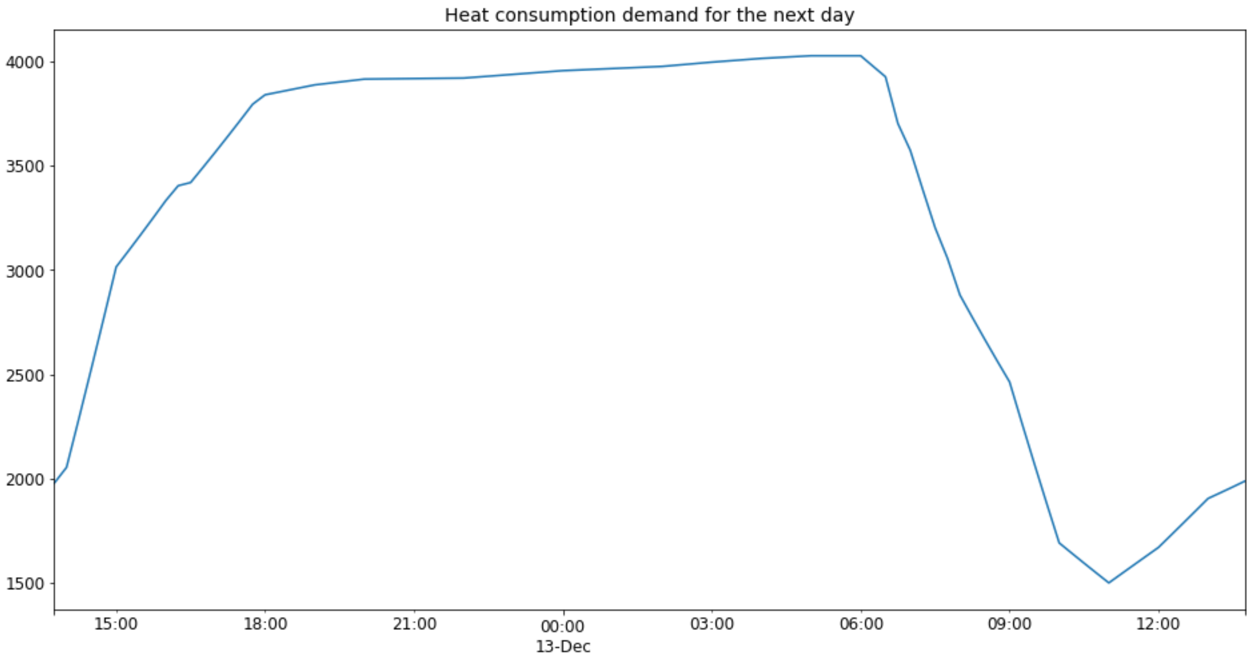

Figure 14: Example household heat demand

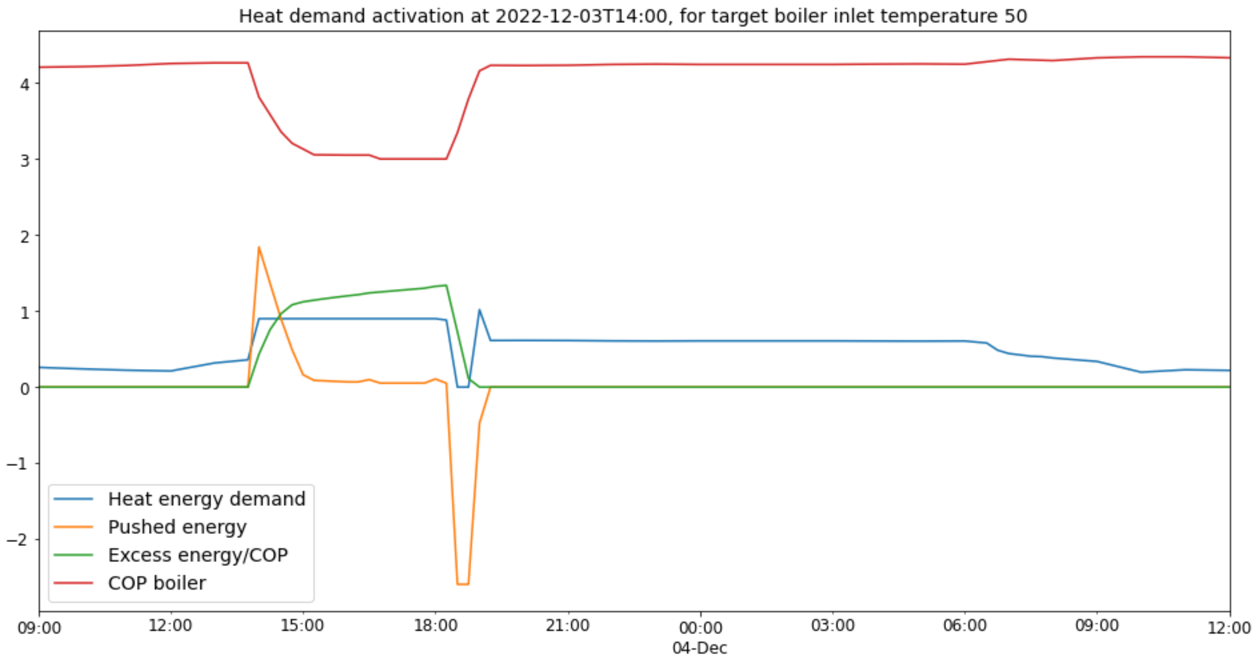

Figure 15: Heat demand and storage boiler

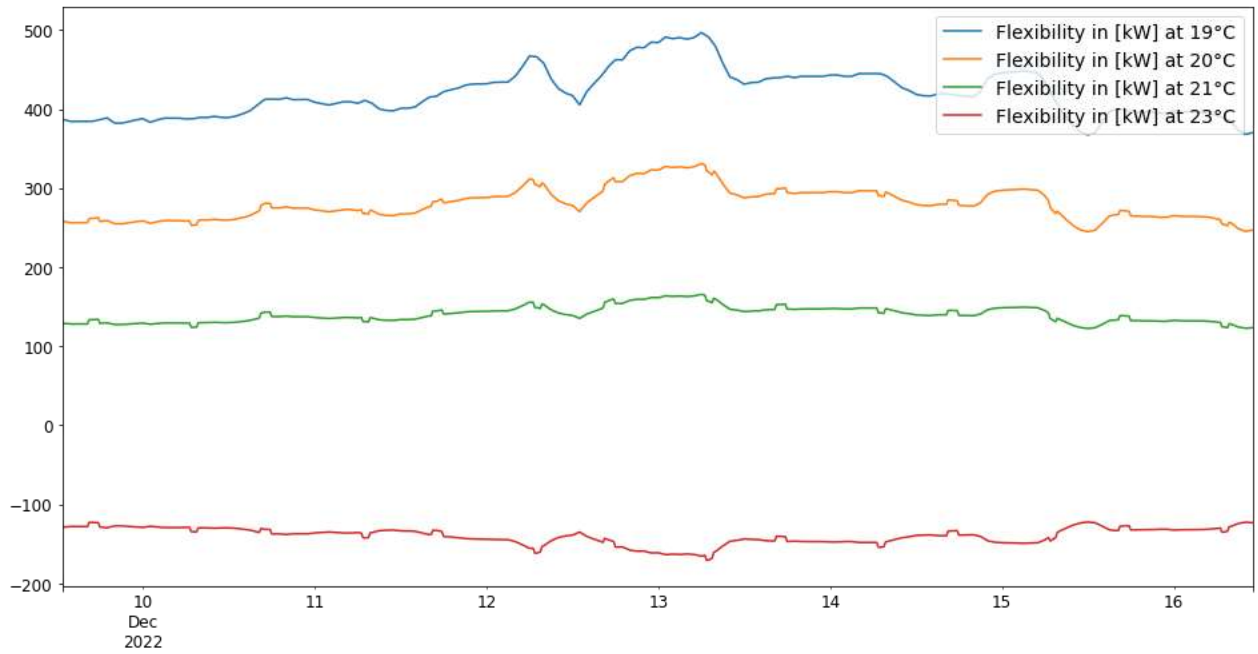

Figure 16: Available flexibility due to different set-point temperatures

3.2.2.5 Weather data interface

In the Slovenian pilot the weather data interface is based on Open Weather Map[1] (OWM) data. The data is collected by a service implemented as a Linux system[2] service in Python and stored in the same database as the RAI data described in Section 3.2.2.1. The service collects the data continuously for a number of locations in close proximity of pilot users' location. In this way the limits imposed for free OWM interface access are respected and the service can provide the historical data for the locations as well. The service provides 48 hours forecast at one hour granularity. The available weather variables list is provided in Table 1. An example forecast for the next 48 hours for the temperature and "feels like" temperature is presented in Figure 17.

Table 1: OMW weather variables

	Variables
0	feels_like
1	pressure
2	humidity
3	dew_point
4	uvi
5	clouds
6	wind_speed
7	wind_deg
8	wind_gust
9	temperature

[1] See the Open Weather Map home page for details: https://openweathermap.org/
[2] See Wikipedia page on systemd service and components: https://en.wikipedia.org/wiki/Systemd

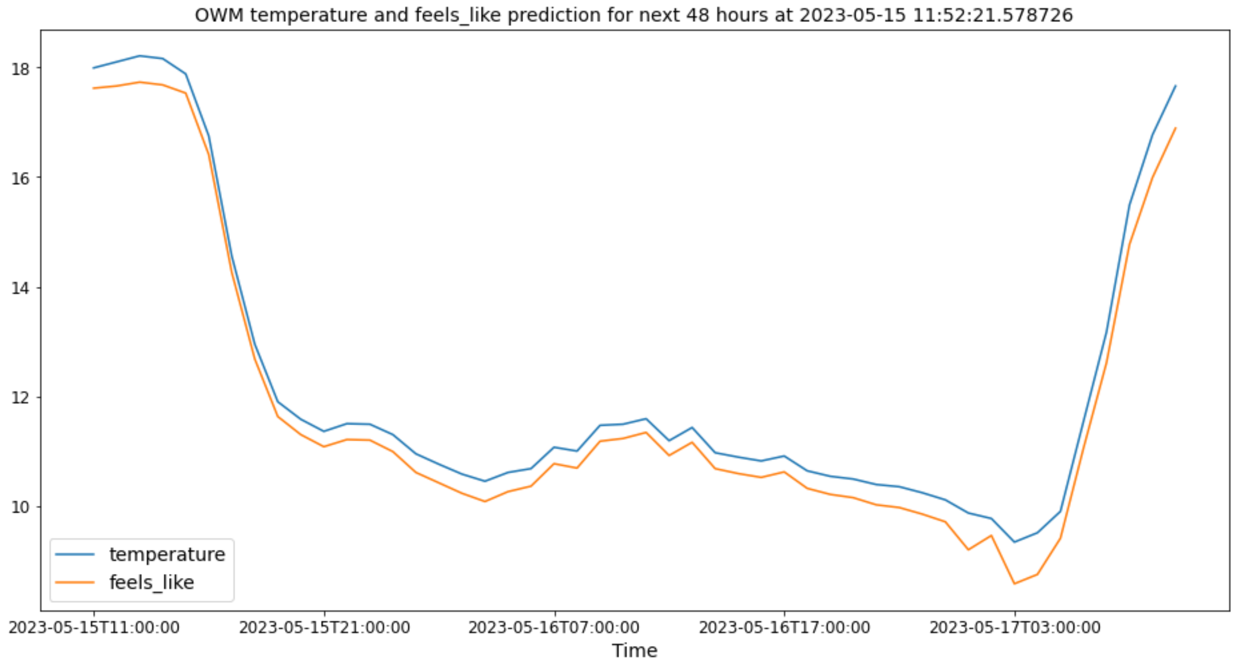

Figure 17: OMW weather forecast for temperature and feels like temperature for next 48 hours

3.2.2.6 Tariff interface

The tariff interface provides current tariffs for the household in Slovenia and Celje region. Current tariffs and the interfaces outputs were specified in the deliverable D4.5 – Revised Market and Aggregation interface [5]. The tariffs interface is implemented within the scope of the RAI module as is described in Section 3.2.2.1. The module is deployed together with the RAI module within the JSI cloud infrastructure.

3.3 Finnish small-scale pilot deployment

The iFLEX Assistant was implemented in a Finnish apartment building as part of a pilot to showcase its capability in managing flexibility for the entire building community. The iFLEX Assistant is tasked with predicting the building's baseline energy consumption and flexibility for both electricity and district heating (DH). The apartment building's flexibility is derived from its heating system and thermal mass, which can be utilized to shift the consumption of DH and electricity (via a heat pump).

Figure 18 illustrates the Finnish pilot building, which is owned by HOAS and offers rental flats to students. The building comprises of 93 apartments and accommodates over 140 residents. Each resident has access to a User Interface, which provides them with visual representations of the building's energy consumption, CO2 emissions, and thermal comfort measurements (registration is required). Additionally, residents can also provide feedback regarding their thermal comfort. During the first phase, four residents participated in the pilot, and sensors measuring temperature, humidity, and CO2 levels were installed in their apartments. In second phase, five more residents were given sensors to their apartment to get more accurate measurements from their apartments.

Figure 18: 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, specifically in relation to HLUC-3 (which is described in detail in D2.1 [6]). In second phase of the piloting, the pilot aimed to verify and validate the technical functionalities that enable explicit demand response (DR) at the apartment building level that were partially demonstrated already in the first phase of the piloting, while simultaneously optimizing for minimal CO2 emissions, energy usage, and energy costs.

During the first phase of the piloting process, the flexibility of the apartment building was attained through limiting the heating level. Subsequently, in the second phase, the level of control was expanded to include the exhaust air heat pump in addition to cutting the heating level in the heating system as it was described in D7.2 [7] Finnish pilot phase 2 scope. The following list of objectives were planned for the phase 2 in deliverable 7.2:

1. Utilizing iFLEX assistant to optimize energy efficiency of the apartment building.
2. To systemically evaluate and compare time periods with and without iFLEX assistant reducing district heating demand peaks in order to analyze potential savings generated by iFLEX Assistant
3. To utilize fully ML-based solution to forecast buildings' electricity and district heating and compare it with hybrid (ML and physics based) solution developed in phase 1
4. To define a means for concretizing the benefits of the demand response actions in apartment buildings
5. To demonstrate the updated user interface for the residents of the apartment building to visualize benefits of the demand response and energy optimization
6. To integrate pilot site in to ENERIM's Virtual Power Plant platform to enable aggregation and market integration in the phase 3.

Optimization is done using iFlex assistant, which tries to find ways to reduce energy consumption, heating costs, and CO2 emissions in a pilot building (**objective 1**). Method of the optimization is to control space heating to minimise the heating need. iFlex assistant calculates the amount of hours heating can be reduced without significant drop in the indoor temperature. Additionally, iFlex assistant tries to maximize the use of the cheaper and/or greener energy source. In the pilot building, heat pump is typically prioritised in both cases. Figure 19 shows how iFlex assistant has reduced the heating level for six hours and how it has affected the indoor temperature. We have tested iFlex assistant optimization mode during the period of 1.12.2022 – 20.3.2023, where space heating has been reduced for several hours (2-12h) every other day or every third day.

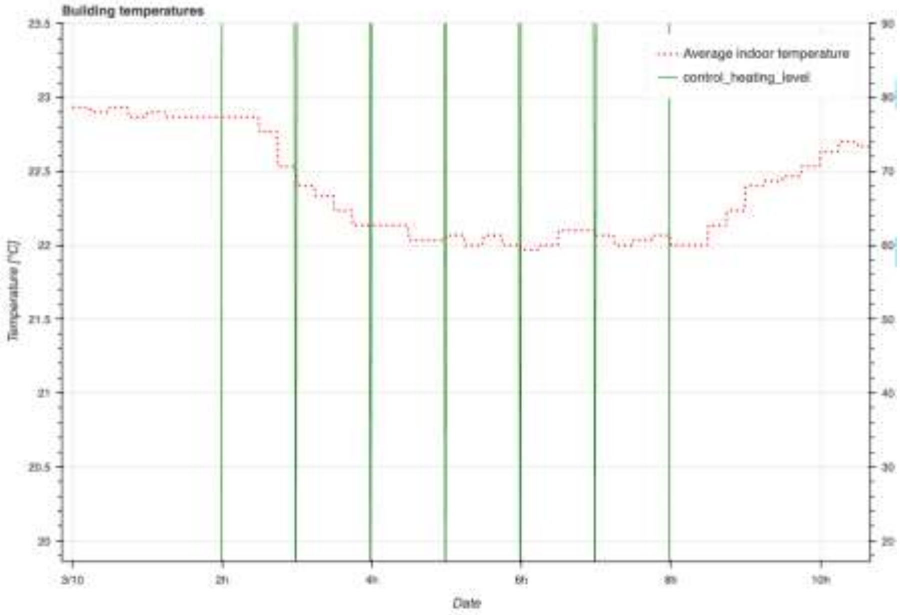

Figure 19: Indoor temperature during the optimization

Then, the days with and without optimization have been compared (**objective 2**) and finally presented to the end-user through the end user interface. Following are the initial savings generated by the optimization:

- Energy consumption: 8.91%
- CO2 emissions: 10.72%
- Costs: 9.42%

Figure 20 presents the average total energy consumption (district heating and electricity combined), where the left bar shows the average for the optimization days and right bar shows the average for the reference days. Mean outdoor temperature during normal operation -1.44 and in optimized operation -1.22 Celsius. Mean indoor temperature during normal operation 21.53, in optimized operation 21.33. Drop in the average indoor temperature explains part of the savings in the optimization. However, because of the large thermal mass it is possible that part of the savings are not actual savings, but instead caused by the long thermal payback delays happening during the reference periods. I.e., it is in theory possible that the optimization days cause the temperature of the building envelope to drop (without visible impact to the indoor temperature measurements), which is then paid pack during the reference days. The idea is to investigate this phenomenon in more detail during the phase 3 piloting.

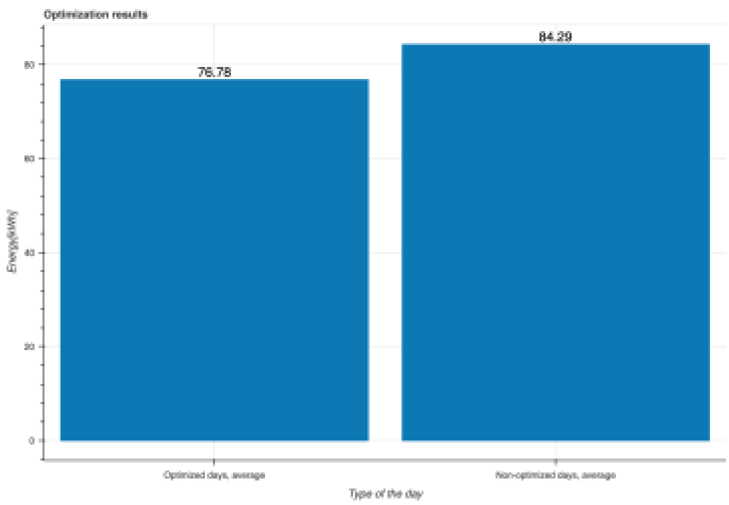

Figure 20: Average energy consumption in optimization days and references days

We have thoroughly evaluated iFlex assistant using state-of-the-art modeling techniques, including pure neural network-based models and hybrid methods developed during the initial piloting phase (**objective 3**). During the optimization period in phase two, we were able to gather large amount of data from various scenarios, including corner cases such as periods when we limit the building heating level. As a result, fully machine learning-based solutions have achieved comparable accuracy to the hybrid solutions from the first phase, while significantly reducing the need for manual fine-tuning and engineering knowledge.

Objectives 4 and 5 are were mainly related to end-user interfaces for the Finnish pilot. In the second phase piloting, we established a method for quantifying the advantages of implicit demand response measures in apartment buildings and showcased the revised user interface for residents of the apartment building, enabling them to visualize the benefits of demand response and energy optimization. In the left side of the Figure 21 savings for the last 30 days are shown to the end-user. This view shows the change in the energy cost, energy usage and CO2 emissions. Second view in the middle shows the days when the optimization has been done, marked with green color, and reference days without optimization are marked with black color. Right view shows a more detailed comparison of the optimization days and days without optimization. It shows e.g. district heating and electricity consumption, costs and emissions for the last 30 days.

Figure 21: Screenshots from End-user interface for the Finnish pilot

Finnish pilot has been tested with Enerim Virtual Power Plant platform in the second phase of the piloting (**objective 6**). Test was carried out on 24.3.2023 together with Enerim and other ONENET-project partners, where Finnish pilot provided about 10kW of flexibility that could be traded in the flexibility market using Enerim platform. In addition to HOAS building, two virtual buildings were set up in order to provide flexibility. First virtual building provided 0.5MW of flexibility and the second one provided 1.0MW. Figure 22 shows activated flexibility in the Finnish pilot (HOAS building) during the test. iFlex assistant forecasts baseline load (grey color), down flexibility (light green) and allocated down flexibility. During the test, heat pump was turned off and heating level was reduced. Electricity part of the figure (top) shows about 10 kW flexibility activation at 14:00PM UTC.

Figure 22: Flexibility activation during Enerim VPP integration testing

In order to validate the results, we measured the effect of the flexibility activation for district heating power and electricity power during the test. Figure 23 shows the measured district heating power and electricity power during the test. Enerim VPP and iFlex pilot integration test was successful and there is a clear drop in electricity power level and therefore we were able to trade real flexibility in the test. However, forecasting error during the test was bigger than expected (Figure 24, Figure 23). This was due to a defect in model training data pre-processing procedure. After fixing the bug, we repeated the same flexibility activation procedure on the same time of the day and got clearly better results, where forecasts are close to actual measurements (Figure 25).

```
control_heating_level
control_heat_pump
```

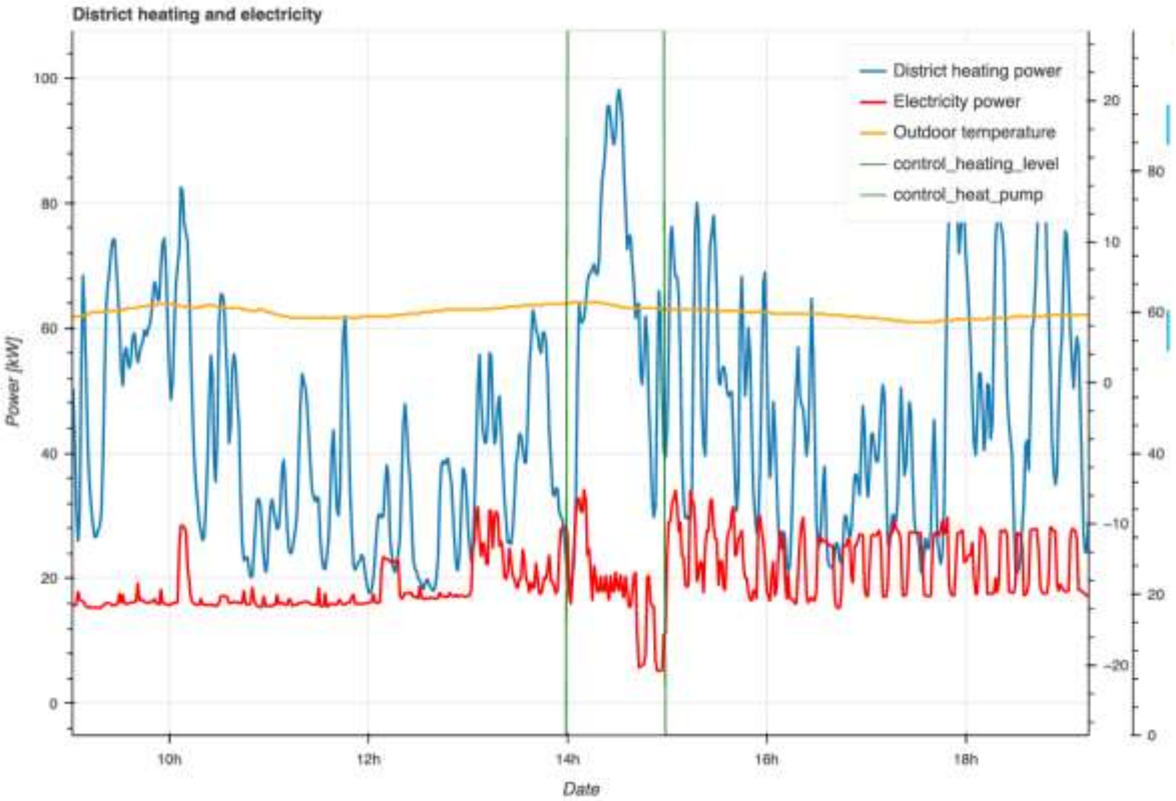

Figure 23: District heating and electricity measurements during the test

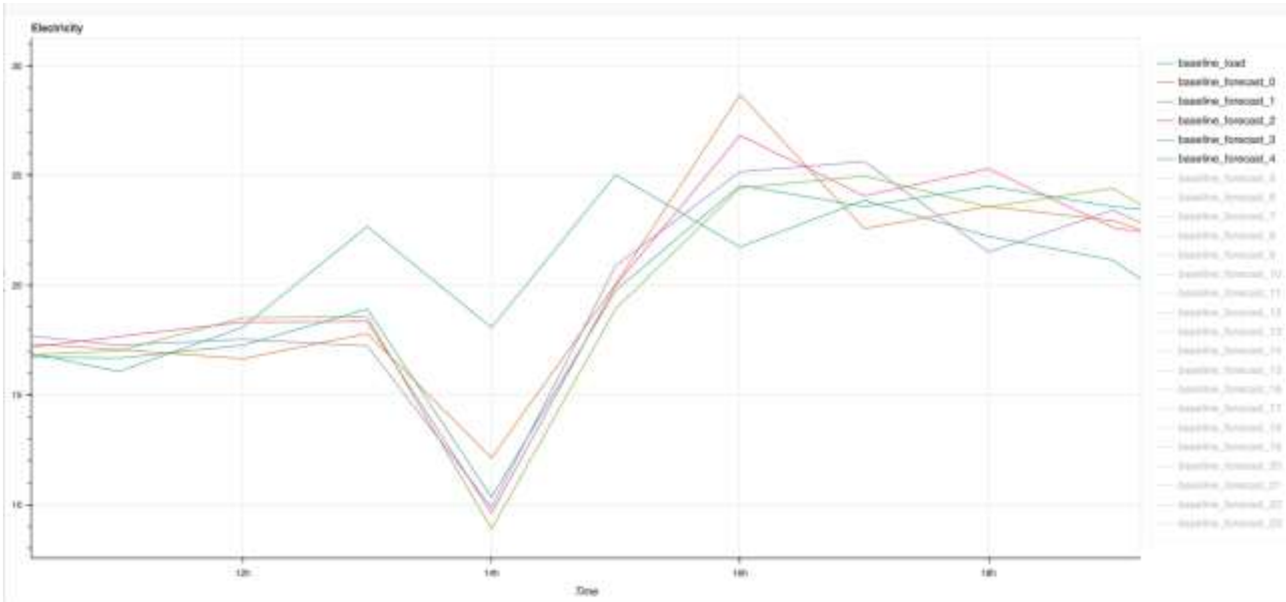

Figure 24: Forecasted electricity during the test vs measured load in original test

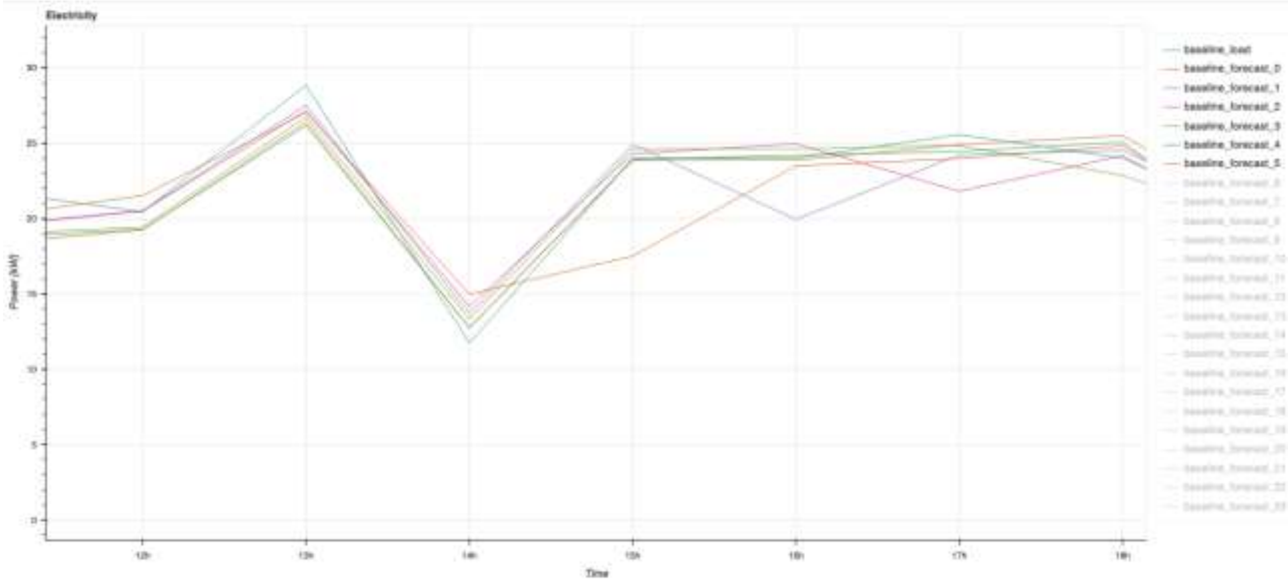

Figure 25: Forecasted electricity vs measured load, fixed version

4 Validation plan for phase 2

4.1 End user validation plan

The end-user validation plan has the same focus for both phase 1 and phase 2 pilots as the overall objective is to gather relevant feedback from end-users which can be used for improving and refining the end-user experience of the iFLEX Assistant. The two validation items for end-user validation in phase 1 and 2 are thus:

- Usability focusing on prototype user interface (UI) of the iFLEX Assistant App (efficiency and effectiveness)
  - Actual testing of the UI with end-users is done as part of technical validation activities
- User acceptance of the iFLEX concept, focusing on acceptance of the use cases as well as the main functionalities and user interface (of the iFLEX Assistant) and incentives/motivational drivers for participating in DR (using the iFLEX Assistance).

While these two objectives are identical, the object (i.e. the iFLEX Assistant) for has been further developed based on both the overall 2nd iteration of the development and requirements engineering work as well as based on the results from phase 1 validation.

Specifically, the following phase 2 end-user validation activities were carried out:

- User acceptance workshop with Greek end-users (not participating in the pilot) focusing on evaluating the features and functionalities of the iFLEX Assistant as well as on incentives and motivational drivers.
- Co-creation workshop with Slovenian end-users (both pilot and non-pilot participants) focusing on user acceptance, i.e., regarding the concept of iFLEX (business use cases), iFLEX Assistant UI and functionalities, and incentives.
- Questionnaire for Slovenian end-users regarding equipment installation.
- Questionnaire for Finnish end-users (both pilot and non-pilot participants) focusing on user acceptance of the iFLEX concept, incentives for participating in DR, and evaluation of thermal comfort (DR effect on thermal comfort).

4.2 Technical validation plan

The technical validation plan has been originally documented in D7.4 [8]. According to this document, it has three basic focus areas/activities:

- Requirements validation (analyse use cases and requirements).
- Internal verification activities.
- Pilot validation of iFLEX Framework and the application-specific iFLEX Assistants (iFA).

The actions on the above activities during Phase 1 were documented in D7.5 [9]. In the following sub-sections, the respective actions in Phase 2 are presented, as well as a high-level planning for Phase 3, on the basis of D7.4 [8]. The outcomes of these actions up to the end of Phase 2 are presented in Chapter 6.

4.2.1 Requirements validation

The JIRA tool has been adopted by the iFLEX consortium, so that the requirements management process could be facilitated. This tool allows to model and monitor the full lifecycle of requirements, from their definition up to their resolution (see D7.4 [8] for more details), as well as to edit and comment on the specifications of requirements. Furthermore, different groups of requirements, categorized by component and pilot, were modelled in JIRA, in order to streamline requirements monitoring.

Based on discussions amongst project partners, and feedback received by users through workshops and usability tests for the iFLEX application, new requirements have been identified and documented, while pre-existing requirements were updated if needed. In case a requirement was perceived as irrelevant to the iFLEX pilots' UCs, it was ultimately closed.

As regards Phase 3, final decisions should be made by the consortium on the requirements which are still open. Namely, they should either be implemented if they are categorized as relevant to at least one iFLEX pilot, or be closed if they are irrelevant to the project. Moreover, the under-development requirements should be monitored until their lifecycle is completed with their validation at the involved pilot(s).

4.2.2 Internal verification activities

The internal verification activities in Phase 2 varied per pilot, depending on their maturity. In all pilots, unit tests have been conducted to validate various fine-grained iFLEX components' requirements. Furthermore, certain integration tests have taken place, so that interoperability between components could be verified. Especially in the case of the Finnish pilot, the integration tests concerned all the pilot's components, and end-to-end system tests were carried out as well. Although the above tests have been successful, more internal verification activities should be executed in the next phase.

More specifically, additional integration tests should be conducted in the Slovenian and Greek pilots in Phase 3. Furthermore, the integration and system tests in all pilots should concern all the UCs that will be investigated in each one of them.

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

By the end of Phase 2, the instance of the iFA in the Finnish pilot has been validated regarding its functionality and security.

In Phase 3, all the pilot-specific instances of the iFA should be validated, as described in D7.4 [8], from four perspectives:

- Functionality.
- Security.
- Performance.
- Acceptance.

Moreover, this validation should consider all the examined UCs per pilot, as stated also for the internal verification activities.

4.3 Business validation plan

We follow a 3-step approach to evaluating the business potential of the iFLEX Assistant, which is shown in the Figure 26.

Figure 26: The overall approach for defining and assessing business models

The first step involves the definition of baseline smart-grid business models. This is done by identifying archetype business models (i.e., business roles) using the "Value Network" methodology [10] and describing them through the Business Model Canvas methodology [11].

The second step moves from archetype business models to iFLEX-enabled business models that can realise the Business Use-Cases (BUC) of interest to iFLEX consortium, as defined in D2.1 [6]. 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. For this reason, we develop custom value networks for each Business Use-Case (e.g., by excluding the inactive roles and their interactions) and finetune these by using the "e[3]value" modelling method for iteration and simulation.

The third step aims to assess the viability and attractiveness of the iFLEX Business Use-Cases and associated business models compared to existing ones i.e., Business as Usual (BaU). Note that several options/instances may need to be explored in order to overcome any market bottlenecks. Figure 27 provides an overview of the approach followed in D5.5 [12], where we focused on one BUC per iFLEX pilot (thus three in total).

- For BUC-1 (Optimise BRP operation by leveraging flexibility from consumer/prosumer through DR) we investigated three main options for the business model of a Greek energy retailer to optimise the activities of its Balance Responsible Party (BRP) department and performed a techno-economic analysis for each of the 8 scenarios[3] that could appear.

- Similarly, for BUC-3, i.e., “Offer the flexibility of a multi-vector energy system (building community) to the energy markets”, we examined 2 alternative setups for the Aggregator’s customer base in each of the 4 scenarios regarding the high/low level of wholesale market prices, and the reduced/max quantity of flexibility that is eventually activated.
- Finally, for BUC-7 (i.e., Optimise end-user’s energy consumption based on own preferences and market price signals) we examined 4 customer profiles[4] in Slovenia and for each one of them we analysed 4 scenarios based on their responsiveness to the market conditions.

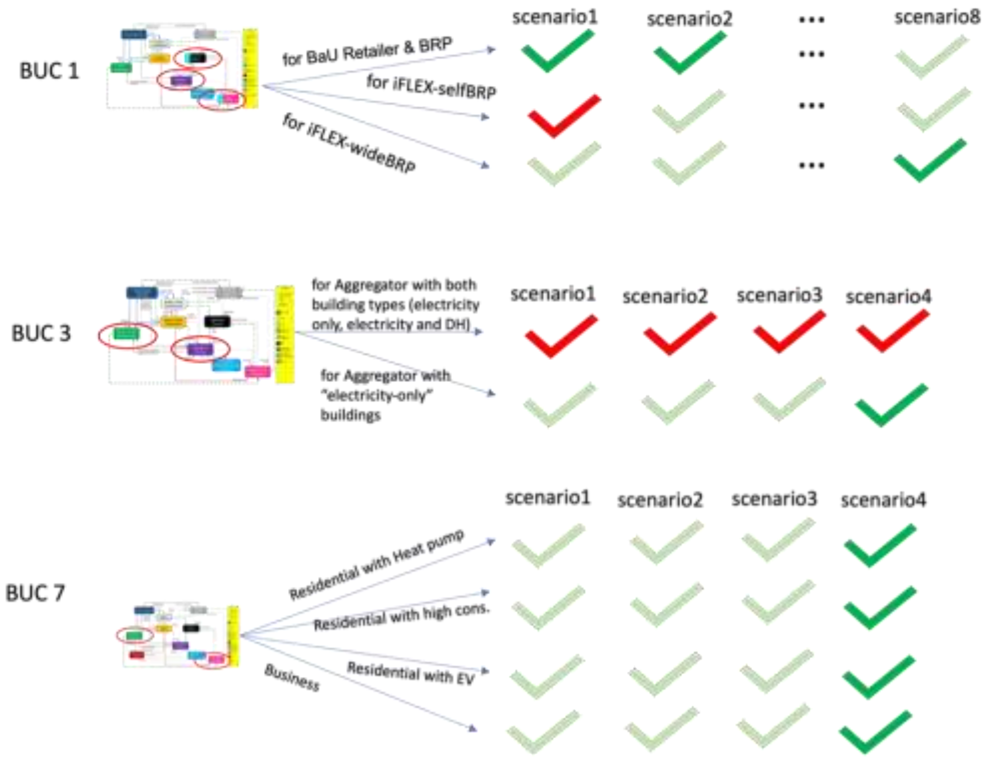

Figure 27: The economic assessment of iFLEX BUCs for different scenarios

As the iFLEX pilot activities progress and more data become available on the performance of iFLEX and the potential flexibility activated, we will be able to adjust the scenarios explored and perform a refined technoeconomic assessment. Furthermore, new scenarios may be introduced to reflect the changing conditions and maturity of iFLEX project. At the same, we will broaden the scope of the economic by analysing the attractiveness of the rest BUCs. For example, section 7.3 includes a preliminary techno-economic analysis of BUC 4 “Optimal energy consumption for multi-vector energy system (building community) based on the behaviour of consumers and market price signals” for the Finnish pilot. Finally, we will replicate the analysis of BUCs in a particular country in the remaining pilot countries of iFLEX.

4.4 DoA KPIs validation plan

Table 2 lists the project KPIs that will be monitored after each piloting phase. The final list of KPIs will be validated only at the final validation phase. The target value refers to the final target at the end of the project.

Table 2: Project KPIs

[3] These scenarios were obtained by making assumptions on the retailer’s load forecasting error, the high/low cost for flexibility and high/low volume of external imbalances.

[4] The profiles examined were: a) Residential consumer with heat-pump, b) Residential consumer with high consumption, c) Residential with electric vehicle and d) Business with heat-pump.

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.	Internal draft of the D2.4 [1] 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), data amounts and load 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.
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.
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.

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 [12], D3.8 [13], D4.2 [2], and D4.5 [5])
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 scenarios (e.g., pessimistic, base and optimistic) related to the assumptions about key techno-economic parameters (e.g., low, moderate and high response to iFLEX signals) and compute the Return on Investment for Prosumers.	Validated via the iFLEX economic sustainability tool from T5.4. A sensitivity analysis will also be performed to account for uncertainty in key techno-economic parameters (e.g., changes to market prices).	Detailed quarter hourly data for a full year regarding consumption, production, environmental conditions, internal conditions and pricing information for all iFLEX pilots. Furthermore, data related to flexibility obtained from iFLEX trials and iFLEX digital twins.
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 participation in Demand Response campaigns, 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, D2.1 Use cases and Requirements [6], D5.4 Final iFLEX consumer engagement and incentive mechanisms [14], technical validation of the services
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

5.1 Usability test

5.1.1 Introduction

A usability study was conducted in order to test the new features of the iFLEX Assistant App. This is the second usability study on the iFLEX Assistant App (the first was reported in D7.5 [15]), therefore only specific screens were tested.

5.1.2 Participants

The participants of this User Research were 12 people from Greece (7) and Slovenia (5), employees of ICOM, ELCE, JSI and Heron. They all had different levels of domain knowledge, ranging from having already seen the iFLEX Assistant to not knowing what a DR Event is.

5.1.3 Procedure

The online interviews were conducted by a facilitator, assisted by an energy domain expert and a front-end developer. First the facilitator briefly explained the project and performed a walkthrough of the iFLEX Assistant App, showing the following screens: Dashboard (including the sub-screens of Asset Operation and Goals), Advice, Costs (including the sub-screens of Tariffs, Estimation and Savings), DR Events, and Notifications. If the participant had limited energy domain knowledge, basic concepts (DR Events, cost estimation) were explained.
After the introduction, the participant was asked to share their screen, open the iFLEX Assistant App on mobile view, login and complete 11 scenarios:

- **Scenario 1**: Can you tell us which of your Assets worked on the 25th of April? At what time did it/they work?
- **Scenario 2**: Edit your Goal for max monthly energy consumption of 500 kWh. Choose to receive alerts relevant to this goal.
- **Scenario 3**: Check your advice and accept the advice the iFLEX Assistant offers you on Asset Operation and Asset Replacement. Is the advice text clear to you? Would you like more/less detailed info?
- **Scenario 4**: What is your current tariff? Do you have a DR event today?
- **Scenario 5**: Check your tariffs on the 25th of April. How many implicit DR events took place that day? What was the tariff during the DR Event(s) and what was the relevant (tariff) drop?
- **Scenario 6**: What is the estimation of your direct energy costs today? Is this term clear to you after reading the note at the bottom of the “Estimation” page?
- **Scenario 7**: What was the amount of your monthly energy cost savings in April?
- **Scenario 8**: Check the notification you will receive regarding the goal you set earlier (i.e., in scenario 2).
- **Scenario 9**: We need you to change your Settings. In preferences, can you set your objectives to focus only on energy cost minimization?
- **Scenario 10**: In preferences, can you check your schedule and tell us what it means?
- **Scenario 11**: Can you understand the information regarding the most recently Accepted DR Event (on 5/2/2022)?

Sometimes energy domain information needed to be repeated during the scenario performance. Some scenarios (3, 8, 10 and 11) required the participant to give their opinion about the look or the text of the page. While the participants performed the tasks needed to complete each scenario, the facilitator recorded the participant’s actions and comments. These were later entered into a table (an example can be seen on Table 3), in order to quantify the qualitative data.

Table 3: Example of notes on a participant's interview

Task Write the task number and directions here.	**Click Path Deviations** Record what path the participant took to complete the task.	**Observations** Note down behaviors, opinions, and attitudes along with any errors, issues, or areas of confusion.	**Quotes** Note any significant quotes (positive and negative).	**Task Completion** Choose if the task was: 1 - easy to complete 2 - completed but with difficulty 3 - not completed
Scenario 1	Took a couple of seconds to click on View More			1
Scenario 2		Forgot to click on alerts		1
Scenario 3		Hesitated to accept the asset replacement after reading it, because replacing fridge is too much	Is 27 C cooling or heating? Maybe it should be clarified	1
Scenario 4	Went to DR Events for the DR Event part of the question	Didn't see the 0.15 on both screens, said the tariff is the graph (which is actually correct). When asked about the DR event, he said all the info but then redirected also to the DR Event page to see if there is more there		2

The column "Task Completion" awarded each scenario with a number of points:

- 1 point if the scenario was easy to complete for the participant
- 2 points if the participant completed the scenario but with difficulty (maybe with minor leading from the facilitator)
- 3 points if the participant did not complete the scenario, needed a lot of explanation and did not seem to understand the concept even after some help from the facilitator

After the completion of the online interviews, a questionnaire was sent to the participants, adapted from the official System Usability Scale (SUS) [16].The System Usability Scale contains 10 questions with five response options for respondents (from Strongly disagree to Strongly agree) and it is a reliable tool for measuring the usability.

5.1.4 Results

In Table 4 there is a sum of all participant Task Completion points per scenario. Given that 1 means "easily completed" and 3 "not completed", 12 being the optimal sum (meaning all 12 participants completed the scenario with no problem) and the bigger the score is, the most issues the participants had with the scenario. In Table 4 the most common issues of each scenario are also explained. The issues reported are only the ones related to the UI and not other issues the participant might had, such as participant was confused because of limited time to think, needed more energy domain explanation, did not read the text carefully, etc.

Table 4: Task Completion points per scenario

Scenario	Nr of points	Most common issues
Scenario 1: Can you tell us which of your Assets worked on the 25th of April? At what time did it/they work?	15	"View More" made 2 participants think "View More Assets"
Scenario 2: Edit your Goal for max monthly energy consumption of 500 kWh. Choose to receive alerts relevant to this goal.	17	
Scenario 3: Check your advice and accept the advice the iFLEX Assistant offers you on Asset Operation and Asset Replacement. Is the advice text clear to you? Would you like more/less detailed info?	12	
Scenario 4: What is your current tariff? Do you have a DR event today?	21	11 participants did not see the DR Event information on the short description (Costs page). DR Event information was not clear even on the tariff page. 3 participants, when asked for the implicit DR Event, went to the DR Event page. Some participants complained about the scroll bar not being obvious.
Scenario 5: Check your tariffs on the 25th of April. How many implicit DR events took place that day? What was the tariff during the DR Event(s) and what was the relevant (tariff) drop?	22	Same comments as above
Scenario 6: What is the estimation of your direct energy costs today? Is this term clear to you after reading the note at the bottom of the "Estimation" page?	15	3 participants had some issues with understanding the text
Scenario 7: What was the amount of your monthly energy cost savings in April?	14	2 participants mentioned some rephrasing options
Scenario 8: Check the notification you will receive regarding the goal you set earlier (i.e., in scenario 2).	12	
Scenario 9: We need you to change your Settings. In preferences, can you set your objectives to focus only on energy cost minimization?	12	1 participant commented that the baseline for this calculation wasn't clear
Scenario 10: In preferences, can you check your schedule and tell us what it means?	25	All participants had issues with the following: Not obvious which asset is "flexible".

		Not obvious what "flexible" means exactly.
Scenario 11: Can you understand the information regarding the most recently Accepted DR Event (on 5/2/2022)?	18	Not obvious which one is the scheduled time and which one the rescheduled because of the DR Event. Only 2 participants with energy domain knowledge and experience with iFLEX Assistant did not have issues.
General comments		Several participants needed more information about various terms and pages, plus a walkthrough. The scroll bar needs to be more obvious.

As seen from the results, the most complicated Scenario was "Scenario 10: In preferences, can you check your schedule and tell us what it means?" Some changes need to be made in order to ensure this page is clear to users. Scenarios 4 and 5, both related to the Tariffs page, also had high difficulty. Participants were mostly confused about the DR Events mentioned in the page, either did not see them or did not understand their meaning. Some changes in format are needed in order to make the page clearer. On the other hand, the Advices page, the Notifications and the Preferences page were clear to all participants. The Goals page was also an easy task for all participants.
The SUS questionnaire results were turned to percentages, following the official formula [16]. The results are shown in Table 5.

Table 5: SUS questionnaire results

Question	Score (%)
1. I think that I would use the iFLEX Assistant app frequently.	96,75
2. I find the iFLEX Assistant app unnecessarily complex.	90
3. I think the iFLEX Assistant app is easy to use.	90
4. I need the support of a technical person to be able to use the iFLEX Assistant app.	90
5. I find the iFLEX Assistant app easy to navigate.	94,5
6. There is inconsistency within the iFLEX Assistant app.	94,5
7. I imagine that most people would learn to use the iFLEX Assistant app quickly.	74,25
8. I feel confident using the iFLEX Assistant app.	96,75
9. I need to learn a lot of things before I can start using the iFLEX Assistant app.	69,75
10. The main user flow is clear	94,5

A SUS score above 68 would be considered above average and anything below 68 is below average [17]. As seen in Table 5, the iFLEX App received good scores on the SUS scale. The statement with the lowest "I need to learn a lot of things before I can start using the iFLEX Assistant app". It is an expected outcome, since the iFLEX App requires some energy domain knowledge and offers many functionalities that require a learning period. That also justifies the lower score on the statement "I imagine that most people would learn to use the iFLEX Assistant app quickly". The iFLEX App needs a walkthrough that users can revisit and information buttons on various pages.

5.1.5 Changes in the UI because of the UX research

The following changes are proposed as action points for the UI solution provider, based on the findings of the UX research:

- DR Event page: rephrasing of text
- Schedules page: it should be clear which assets are flexible and the kind of flexibility they have
- Costs page: change Tariff section so that it is more clear to understand the DR event information
- Tariffs page: remove current tariff, make calendar more easy to see
- General: increase contrast in scroll bar, information buttons will be added in most pages, an app walkthrough will be added.

5.2 Greek pilot

A workshop was conducted in Athens on the 27th of September in AUEB premises inviting members of public to comment on the core objectives of iFLEX assistant and give feedback on Phase 2 iFLEX Assistant implementation. Overall, 15 of the attendants were surveyed following the workshop, through a Google Forms 37 question survey.

Participants were asked to grade various features and aspects of the iFLEX Assistant, with Figure 28 presenting the answers in descending order, from the most liked aspects/feature to the least liked. Specifically, the application and the project generated positive feedback with 79% of the public expressing interest in personalised advice, while an equal percentage found the app easy to use. Furthermore, the Landing Page got mostly 4s, with 79% positive (4s-5s) and no one disliking it, while Tariff changes got mostly 5s, though one participant gave it a 2. 79% think the app is easy to use although half of the surveyed users seemed to be uninterested in the Auto Mode. The lack of interest in the Auto Mode was further reinforced by a trend in increased engagement with the app as shown by the significantly positive interest in receiving goal progress notifications and the interest in setting personal goals which demonstrated that Goals seem to be a feature of interest.

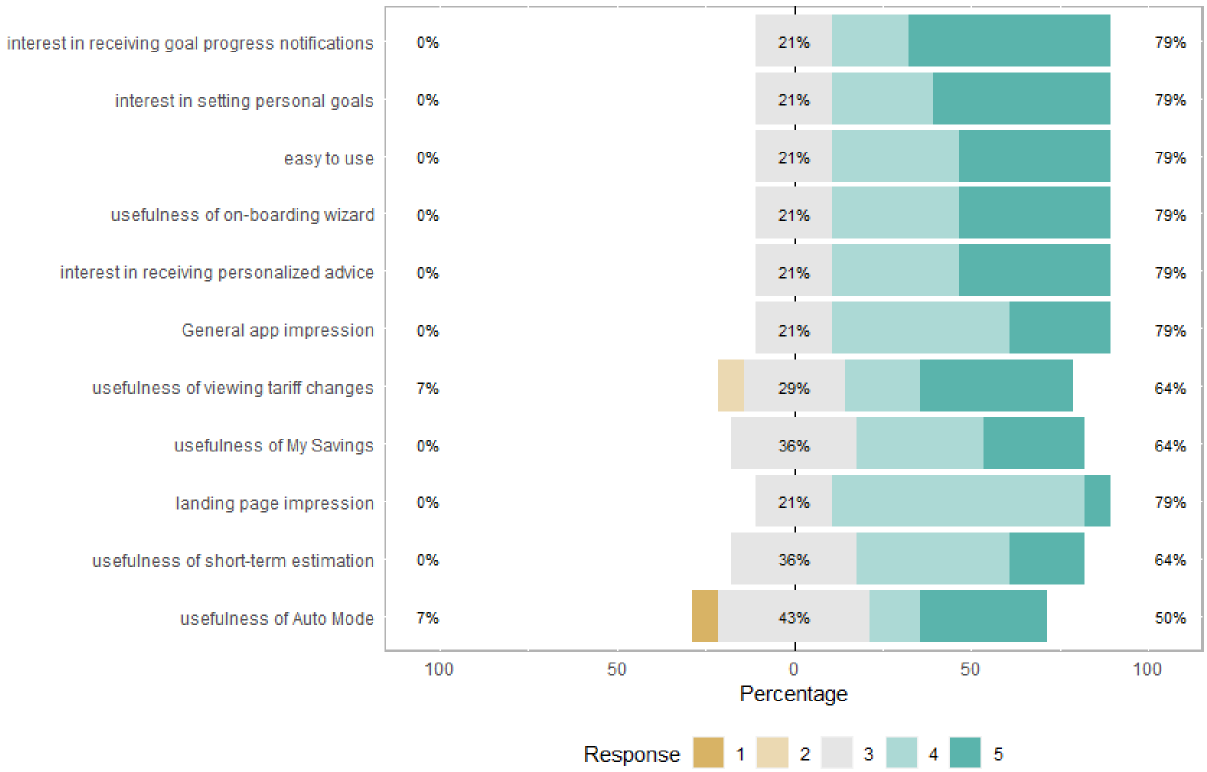

Figure 28: Answers to the likert scale questions

In addition, there were Yes/No questions which encouraged participants to give written feedback. Overall the sentiment was overwhelmingly positive.

Table 6: Collected feedback from questioner

Question	**Yes**	**No**	**Comment**
*Do you think that you will be able to **achieve your goals** through the app?*	14		
*Are there any **features** that you think you need, but are **missing** in the mobile application?*	13	1	Live indication of estimated cost
*Are the **terms** that are used throughout the app understandable?*	14		
*Did you find anything **difficult or unnecessarily complicated** while using this application?*	13	1	
*Is **optimization policy** selection important to you?*	14		
*Is it useful for you to be able to select more than one options as drivers of the **optimization policy**?*	13	1	
*Is the concept of **temporary silence** and **silence rules** clear to you?*	14		
*Do you find it easy to manage (accept / reject) **notifications** from the notifications page?*	14		
*If your participation in a **Demand Response** program earns you a monthly benefit of 5 euros, would you be willing to receive a lower benefit (e.g., 3 euros) if you were able to learn that you were the most successful consumer / consumer in your area in the Demand Response program?*		14	

Other comments from the comment section:

- Purple color reminds me of other apps (e.g. Viber)
- Have the option of Greek language
- Regarding the Monitoring of Energy Tariffs, I would like to have the possibility if I can't do what is proposed, to have the possibility to write why I can't do it and to receive an alternative option.

Finally, in support of the WP5 effort with respect reward and incentive mechanisms, participants were given a series of multiple grid questions on the relevant topics. The results are summarised in Figure 29 to Figure 32. In more detail, it becomes apparent that as a first choice participants chose the 5 euro return and as second choice the 5 euro gift. Generally, it seems that they prefer a small but sure monetary reward and not to gamble for more money.

Regarding their motivation to participate in DR programmes like the one in iFLEX, monetary rewards has been the most popular first choice while a compromise between less money and CO_2 savings appeared to be the favourite second choice. Learning the CO_2 impact of consumption appeared to be of interest to the participants while the comparison to others not so much.

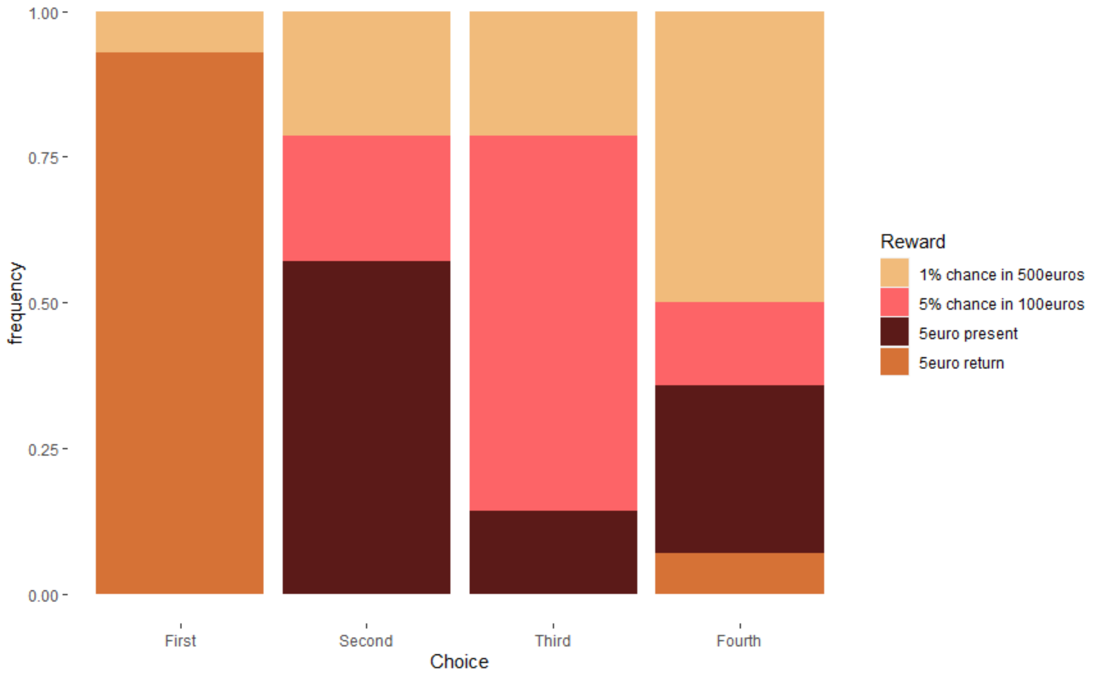

Figure 29: Preference of reward for participating in DR event (choice order by reward)

Figure 30: Preference of reward for participating in DR event (reward by choice order)

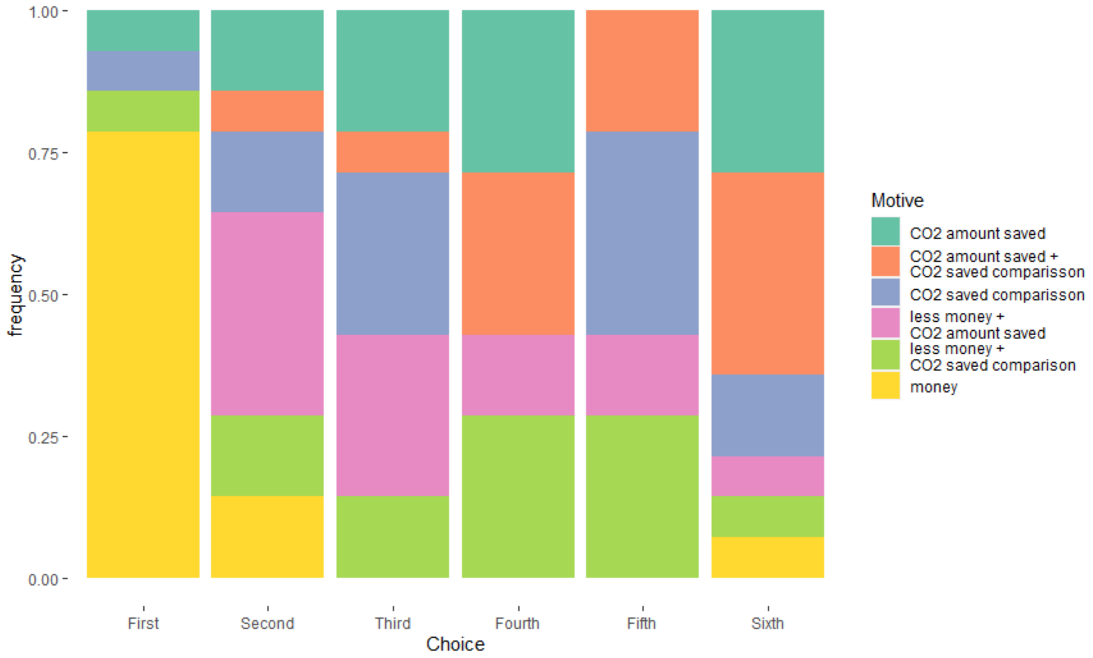

Figure 31: Preferred motive for participation in DR event (choice order by motive)

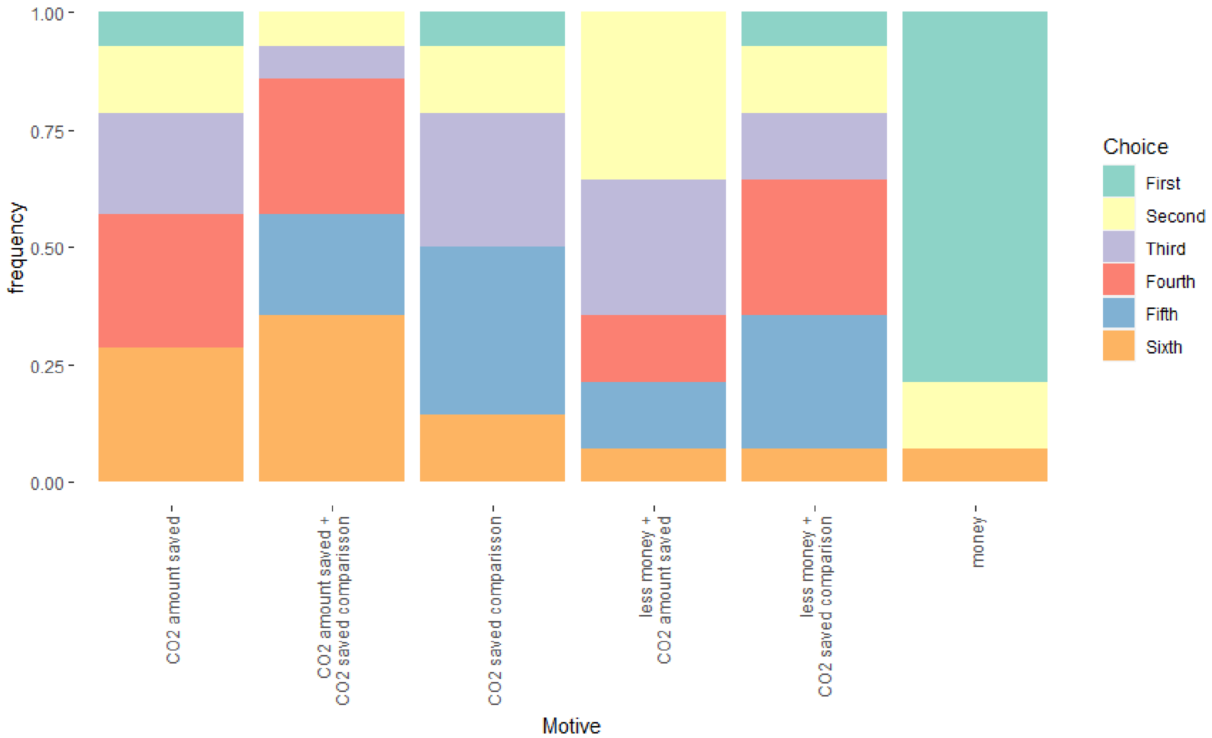

Figure 32: Preferred motive for participation in DR event (motive by choice order)

To conclude, the main findings of the survey can be summarised as follows:

- Participants like the app
    - Yes/No questions are almost always positive
    - Likert Scale answers are almost never 1 or 2
- Half of the participants seem to be uninterested in Auto Mode
- They were very interested in setting goals and being informed on their progress

- They found the app easy to use
- The on-boarding wizard was useful for the participants
- Short-term estimation was one of the least impressive features, still positively evaluated.
- Participants are interested in direct money as a reward for DR participation.
- Concerning the CO_2 emissions saved, participants are not interested in being compared to others, but there is some interest in knowing the amount they saved.

5.3 Slovenian pilot

At the end-user level, a workshop and end-user survey were carried out in the Slovenian iFLEX pilot project. The results are presented in following sections:

5.3.1 Workshop with pilot and potential pilot users

A workshop was held on October 27th, 2022, in Šempeter v Savinjski dolini with 15 participants (9 man and 6 women). The purpose of the workshop was the presentation of iFLEX to (potential) pilot users and the co-creation of iFLEX solution with participants related to business, application and incentives aspects. One important purpose of the workshop was also recruitment of new pilot users. We used the World Café method for the workshop to engage the participants in small-group conversations on three different topics.

With the workshop we covered 3 key areas of co-creation within iFLEX project:

- **Business aspect** – with the aim of getting feedback on how users understand the business use cases of iFLEX Assistant and to get ideas/suggestions on how to improve this aspect.
- **Application aspect** – with the aim of getting feedback on how users understand the purpose of the iFLEX Assistant and its key functionalities, and to get ideas/suggestions on how to improve these functionalities.
- **Incentives and rewards aspect** – with the aim of getting feedback on which incentives/reward mechanisms would convince users to use the iFLEX Assistant, and to get ideas/suggestions on how to design these mechanisms as effectively as possible.

Before the start of the workshop, we presented the most important information to potential pilot users: basic information about the iFLEX project, the area of operation of the project in Slovenia, how to get involved in the project, the idea of iFLEX Assistant, reasons for participating in the iFLEX project, example of using the iFLEX Assistant, specifications of the first pilot user, iFLEX device integration and connection methods
renewal of the grid fee calculation methodology and the tariff system.
After the introduction we divided participants into 3 working groups, each of which, under the guidance of a moderator, processed each of the aforementioned 3 areas of co-creation in a maximum of 20 minutes.
At the end, we shared the key findings from each of the 3 areas of co-creation with all participants. Summary and key findings are also described further in this chapter.

5.3.1.1 BUSINESS ASPECT – Short summary

When asked what benefits participants expect from iFLEX Assistant, they most often pointed out:

- cost reduction by at least 10%,
- lower bills,
- additional income,
- a realistic price on the market for the sale of surplus electricity produced,
- optimal use of excess energy from one's own source, especially in periods of high production, e.g. optimal self-consumption.

Among the effects that the iFLEX solution can offer, the participants highlighted the following aspects in particular, which they ranked in descending order of priority:

- reliable operation of the grid (although in Slovenia and Europe we do not have major problems with grid outages),
- reliable supply of electricity,
- reducing energy costs,

- ensuring adequate quality of electricity,
- more efficient energy consumption (detection and limitation of wasteful consumption in the household),
- increasing self-supply and/or consumption from own energy source.

Figure 33: Business aspect; left figure show presentation and right figure show co-creation activities

The business use cases (BUCs) identified by the iFLEX project and most relevant for end-users were ranked in the following order:

- BUC-2: Optimise grid operation by leveraging flexibility from consumer/prosumer through DR
- BUC-7: Optimise end-user's energy consumption based on own preferences and market price signals
- BUC-5: Customer load profile analysis and overview
- BUC-6: Increase self-balancing through advanced monitoring and automation
- BUC-8: Offer flexibility through participation in explicit demand response programmes

5.3.1.2 APPLICATION ASPECT – Short Summary

Before the start of the workshop, each of the 3 groups was presented with an iFLEX (iFA) application on two smart tablets. The basic functionalities and options offered by the iFA application were presented. After the presentation, the participants could practically test the responsiveness and readability of the application. Based on a practical test and pre-prepared questions, the participants gave initiatives and assessed the importance of iFA application functionalities.

Figure 34: Application aspect; left figure show presentation and right figure show co-creation activities

Among the shortcomings of the user experience of the iFLEX Assistant application, the participants pointed out:

- poor contrast,
- small font size,

- lack of possibility to choose a language, including Slovenian.

When it comes to optimization, they consider the following to be most important:

- price,
- consumption,
- device efficiency,
- For push messages, most participants would choose two options:
    - Silence,
    - setting the time interval/window when the user should receive notifications or not.

When it comes to consumption monitoring, the following are most important to the end user:

- consumption energy production measurements,
- external and internal temperature measurements (but not for those who already have an application that monitors internal and external temperature),
- measurements in near real time,
- device efficiency measurements.

5.3.1.3 INCENTIVES AND REWARDS ASPECT – Short Summary

Each of the 3 groups was presented with a simplified concept of the operation of incentives in flexible EE consumption with the main stakeholders and roles. In the following, we discussed with each group 4 specific questions related to iFA and the model of incentives and rewards (results presented below).

Figure 35: Incentives and rewards aspect; left figure show presentation and right figure show co-creation activities

Among the incentives that would convince them to use iFLEX Assistant and join demand response program, the workshop participants mentioned the following 4 most often:

- one-time cash prize or lower bill,
- environmental aspect (so that the consumer can see how much he contributes to protecting the environment, reducing emissions, green transition ...),
- to what extent they as a community (not as an individual) help to protect the environment,
- feedback about what someone has done good based on my contribution (grid improvements, connection of new solar power plants, etc.).

The data on the performance of the individual in flexible EE consumption system compared to other users was not important to the participants. It was more important to them what they create or what benefit they contribute to the system and society as a community.

Regarding the operation of the iFLEX Assistant in connection with the dynamic tariff scheme, they would prefer to choose:

- receiving notifications about tariff changes, which practically all participants would like,

- followed by options for automatic optimization of the consumption schedule and receiving advice on adapting the consumption. By automatic operation, the participants understood that they can interrupt it or change when they want to.

Informing them that they are the most successful in their area in the demand response program would not at all persuade them to accept a lower (financial) benefit in exchange for this information.

5.3.2 Installation survey

During the second phase of the project, we worked closely with pilot users to install equipment for capturing measurement data and controlling user devices. These installations often involved working in the user's private premises, which required interventions in specific areas of the property. In each case, we obtained verbal confirmation from the building owner before proceeding with any work that may have impacted the property's infrastructure, such as drilling through walls or installing overhead cable connections. To improve the installation process and enhance the user experience during the third pilot phase, we engaged with equipped end-users to solicit their feedback. We reached out to 16 end-users, providing them with an online questionnaire consisting of eight questions. Equipped end-users had the opportunity to return the online questionnaire within 7 days from 11.4.2023, to 18.4.2023. Of the 16 individuals approached, 11 responded and completed the questionnaire.
The end users were asked the following questions:

1. **How satisfied are you with the installation of the equipment as part of the iFLEX project?**
2. **How satisfied are you with the progress of the installation, was it up to your expectations?**
3. **How satisfied are you with the appearance of the final product?**
4. **How satisfied are you with obtaining information about the iFLEX project?**

The end-user was able to rate their satisfaction level on a scale of 1 to 5 (Rate), where 1 means 'not satisfied' and 5 means 'very satisfied'. The graphical representation below (Figure 36) shows the results of the received responses, from which it can be concluded that the end-users are satisfied with the installation of the equipment.

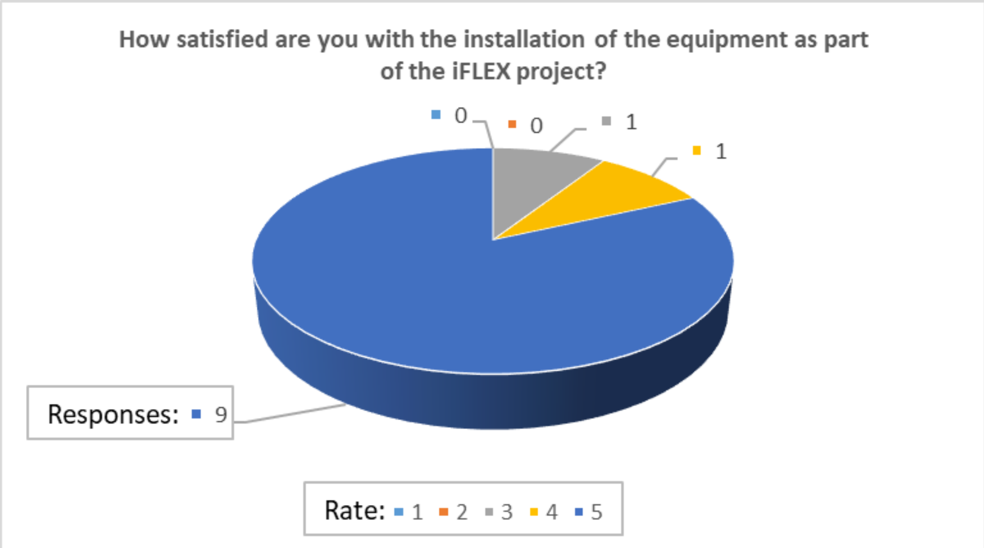

Figure 36: Results to the question of how satisfied the end-users are with the installation

Figure 37 shows the results of the received responses, from which it can be concluded that the end-users are satisfied with equipment installation progress, this means that the coordination between the end-user and the planner for scheduling the installation time went well, and the installation on the site itself was carried out as expected by the end-user.

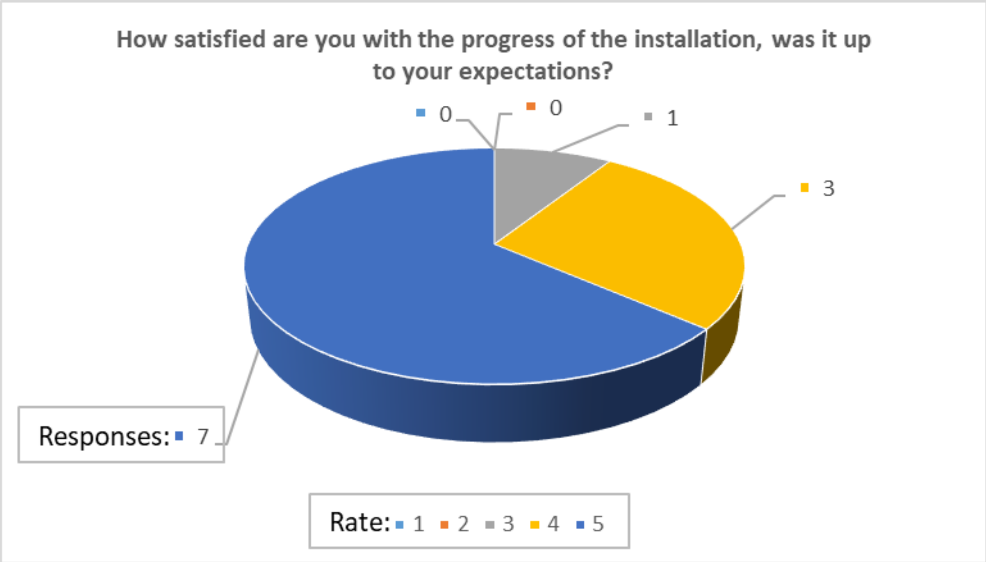

Figure 37: Results to the question of how satisfied the end-users are with the progress of the installation

Figure 38 shows the results of the received responses, from which it can be concluded that the end-users are satisfied with the appearance of the final product.

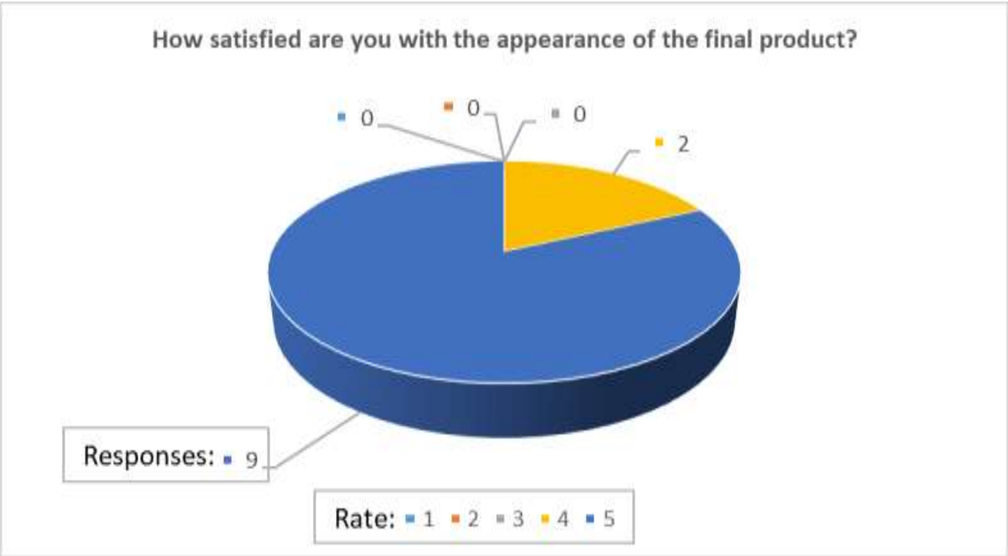

Figure 38: Results to the question of how satisfied the end-users was with the appearance of the final product

Figure 39 shows the results of the received responses, from which it can be concluded that the end-users are satisfied with the exchange of information and with support to end-users regarding communication and clarification of uncertainties about the iFLEX project.

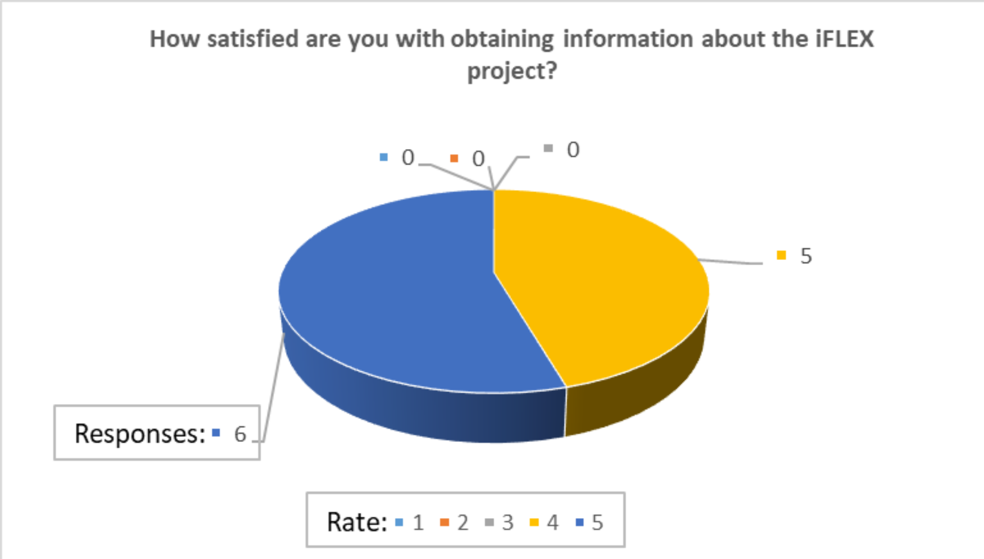

Figure 39: Results to the question of how satisfied the end-users was with obtained information about iFLEX project

5. **In your opinion, what would need to be improved in the installation?**
The end-user could answer this question with their suggestions on how to improve the user experience from the perspective of equipment installation. They could provide recommendations and observations before, during, and after the installation of the equipment that was being installed as part of the iFLEX project. Out of 11. received questionnaires, 3. provided additional explanations, which are written below:
    - "*More serious cooperation between the on-call electrician, who comes to open the distribution electrical cabinet (it's not exactly the fault of the on-call electrician, probably more of a communication issue), and the installer who is mounting the device developed under the iFLEX project. It often happens that they can't finish the work because the electrical cabinet is closed, as was the case with me.*"
    - "*Program support for installers.*"
    - "*The installation is not yet complete.*"

    We have prioritized all received comments, and a meeting with Slovenian partners in the iFLEX project was called to address issues and deficiencies with end-users. After the meeting, all discrepancies were resolved.

6. **Would you like to connect any other consumers/generators to the existing system? If yes, which ones?**
The end-users had the opportunity to express their opinions on the appliances and generators they would like to add to the iFLEX assistant's energy management system, either now or in the future. Out of the 11 received questionnaires, 6 end-users provided additional suggestions on which devices they would like to integrate into the currently installed energy management system as part of the iFLEX project. The following were received:
    - "*Not at the moment, but in the future, I would definitely consider connecting another device if it is feasible.*"
    - "*Washing machine, dryer, dishwasher.*"
    - "*In the future, a solar power plant!*"
    - "*Washing machine and dryer.*"
    - *"Yes, if we were to purchase an additional high-energy consumption device, I would like to connect it to the system.*"

    In the iFLEX project, the devices that will be subject to energy management are strictly defined. White goods are not included in the priority types of target devices, but we will try to make an effort to offer users support for devices that belong to the category of white goods within the project timeframe.

7. **Would you recommend participating in the iFLEX project to your friends and acquaintances?**

The end-user had the option to answer this question with 'YES' or 'NO'. If the user selected 'NO', an additional question would be displayed "*Can you tell us why you wouldn't recommend participating in the iFLEX project?*". Out of the 11. received questionnaires, all respondents chose the answer 'YES', from which we can conclude that we have chosen the right approach to end-users with in the iFLEX project: as one user commented "*All praise to the team*".

5.4 Finnish pilot

The end-user engagement and validation were implemented in Finnish pilot according to the following phases.

5.4.1 User recruitment

During the first pilot phase, four residents registered in the pilot. In pilot phase two, five more residents were 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.

5.4.2 Identifying the current status

After the user recruitment in the second pilot phase, an on-line survey for the registered residents were implemented. The purpose was to examine the starting point and the current status of the residents. The collected data related to the following topics: general information, resident's living comfort, energy awareness, engagement to energy conserving actions, data needs, and demand flexibility potential. The survey was open 15.12.2022 - 5.2.2023.

5.4.3 Sensor installation

After the survey, apartment-specific sensors were installed for the registered users to get more accurate measurement from their apartment. This enables the registered residents to monitor their apartment-specific data: temperature, humidity and CO_2 measurements.

5.4.4 Test period

Test period was 1.12.2022 – 20.3.2023, during which control commands were implemented when the space heating of the apartment building was cut for several hours (2-12h) every other day or every third day.

5.4.5 Feedback collection

After the test period, the second survey for the registered residents was implemented. The purpose of the survey was to collect feedback of the project actions and the project itself, and to detect the possible changes caused by the data visualization. The collected data related to the following topics: feedback on the data, feedback on the control commands and their impact on living conditions, impact of data visualization on awareness and consumption habits, feedback on user interface, and feedback on iFLEX project (advantages and experiences). The survey was open 3.4.2023 - 14.4.2023.

5.4.6 User interface

All the residents are provided with the User Interface, using which they are presented the collected data from the building: district heating consumption, electricity consumption, average temperature of the apartments and possible savings. For the registered users, also the apartment-specific data is visualized. Additionally, residents can also provide feedback regarding their thermal comfort. Figure 40 illustrates the user interface at the building level.

Figure 40: User interface for the end-users in the Finnish pilot

5.4.7 The results of surveys

<u>The first survey:</u>

Characterization of the respondents: <u>Number of respondents: 7.</u> 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 CO2 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 behavior: The respondents were asked to estimate the changes in their awareness and consumption behavior 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 residents were asked to evaluate the 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.

5.4.8 Conclusions

The participants of the Finnish pilot live in an apartment building connected to district heating. Therefore, their possibility to influence on demand flexibility by their own energy consumption behavior is quite small. However, 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 iFLEX project has increased the energy awareness of the pilot participants.
- The participants are willing to receive more energy related information, some of them even after the iFLEX project has ended.
- The pilot participants have gained new knowledge about demand flexibility and are more aware of how they could participate in it.
- The willingness of the pilot participants to participate in demand flexibility in the future has increased.

6 Technical validation

In Phase 2, the work on technical validation varies per pilot, depending on their maturity level. The Slovenian and Greek pilots focused mainly on internal verification activities, which involved unit tests for the various functional components, as well as certain integration tests between them. According to the fine-grained documentation of requirements for each iFA component during Phase 2 in JIRA and the deliverables of WP3 and WP4, different tests took place to validate the operation of these components. Additionally, the interactions between them were tested, when the maturity level of the involved components enabled this. On the other hand, validation of specific iFA instances was of reduced scope so far. Nevertheless, complete integration tests for these two pilots, as well as system tests for the various Use Cases (UCs) will start shortly, according to the current plan. As regards the Finnish pilot, whose maturity level is higher, apart from unit and integration tests, also system tests have been run, in order to validate the successful operation of the iFLEX Assistant end-to-end for certain UCs.

6.1 Greek pilot

In Phase 2 of the Greek pilot, technical validation was focused mainly on the functional testing of various iFA components or external systems. Various functional and/or unit tests were conducted on all the iFLEX components, as shown in the following Figure. Communication with the external CO_2 emissions service is mocked so far. Integration-wise, the interoperability between RAI and HERON's REMAP system has been tested, as well as the integration of the Trust Management with the Security and Privacy Interface and the JSI Server. As regards the integration tests between the other iFLEX components, these should start in the upcoming period, so that interoperability between all the pilot's components and systems can be validated.

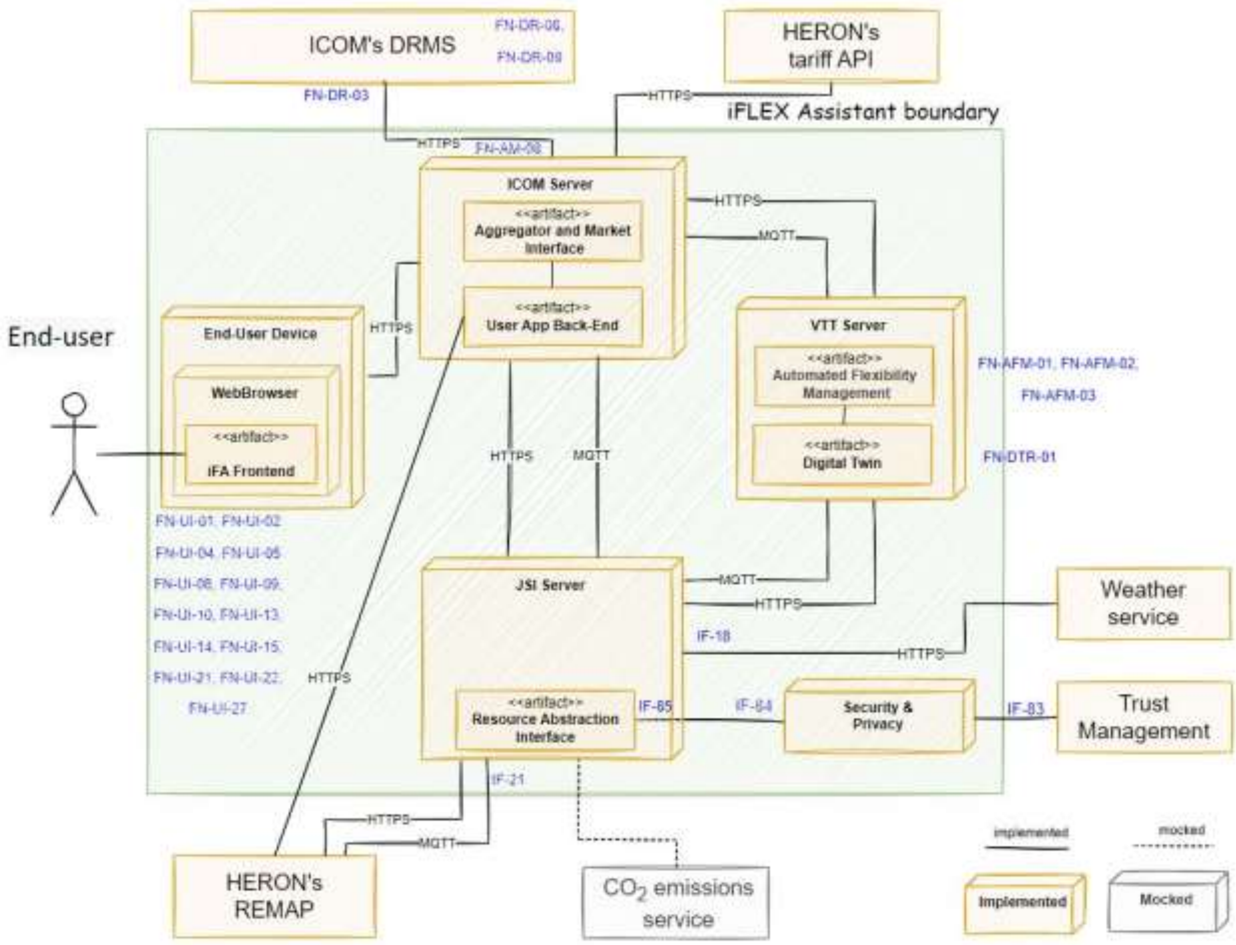

Figure 41: Deployment diagram of the Greek small-scale pilot

The requirements, which were validated via functional or unit tests, concern all the iFA's components and external systems, with the exception of the CO_2 emissions service, as shown in the above Figure 41. These requirements are presented in more detail in Table 7.

Table 7: Implemented requirements in the Greek small-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-04	Optimisation policy selection	UI	PUC-1
FN-UI-05	Automation level customisation	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-10	Insights into sustainability metrics	UI	PUC-3
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-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
FN-AM-08	Receiving Flexibility Signal	A&M	PUC-8
FN-DR-03	Sending Flexibility Signal	DRMS	PUC-8
FN-DR-08	Response to flexibility request	DRMS	Pilot-specific
FN-DR-09	Flexibility dispatch	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-18	Weather data	RAI	PUC-5, PUC-10
IF-21	Sensor data	RAI	PUC-2
IF-83	Trust management	TM	/
IF-84	Authentication, Authorization and Accounting	S&P	/
IF-85	Communication security	RAI	/

6.2 Slovenian pilot

The deployment diagram of the Slovenian small-scale pilot is shown in the following Figure. By the end of Phase 2, some unit tests have been performed in all the iFLEX components. Only the external CO_2 emissions service is still mocked. Furthermore, integration between RAI and HEMS, smart meters, weather service, and

ELE/ECE's tariffs API has already been tested. According to the current plan, integration tests between the other components should start soon, so that interoperability between all the iFLEX components can be validated. The Trust Management has also been integrated and tested with regards to the Security and Privacy Interface and the JSI Server.

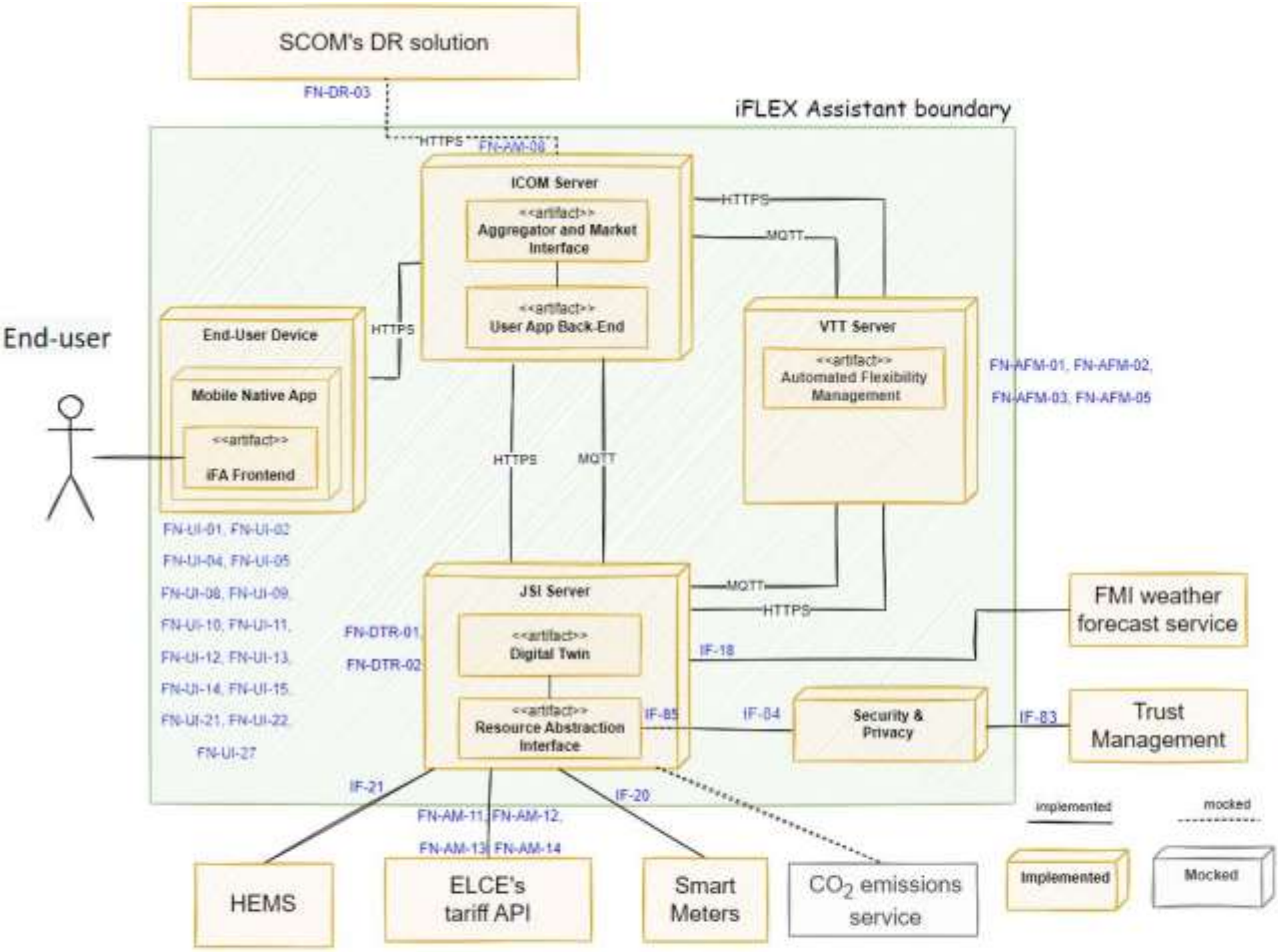

Figure 42: Deployment diagram of the Slovenian small-scale pilot

A list of the requirements, which have already been validated through unit testing in the Slovenian pilot, is presented in the following Table 8. These requirements are related to all the iFLEX components, and most of the external systems and interfaces, as shown also in the above Figure 42.

Table 8: Implemented requirements in the Slovenian small-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-04	Optimisation policy selection	UI	PUC-1
FN-UI-05	Automation level customisation	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-10	Insights into sustainability metrics	UI	PUC-3
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-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
FN-AM-08	Receiving Flexibility Signal	A&M	PUC-8
FN-DR-03	Sending Flexibility Signal	DRMS	PUC-8
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-05	Optimize flexibility locally (self-consumption, consumer load reduction)	AFM	PUC-1, PUC-9, PUC-10
FN-DTR-01	Household electricity model	DTR	HLUC-1, PUC-4, PUC-6, PUC-8, PUC-10
FN-DTR-02	Household thermal model	DTR	PUC-5
IF-18	Weather data	RAI	PUC-5, PUC-10
IF-20	Smart metering data	RAI	PUC-2, PUC-4, PUC-5, PUC-6
IF-21	Sensor data	RAI	PUC-2
IF-83	Trust management	TM	All
IF-84	Authentication, Authorization and Accounting	S&P	All
IF-85	Communication security	RAI	All

6.3 Finnish pilot

By the end of Phase 2, all the components of the Finnish instance of the iFA have been deployed, as shown in the following Figure. This iFA has been so far validated via demonstrations in operational environment at an apartment building. Furthermore, system tests involving also ENERIM's Aggregation Platform (i.e., DR solution) have been run successfully, 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 D8.4 Initial Validation of Federated Pilots [18].

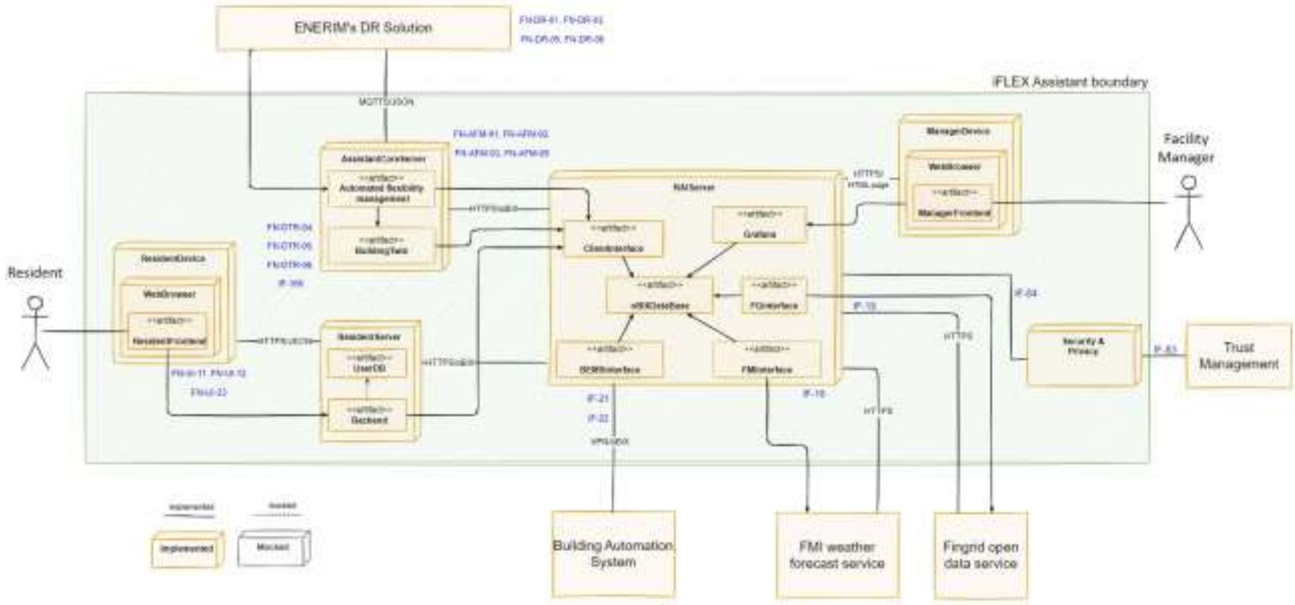

Figure 43: Deployment diagram of the Finnish small-scale pilot

The requirements which were implemented in Phases 1 and 2 of the Finnish pilot concern all the iFLEX components, as shown in the above Figure 43, and are presented in more details in the Table 9.

Table 9: Implemented requirements in the Finnish small-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-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
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 Business validation

As part of the pilot project, a comprehensive business analysis was conducted for all three pilot areas. The objective of this analysis was to understand the commercial viability of the project and to evaluate the economic feasibility of implementing the pilot on a larger scale.

The business analysis took into account a range of factors, including the price aspects of each pilot, consumer habits, and market demand. The team conducted extensive market research to understand consumer behavior and preferences regarding energy management systems, including factors such as pricing, features, and usability. They also analyzed the competitive landscape, identifying potential competitors and assessing their strengths and weaknesses.

Based on the analysis, the team developed a detailed pricing strategy for each pilot area, taking into account factors such as installation costs, device costs, and ongoing maintenance expenses. They also considered the potential revenue streams for the project, such as energy savings, demand response programs, and ancillary services.

To evaluate the economic feasibility of implementing the pilot on a larger scale, the team conducted a cost-benefit analysis, comparing the projected costs of the project with the potential benefits, such as increased energy efficiency, reduced energy costs, and improved grid stability. They also considered the potential environmental benefits of the project, such as reduced greenhouse gas emissions and improved air quality.

Overall, the business analysis was a critical component of the pilot project, providing valuable insights into the commercial viability and economic feasibility of implementing energy management systems on a larger scale. The pricing strategy and marketing plan developed as part of the analysis will be instrumental in promoting the project to potential customers and ensuring its long-term success.

7.1 Greek pilot

Due to their intermittent and stochastic nature, non-dispatchable RES units are one of the primary drivers of energy imbalances, which necessitates the provision of flexibility services from other eligible resources. Thus, cooperation between RES Aggregator and DR Aggregator is proposed, for bilateral mitigation of such imbalances. End-user DR (flexibility from pilot participants) can internally handle and mitigate RES imbalances, before the RES Aggregator needs to perform balancing through third parties in the relevant markets. Assets, typically represented by DR and RES Aggregators, are represented by HERON, as a market entity. Under the current legal framework, DR and RES Aggregators can be a single entity; despite this, the assets they represent, participate in the market and receive compensation separately.

In more detail, the imbalances arise from variations in actual RES generation as compared with the declared generation schedule of the RES portfolio involved in the Day Ahead Market (i.e., DAM schedule) due to intermittent and unpredictable real-time RES generation. It is important to note, therefore, that OPTIMUS should not be required to provide 100% of the requested balance. The precise number of end-user households, which will actively participate in the project, will indirectly define the number and maximum capacity of the RES (PV) plants that jointly make up the previously mentioned RES portfolio. In order to create more practical flexibility specifications, it is necessary to obtain comparable RES and end-user DR portfolios in terms of aggregated capacity.

Practically, in case that the RES portfolio generates in real-time more (or less) than the declared Day-Ahead Market (DAM) schedule, the end-user DR resources will be called to increase (or decrease) their consumption accordingly, in order to mitigate RES imbalances. In this concept, the bilateral trading between HERON – OPTIMUS, results into a combined strategy for the DR Aggregator which is evaluated against the market strategies of both Aggregators in DAM and balancing market separately.

Although the current settlement scheme in Greek Balancing Market is the “single-price” scheme, we evaluated the “dual-price” settlement scheme, as a more optimistic scenario from which both Aggregators benefit. “Dual-price” settlement scheme means that the price for surplus and deficit differ. When single pricing incentivizes to reduce the imbalance that is aggravating and create the imbalance for the direction that supports the system, dual pricing can be used to create incentives that will encourage BRP (Balance Responsible Party) to maintain its own balance. The BRPs can be said to participate more actively in the TSO balancing under single pricing.

In particular, for HERON-OPTIMUS interaction, a few safe assumptions were made, in order to define the final bilateral contract price, from which both benefit. First of all, both RES and DR Aggregators have access to a common forecast for system’s position, given that both entities operate under one market participant. Also, Aggregators focus only on the sign of the system imbalance and not on the imbalance prices. Both Aggregators have clear targets; to reduce overall market exposure and not profit from each other, I.e., RES entity wants to increase profits, while DR wants to reduce costs. This scenario evaluation consists of two steps; a) Benchmarking – RES participate directly in the market and are charged/paid by the TSO b) Bilateral Agreement – RES and DR Aggregators agree on a bilateral trade. In both steps, two general cases were identified, when DR Aggregator addresses RES portfolio short imbalances and when the DR Aggregator addresses RES long portfolio long imbalances. Each case breaks down into two subcases depending on the direction of the system imbalance (short/long).

Finally, simple numerical examples were used in order to benchmark and define the bilateral contract. Calculations indicated that all scenarios are economically feasible for both entities under certain circumstances. It is worth mentioning that a Premium component needed to be added, as a reward to HERON's customers for their participation in the Greek pilot, and it should be bigger than the bilateral contract price. In case of RES long position, this Premium component appears as discount parameter, which still guarantees profit for both entities. General formulas for the final bilateral contract price (including Premium) were defined, which satisfy two different conditions, according to RES position (short/long).

7.2 Slovenian pilot

In this section we repeat the study we performed in D5.5 [11] regarding the economic attractiveness of dynamic prices for a Residential end-user with Heat Pump in Slovenia based on actual measurements for consumption and production (if relevant).
A simulation environment has been prepared in order to compute the following technoeconomic KPIs:

- The total flexibility activated
- The total electricity cost
- for network
- for electricity

The simulator makes the following assumptions:

- The consumer is informed in advance (e.g., one day ahead compared to consumption) about the dynamic price for each slot quarter-hour (15min) slot.
- A real anonymized load profile for each customer type, containing load (in KW) for each 15minute slot of the first quarter of 2023 (January - March), was used as a baseline.
- The electricity prices are given by the following table. Note that a 45% subsidy was assumed to be applied by Slovenian authorities.

Table 10: Slovenian electricity price

	ToU (€/KWh)		Fixed (€/KWh)
	Low	High	
energy tariffs (baseline)	0,082	0,118	0,1
network tariffs (baseline)	0,02963	0,03827	0,03537
Total tariff (baseline)	0,11163	0,15627	0,13537

- Real-time prices were synthetic and included both network and energy components. In particular, a retail markup that was treated as a free variable was applied on wholesale market data for each 15minute slot of the first quarter of 2023 (January - March) in the Slovenian market. The markup was assumed to be equal to the subsidy applied to the fixed price.
- A dynamic price can be considered as "High", "Low" or "Normal".
- If dynamic price is "High" during a slot t AND there is some flexible load to be shifted, then the iFLEX Assistant is instructed to reduce load with a probability r based on customer's preferences.
- For those slots that iFLEX Assistant has chosen to reduce load, the (negative) implicit flexibility offered is a fixed %s of the baseline load during that slot.

- We assume that the daily electricity consumption of consumer is not affected as the load during some “Low-priced” slots is increased. In other words, a consumer offers daily positive implicit flexibility that equals the daily negative implicit flexibility. The exact slots are chosen by the iFLEX Assistant by taking into account user’s preferences.

The following Figure 44 presents preliminary results for such a consumer. We observe that the iFLEX Assistant can reduce electricity costs by 17.8%, by adapting consumer’s flexible load depending on the dynamic prices.

Figure 44: Preliminary result for consumer cost reduction

These cost reductions are attributed to the increased share of consumption during Low-cost and Normal-cost periods (or equivalently due to decreased consumption during High-cost periods), as seen in figure below.

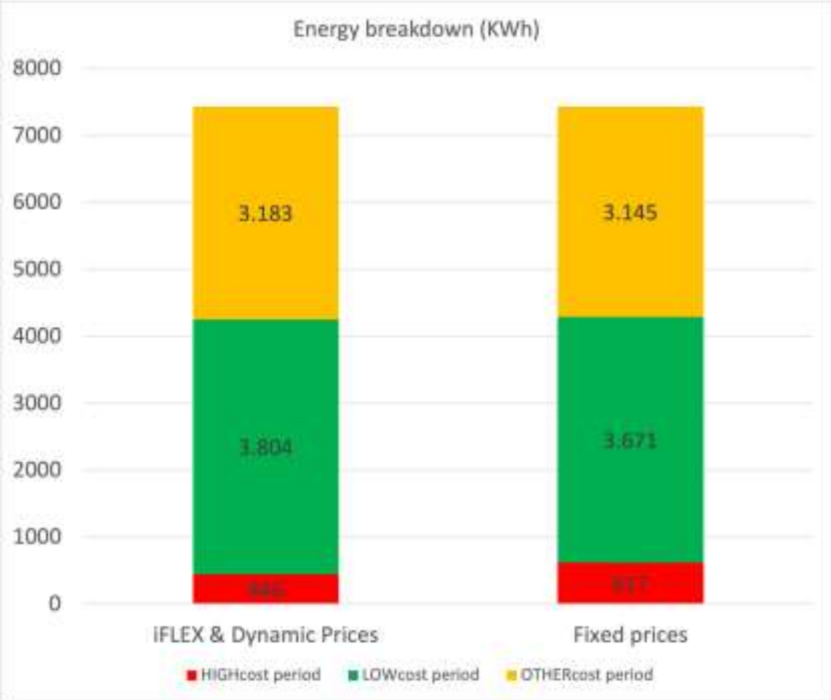

Figure 45: Consumption during Low-cost and Normal-cost periods

7.3 Finnish pilot

We performed a business validation of BUC 4 “Optimal energy consumption for multi-vector energy system (building community) based on the behaviour of consumers and market price signals” for the Finnish pilot. The objective was to estimate “whether and how building managers can minimize heating costs by making effective use of Heating Pump (electricity) and district heating?”.
In doing so compared the heating requirements (KWh/year) and costs (€/year) in 2022 for such a building in two (2) cases:

- Baseline case using actual measurements, where a Heat Pump of 80KW and 3.5 Co-efficient of performance (COP) was the default source of heating, while District Heating was used for meeting any excess heating needs.
- iFLEX-enabled case by simulating the iFLEX Assistant behaviour, which acts based on the retail electricity price and the in-building temperature as shown in Table 11.

Table 11: Simulated cases

		Retail Electricity Price			
		Low	Normal	High	Unattractive
In-Building temperature	Below Desired	Maximise Heating Using HP & DH	Maximise Heating Using HP & DH	Minimum Required Using HP&DH	Minimum Required Using DH
	Desired	Pre-Heat	Minimum Required Using HP&DH	None	None
	Above Desired	Pre-Heat	None	None	None
	Warm	None	None	None	None

The iFLEX Assistant can choose one of the following controls:

- "Maximise Heating Using HP & DH": Heat Pump is used at max power. District Heating is used only if desired temperature would not be obtained by Heat Pump alone
- "Minimum Required Using HP & DH": Heat Pump is used so that the desired temperature is obtained. This means that sometimes Heat Pump is used at reduced power, while there are cases when it used at full power (perhaps together with the Heat Pump).
- "Minimum Required Using DH": District Heating is only used so that the desired temperature is reached during that slot.
- "Pre-Heat": Heat Pump is used at full power so that we take advantage of low electricity prices.
- "None": no heating at all

We followed a rule-based approach for characterising the in-building temperatures and the Retail Electricity Price that constitute the "base" scenario. In particular, the in-building temperatures were estimated using the Digital Twin thermal model and characterised as "Below Desired", "Desired", Above Desired" and "Warm" based on the following criteria:

- If $temp \leq 20C$ then conditions are assumed to be "Below Desired"
- If $20C < temp \leq 22C$ then conditions are assumed to be "Desired"
- If $22C < temp \leq 23C$ then conditions are assumed to be "Above Desired"
- *Otherwise*, the conditions are assumed to be "Warm"

Similarly, the retail electricity prices were computed by adding a 10% markup on Day Ahead prices and are characterised as "Low", "Normal", "High" or "Unattractive" as follows:

- If $hourly\ electricity\ price\ <\ Mean\ annual\ electricity\ price\ - 25\%$ then electricity price is considered to be "Low"
- If $hourly\ electricity\ price > \ Mean\ annual\ electricity\ price + 25\%$ then electricity price is considered to be "High"
- If $hourly\ electricity\ price > DH\ price$, where DH price was assumed to be static and equal to 0.077/KWh, then electricity price is considered to be "Unattractive"
- Otherwise, the retail electricity price is "Normal".

The following Figure 46 presents the total Heating Costs for the two cases (along with the breakdown in electricity costs and district heating costs) for a 2022 (full year). We observe that the consumers' monetary benefits in the base scenario was 14.2% (compared to 8% that was the original target value of KPI 4c).

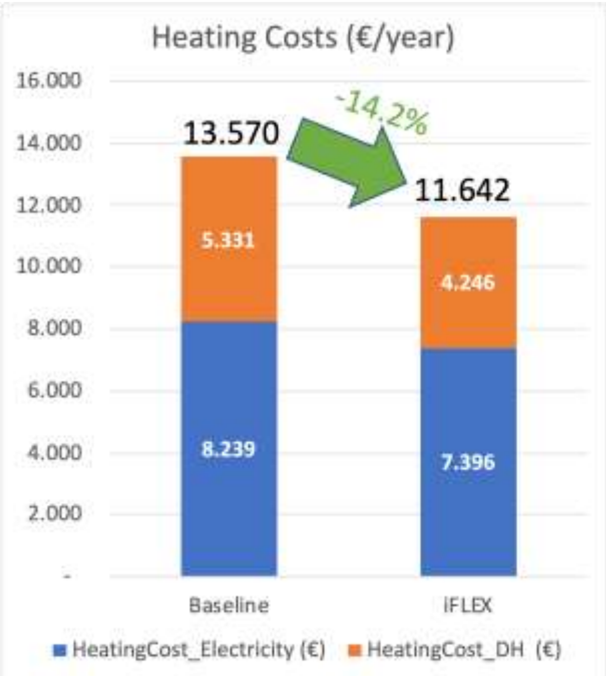

Figure 46: Heat cost

Notice that the decrease in annual heating costs (from 13,570 to 11,642 or -14.2%) was achieved even though there was a slight increase in heating activated (from 340,685 KWh that were measured compared to 341,268 KWh that were estimated if iFLEX Assistant had been used). This appears in the following Figure 47.

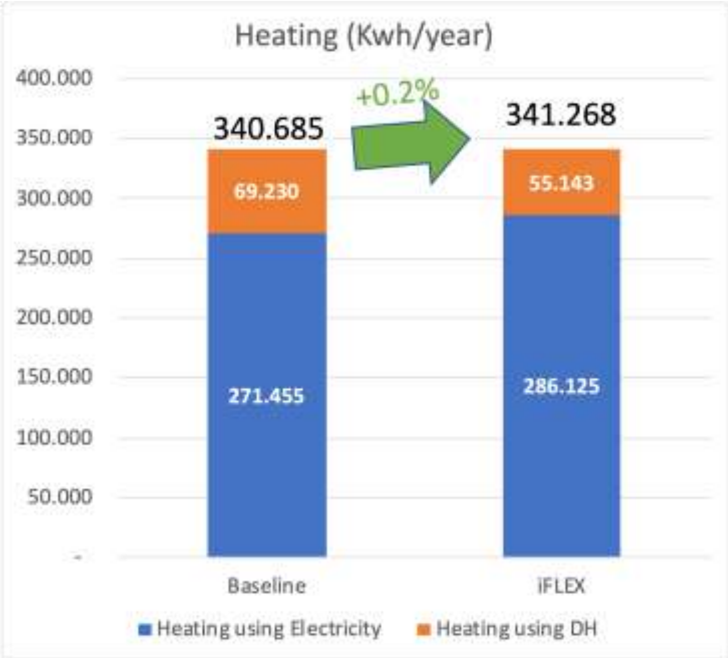

Figure 47: Heating through electricity (HVAC) and through DH

8 Validation progress monitoring (KPIs)

Table 12 presents the current values of the project KPIs obtained during the second round of validation. The methodology, validation data and success criteria for the validation is presented in section 4.4.

Table 12: 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.	7	6	Contributors (types) at the end of phase 2: Consumers, prosumers, DSOs, retailers, aggregators, technology, providers
KPI2a	Increased accuracy of consumer load forecasting compared to state-of-the-art methods	0%	20%	The current baseline forecasts in iFAs are based on SotA models that have been implemented and integrated to Digital Twin repository. There is thus now increase in the accuracy yet. The work on novel baseline forecasting models, providing beyond SotA results, will be integrated to the IFAs for the phase 3.
KPI2b	Increased accuracy of flexibility modelling compared to state-of-the-art methods	14,2%	15%	The current results are based on the Finnish pilot where we have the most data on DR events and validation available. The improvements are obtained by comparing the novel hybrid model, documented in D3.2, with SotA machine learning methods. It is important to that the models work well from day one and also in situations not covered in the historical measurement (i.e., model training) data. To take this into account in the validation, the models were validated with two separate datasets. The first dataset did not include any data on the DR evets (i.e., day-one) and the second dataset included over 60 DR events. Average results of the models in these two datasets were used to estimate the accuracy of flexibility modelling.
KPI2c	Increased effectiveness of automated flexibility management compared to standard methods	9,7%	10%	The current results are validated based on the results collected from the Finnish pilot where implicit and local control flexibility management solutions were tested during the second phase piloting. The validation was executed by comparing the results obtained with the automated flexibility management algorithm with the default methods applied in the pilot building. This was done by enabling the iFLEX Assistant to optimize every other day. The other days (not optimized by the iFLEX Assistant) formed the reference dataset. This split led to quite equal conditions (in terms of prices, CO2 emissions, and energy demand) for the optimization and the reference periods. Nevertheless, the optimized and reference periods were further normalized with respect to outdoor temperature to have identical conditions.
KPI3a	Level of interoperability (coverage of common standards)	100%	100%	The interfaces of iFLEX functional components provide interfaces implemented on top of standard communication protocols and serialisation formats. The current Resource Abstraction Interface covers the standards required in the project pilots.

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). 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		>15%	The economic assessment of prosumers' business models will be performed in the last phase of the project.
KPI4b	Internal Rate of Return for all commercial entities in the base scenarios		>15%	According to D5.5 [11], the Internal Rate of Return for a Finnish Aggregator in BUC-3 who offers flexibility to relevant energy markets by utilising the heating capacity of community buildings in its portfolio (i.e., the restricted portfolio case) exceeds 15% for 3 out of 4 scenarios. Similarly, by analysing the Internal Rate of Return for a hypothetical Slovenian Retailer when offering dynamic prices (D5.5 [11]), we found that it the target threshold of 15% is exceeded, as well as that it is higher compared to the Business-as-Usual IRR (I.e., the one obtained from standard pricing schemes).
KPI4c	Monetary benefits to the consumer in the base scenarios		>8%	According to preliminary results presented in Section 7.3, the monetary benefits of a typical community building's residents in the base scenario are 14.2%. Similarly, based on the preliminary results documented in Section 7.2, 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 6-7	TRL 7	A full-scale prototype of an iFLEX Assistant was demonstrated in operational environment in the Finnish pilots (TRL 7). The iFLEX Assistant technologies were demonstrated in the Slovenian and Greek pilots (TRL 6). The full-scale (TRL 7) versions of the Slovenian and Greek iLFEX Assistant will be finalised for phase 3.
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 Initial Report on Exploitation [19].

KPI6a	Number of consumers in the pilots	501	>600	Final number at the end of phase 2 was calculated as follows[5]: **•Finland (144 in total):** •Residential Pilot users – consumers/prosumers: Residents of the pilot building are all affected by (and can interact with) the iFLEX Assistant (9 of them are actively involved with signed consents and special sensors) = 143 •Business Pilot users – consumers/prosumers: Number of employees directly involved and managing iFLEX solution at the apartment building = 1 **Slovenia (327 in total):** •Residential Pilot users – consumers/prosumers: 8 pilot households are equipped, with a larger number of family and household members. Total number of pilot users = **36** •Business Pilot users – consumers/prosumers: 1 large industrial facility with 190 employees is equipped; 2 smaller business entities with a total of 101 employees are equipped. In total iFLEX pilot users = **291** **Greece (30 in total):** •Residential Pilot users – consumers/prosumers: Number of external residential users actively involved (with signed consents) until end of February: **30** •Business Pilot users – consumers/prosumers: N/A
KPI6b	Number of consumer groups targeted with novel demand response services	6	3	1.Residential consumers living in detached house or apartments (SLO, FIN, GRE) 2.Residential prosumer living in detached house (SLO) 3.Business consumers/prosumers – Industry (SLO) 4.Business consumers/prosumers – SME (SLO) 5.Community (FIN) 6.Apartment building manager, owner (FIN)

[5] Counting consumers/prosumers principle:

- „Consumer“ is considered in iFLEX project as Consumer or Prosumer.
- Consumer/prosumer who is taking active role as a pilot user in iFLEX project, based on signed informed consent or is directly affected by iFLEX solution or can interact with iFLEX solution, counting all family or household members who are directly impacted by the iFLEX solution provided within the project. (Count base: person who signed consent or is directly affected or can interact with iFA + number of directly impacted family/household members).
- Business consumers/prosumers: A company who is taking active role in the project based on signed informed consent and is provided with the iFLEX solution, where counting all employees who are fully employed and are located in the building or office where iFLEX solution is provided (Count base: number of employees)

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 [20] 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).

9 Conclusion

Delivery document D7.6 serves as a validation document summarizing the outcomes of the second pilot phase conducted in Greece, Finland, and Slovenia. The document presents the findings and conclusions obtained from the validation process, focusing on the performance and effectiveness of the implemented solutions in each pilot region.

In the Greek pilot, the aim was to address imbalances in a 500 KW PV plant owned by OPTIMUS by demonstrating the interaction between renewable energy sources (RES) and demand response (DR) aggregators. The pilot underwent partial redesign to overcome challenges identified in Phase 1, such as the lack of availability of water boilers and legal issues with electricity contracts. The pilot successfully recruited 30 households and around 65 users and made changes to the consent process and included additional IoT devices like smart plugs.

The Slovenian pilot aimed to establish a pilot area with residential and small business users equipped with home energy management systems (HEMS). The first phase focused on selecting suitable pilot endpoints and conducting a needs assessment. HEMS devices were deployed based on the assessment, and advanced modules like MQTT communication bridge, enrolment, digital twin, and trust, security, and privacy interfaces were integrated. The pilot successfully implemented measurement and control signals for various devices, provided an application for end-users to monitor energy performance, and offered incentives to users in the form of reduced electricity costs.

The Finnish pilot focused on the iFLEX Assistant, which provided personalized energy-related recommendations to users. The pilot integrated the iFLEX Assistant into existing home devices and systems and developed interfaces for controlling and collecting measurement data. The pilot also implemented various modules and interfaces to enhance functionality. The iFLEX Assistant provided users with data on energy consumption, enabling them to make informed decisions and optimize their energy usage.

Usability testing, workshops, and surveys were conducted separately in each pilot region to gather comprehensive feedback from end-users. The usability test on the iFLEX Assistant App identified certain challenges and areas for improvement, leading to recommended UI changes. The workshops and surveys conducted in the Greek and Slovenian pilots revealed positive responses and valuable feedback from participants, while the Finnish pilot successfully engaged and validated end-users.

The technical validation process in the iFLEX project was enhanced by adopting the JIRA tool, which facilitated requirements validation and monitoring. The consortium made final decisions on requirements, conducted integration tests, and validated the functionality, security, performance, and acceptance of pilot-specific instances of the iFLEX Assistants.

Additionally, a comprehensive business analysis assessed the commercial viability and economic feasibility of implementing energy management systems on a larger scale. The analysis considered factors such as pricing, consumer behavior, market demand, and potential revenue streams, providing insights for developing a detailed pricing strategy and marketing plan.

The document also includes the current values for various key performance indicators (KPIs) after each pilot phase, covering stakeholder contributions, load forecasting accuracy, flexibility modeling, automated flexibility management effectiveness, interoperability level, compliance with privacy and data management regulations, return on investment, technology readiness, number of demand response services, number of consumers, and number of consumer groups targeted.

10 List of figures and tables

10.1 Figures

10.2 Tables

11 References

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