Intelligent Assistants for Flexibility Management (Grant Agreement No 957670)

D8.4 Initial Validation of Federated Pilots

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1 Executive summary

This deliverable reports the evaluation and validation of the federated Finnish pilot of the iFLEX project. The task 8.2 integrates the iFLEX Finnish pilot cluster to the single flexibility platform of the INTERRFACE / OneNet project. The collaboration is also sought with the MAKING-CITY project by organizing a joint pilot. Both iFLEX and MAKING-CITY projects are end-consumer centric whereas INTERRFACE / OneNet is more focused on system perspective. Hence, the federated Finnish pilot cluster provides a holistic solution by harnessing flexibility service from the consumer side and offering to the affected network where it is needed the most, and thus through end-user engagement, validates the iFLEX Assistant in the energy value chain. Additionally, the deliverable exploits possible synergies and seeks cooperation with similar European Commission (EC) Horizon projects including InterConnect, UIW and BD4OPEM as part of the task 8.3. The objective of the planned cooperation is to achieve integrated solutions that are otherwise not possible.

The initial plan was to connect the iFLEX Finnish pilot to the INTERRFACE project but the individual demonstration schedules could not provide such an opportunity, and as to date, the INTERRFACE project has already ended. Alternatively, the integration to the OneNet project is sought. The OneNet project is granted from the same call as that of the INTERRFACE, and has almost the same partners, and objectives. More importantly, the demonstration schedules better overlap in time providing an opportunity to validate the federated iFLEX Finnish pilot.

In this joint pilot, the iFLEX pilot building located in Helsinki is connected to the OneNet platform. The scenario utilized for the demonstration exhibits the complete process of flexibility uptake by the network, i.e., from end-user to the OneNet platform via flexibility market and vice-versa. The functional view / demo setup of the joint pilot and the step-wise data flow are thoroughly illustrated. The iFLEX Assistant performs local energy optimization based on the day-ahead electricity prices, district heating prices and end-user comfort levels. Based on this, the iFLEX Assistant proposes base-line consumption and the flexibility potential of the pilot building that can be offered to the network. The flexibility profile is sent to aggregation and market interface module. The aggregator submits bid(s) to the relevant market which is then forwarded to the OneNet platform where respective energy network optimization takes place. The results are then conveyed to the respective market operator, based on which either the bid is accepted or rejected. In case, the bid is accepted, the command for activating the flexibility is generated and communicated via the iFLEX Assistant. Finally, the activated flexibility is measured and verified against the bid and the base-line consumption for the purpose of remuneration or penalty calculations.

In the last section, the contribution of the iFLEX Assistant in terms of value is discussed from both the end-user and grid perspectives. Apart from the technical validation, possibilities of enhancing end-user's engagement, satisfaction and incentive development are examined with the aim of creating social awareness and market demand for the iFLEX Assistants.

2 Introduction

2.1 Purpose, context and scope

The core concept of the iFLEX Assistant is an intelligent agent that can interact with local energy systems, and other stakeholders in the grid system or markets on consumer's behalf, with the objective of maximizing benefits through automated local energy management. The iFLEX Assistant brings the most value when integrated into the local energy management system (HEMS or BEMS) as it results into efficient learning of consumers' behaviour enabling load control, automating DR, and cost savings etc.

The iFLEX solution alone focuses on engaging end-customers and prosumers to participate in demand response programs through automated management of flexibility. To ensure its replication at the EU level, the iFLEX Assistant is designed in a way so that it can be exploited in continuously evolving market structures as well as under possible conflicting incentive scenarios. Moreover, the iFLEX solution is customizable such that it can manage consumer incentives while managing the flexibility to be used for the grid as well. For instance, the iFLEX Assistant can manage DR according to site-level incentives including self-consumption and dynamic tariff, while offering a part of available flexibility to the grid if the market revenue of flexibility offsets the local savings. However, to validate this functionality encompassing holistic energy and flexibility services, the consumers equipped with iFLEX Assistants need to participate in flexibility markets and trade flexibility potential.

In this context, the iFLEX Assistant prototype, in addition to the actual pilot site in Helsinki, is also planned to be piloted in the Oulu PED area (MAKING-CITY project). The site-level flexibility potentials will be aggregated and offered to the OneNet platform. The OneNet developed a single platform that, through a variety of markets, enables universal participation of network operators and flexibility providers to coordinate close to real time and trade flexibility for power balance and congestion management. During this process, the centralized components such as flexibility register, and TSO-DSO coordination platform perform necessary checks, gather information, and optimize the network operation in question.

To this end, the iFLEX Assistant is first integrated to the pilot building's BEMS and then interfaced to aggregation and TSO/DSO market platforms in the OneNet. This cooperation enables viewing the whole flexibility chain originating from the end-user to multiple markets in relation to incentive mechanism and competitive procurement. The incentives include sustainability, energy cost savings, congestion, and network management. The cooperation with the OneNet also validates the iFLEX Assistant in a large-scale deployment, i.e., universal flexibility market environment, thus signifying the future market needs that can be used to develop business strategy.

2.2 Content and structure

The remainder of the deliverable is organized as follows. Section 3 discusses the cooperation with relevant ongoing EC projects by exploiting synergies and synchronizing common challenges related to the policy and regulatory issues associated with the iFLEX framework. Section 4 specifies the federated Finnish pilot and briefly describes the involved participants, e.g., flexibility assets, aggregator, and marketplaces etc. Section 5 outlines the complete demonstration process and phases involved in the flexibility procurement. It also analyses the results and possible further implications. Finally, Section 6 concludes the deliverable by highlighting impact and important findings.

3 Cooperation with linked projects

3.1 Cooperation with MAKING-CITY

MAKING-CITY is a 60-month project funded by the Horizon 2020 initiative, aimed at transforming urban energy systems towards smart and low-carbon cities using the Positive Energy District (PED) concept. The project develops innovative operational models and technologies to enable large-scale implementation of PED concepts, which will help cities reduce their carbon emissions and achieve a long-term City Vision 2050 for energy transition and sustainable urbanization. The PED concepts are deployed into two Lighthouse cities, Oulu (Finland) and Groningen (Netherlands), and then replicated in 6 Follower cities.

The MAKING-CITY project will be part of the federated pilot together with OneNet and iFLEX projects. In the federated pilot, the iFLEX Assistant solution will be replicated into a supermarket in the Oulu PED area. In addition to the supermarket, there are also apartment buildings in the Oulu PED area. The supermarket was selected as it provides a new type of building type for the pilot. The supermarket uses an energy-efficient vapour compression cycle to produce cooling and heating, with electricity and geothermal energy. It also has solar panels generating 70 kW of electricity. The status of the iFLEX Assistant implementation to the supermarket is presented in more detail in section 4.1.2

3.2 Cooperation with INTERRFACE / OneNet

The OneNet project is developing a single platform for providing flexibility to electrical system. The OneNet platform includes harmonized market products, TSO-DSO co-operation module, flexibility register, and optimization module. In case of electricity network congestion, TSO and DSO can procure locationally focused flexibility resources to mitigate the congestion. This is due to the flexibility register, where all flexibility providers can register their flexible resources with locational information. Thus, flexibility service provider can offer demand response to a specific grid situation. OneNet's optimization module calculates optimal set of flexibility offers, that properly clears the congestion. Furthermore, harmonized market products integrate networks together by offering standardized tools for TSOs and DSOs.

In the OneNet project, Northern cluster's demonstration include iFLEX HOAS residential building as a flexibility resource. This resource is registered to the flexibility register with its respective location in the grid. In the OneNet demonstration, a scenario was run where grid had a congestion, which was mitigated by multiple flexibility bids of which one was generated by the HOAS Building.

3.3 Cooperation with UiW

The Use it Wisely (UiW, Uporabljaj Pametno in Slovenian) was a project financed by the Energy Agency in the Slovenian energy market. The project was active in 2021. The main goal of the project was to evaluate two network fee tariffs. The first was NKKT (Negativna Kritično Konična Tarifa, Negative Critical Peak Tariff), used to stimulate consumption during the times of high PV generation. The tariff was 1/3 of a usual tariff. The tarif was available for 10 hours per day, 3650 hours in a year. The second tariff was PKKT (Pozitivna Kritično Konična Tarifa, Positive Critical Peak Tariff). The tariff tried to reduce peak consumption. Up to 100 hours of PKKT was available per year. The tariff was 9 times higher than ordinary tariff. The key partners in the project were ELE, SCOM and JSI.

Some of the services deployed in UiW project are used in iFLEX project as well, like enrollment module, a data pipeline used to ingest smart-metering and weather data from ELE into RAI layer, the RAI layer itself and parts of data analytic services. The projects were cooperating on service development and improvement. The data collected in UiW is serving as a basis for development of Digital Twin component in the iFLEX project. The data collected in the UiW project has been used to select temperature depended households in the iFLEX project. The households have been invited in the iFLEX project, some of them responded positively to the invitation.

The partners of UiW are evaluating possibilities to repeat the project in 2023 with a help of the iFLEX project piloting group. The possibilities are real, since a forthcoming agency regulation foresee UiW like network fee tariffs starting with 1. 1. 2024. The UiW and iFLEX project could join forces in two ways: the UiW project could benefit from technologically advanced iFLEX pilot users as a larger and more controllable source of flexibility and the iFLEX project could benefit from network tariffs as an incentive to adjust the consumption during consumption and generation peak hours.

3.4 Cooperation with InterConnect and BIGG

3.4.1 Cooperation with InterConnect

The InterConnect (Interoperable Solutions Connecting Smart Homes, Buildings, and Grids) addresses the issue of lack of interoperability, which is a significant concern in the widespread deployment of intelligent smart grid technologies given that a provider change could necessitate the replacement of installations. Instead of being restricted to a single provider, end-users should be free to switch technology providers whenever they feel the need to do so and still be able to adopt sustainable behaviour and take advantage of developments in technology across the board.

Through adaptable and interoperable technologies, the project aims to create an end-user-centric, effective, and open energy management ecosystem where demand side flexibility can be firmly linked with end-user benefits. Fifty European organizations work together in this direction and are interested in the proposed new energy framework. Members of the consortium represent the whole value chain, including R&D institutions, manufacturers, DSO, retailers, IT providers, and energy users, and have expertise in ICT, IoT, energy, data science, and software.

HERON is part of the Greek pilot, deploying pilot assets (i.e., households with smart meters and smart appliances), acting also as a virtual DSO, which is responsible for contracting DR flexibility based on specific grid conditions such as peak load or market spikes. As a result, there are some substantial synergies at design level, with iFLEX gaining from discussions and judgements made on the functionality of the DR solution from the Utility's perspective. InterConnect was launched a year before iFLEX, thus it has extensive experience with technical issues relating to management of the pilot and its assets.

Finally, HERON has been in charge of facilitating knowledge exchange between participants in the iFLEX and InterConnect consortia. In order to address issues with the deployment and use of the pilot equipment for the Greek, Slovenian, and Finnish clusters, iFLEX maintains an open channel of communication given the number of technical providers, manufacturers, and retailers involved in InterConnect.

3.4.2 Cooperation with BIGG

The BIGG project demonstrates the digitalisation of buildings, homes and electricity grids based on an Internet of Things (IoT) architecture, big data, demand response and data analytic techniques for more than 4,000 buildings in Spain and Greece. Solutions include an Open Source Data reference architecture and a standard data model for buildings and a cloud-based Data Analytics Toolbox. HERON is leading the Business Model work package and provides data for the Greek pilot.

In support of the BIGG, HERON upgraded its smart metering platform monitoring real-time consumption in two pilot sites across Athens and Thessaloniki. Acting as a Demand Response Aggregator, HERON has prepared the ground for almost 100 residential consumers to actively monitor their electricity load and receive real-time advice on consumption shifting, based on environmental and electricity market conditions.

The iFLEX Assistant comes to complete and highlight the three aspects of energy savings and efficiency improvements, i.e., know where your energy comes from, know how much energy heavy appliances consume and how energy usage is distributed within the day/week.

3.5 Cooperation with BD4OPEM

The BD4OPEM - Big Data for OPen innovation Energy Marketplace - project is a large-scale project financed through EU Horizon 2020 H2020-DT-2018-2020 call. The main goal of the project is to bridge between the data available in energy/smart grid domain with novel analytic and services by developing a marketplace for data and service providers. The marketplace will be available to a number of stakeholders in a role of service users, data providers, service providers or their combination. The key partners in the project are ICOM and JSI.

A number of energy services being developed in the BD4OPEM project have roots in a Flex4Grid project and have been further developed in UiW project, see Section 3.3. In this way the services being developed in BD4OPEM have influenced the development of services in the iFLEX project, in particularly in WP3. On the other hand, some of the solutions developed in the iFLEX project, like a library for feature extraction from smart-metering data, are being currently reused as a developing prototypes in the BD4OPEM. The load profile

forecast service developed in the BD4OPEM has been used in the iFLEX project for profile forecast in the Digital Twin. The BD4OPEM project will end in the end of this year, 2023. Currently running the piloting period in the BD4OPEM will be an opportunity to further improve the synergies between both projects.

4 Federated pilot

4.1 Flexibility resources

The flexible resources utilized in the demonstration are detailed in the following.

4.1.1 HOAS Building, Helsinki

The initial source of flexibility in the Finnish pilot study was a residential building owned by HOAS (student housing association), which provides rental apartments to students. The building consists of 93 apartments, accommodating over 140 residents. Each resident has access to a User Interface that displays visual representations of the building's energy consumption, CO2 emissions, and thermal comfort measurements (registration required). Residents can also provide feedback on their thermal comfort. Currently nine residents have sensors measuring temperature, humidity, and CO2 levels installed in their apartments.

The flexibility in the system is achieved through a centralized heating system that handles both space heating and heating of domestic hot water. The flexible component is the space heating, which is controlled by actuating various components in the heating system, such as valves, water pumps, and heat exchangers, simultaneously. There are two main modes of controlling the space heating that has been used during the piloting. Firstly, the space heating can be constrained by lowering the heating water temperature during a demand response event. Secondly, the heat pump can be turned off, transferring the responsibility for all heat production, including space heating and heating of domestic hot water, to the district heating network. In this mode, incoming heating energy is obtained from the district heating network and electricity used to heat apartment air, with an exhaust air heat pump capturing energy from the exhaust air and returning it to the apartment heating.

4.1.2 Supermarket, Oulu

The supermarket is a 2000 m^2 sized building. It uses 457 MWh of electricity yearly, of which ~30 % is used to run the heat pump compressors. Solar panels (max. capacity 55 kW) are utilized to compensate the pilot's electricity use.

The supermarket uses a heat pump system to generate heating and cooling. CO2 is used as the heat transfer medium. The CO2 circulation is integrated with other systems via heat exchangers:

- District heating network
- Building heat distribution system
- Utility water heating
- Geothermal well system
- Freezers and fridges.

The pump system can produce high temperature and pressure CO2, while also providing cool CO2 for the fridges and freezers. Any extra energy can be offered to the district heating network through a heat exchanger. Next the heat is offered to the building heat distribution system, which contains a 2 m^3 hot water storage. The geothermal well system is used as a cooling storage for situations when the heat pump is used more than the supermarket heating and cooling needs. The cold end of the heat pump is used to provide cooling for fridges and freezers.

Most of the down flexibility potential is in the building heat distribution system, because of the large thermal mass of the building and the heat water storage. Models of the building thermodynamics and of the heat water storage have been developed and tested against the measurement data. With these models and historical data, it is possible to estimate a theoretical down flexibility potential at a point in time in the past.

Demand response prediction requires predictive models of the heat pump system and its integrations. No predictive models have been successfully validated yet.

Next goals in the development work are:

- Integration of the models in a larger pipeline for testing and further validation
- Predictive models for key parameters, which will enable demand response prediction

4.2 iFLEX Assistant & interface

The iFLEX Assistant is deployed on the HOAS building (work in progress for the supermarket). It is responsible for executing local, implicit, and explicit demand response in the building to maximize the consumer benefits. To this end, it models the baseline and flexibility available in the buildings and provides the Enerim's Aggregation Platform with this information. Additionally, the iFLEX Assistant provides the Enerim's Aggregation Platform with interface for activating flexibility at specified time periods. The interface provided by the iFLEX Assistant in the federated pilot is based on the Automated Flexibility Manager (AFM) interface. A logical level representation of this interface is described in Table 1 and Figure .

Table 1: Logical interface of the Automated Flexibility Manager.

Data item	Description
Flexibility Potential	This data item contains a forecast of the baseline and flexibility potential for the customer.
Explicit Flexibility Activation	This interface is used for explicitly activating flexibility of the consumer.
Load Measurement	This interface provides load measurements for estimating how reliable the forecasts are for a given consumer. This information can be used by the aggregator to estimate the uncertainty of the flexibility management.
Flexible Asset Schedule	This data item specifies the schedule for a flexible asset.

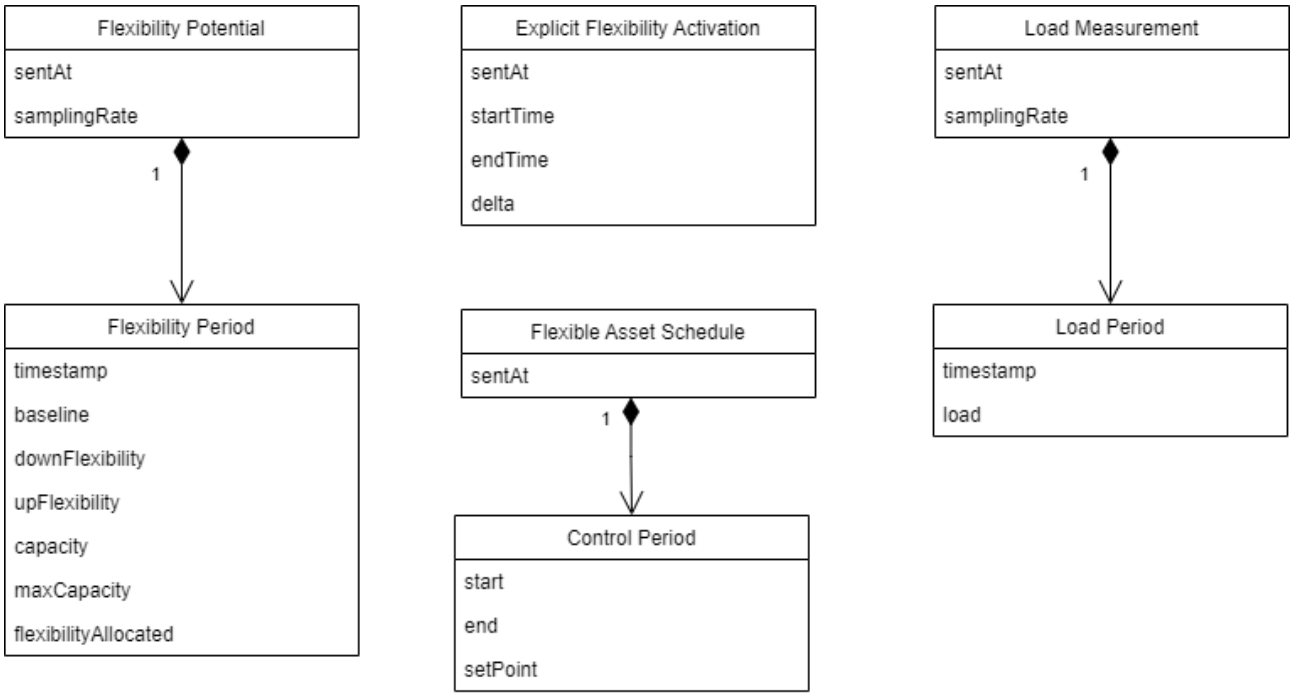

Figure 4-1: Data models for Automated Flexibility Manager interface

In practice, the interface is implemented on top of MQTT with JSON as the serialisation format. The reader is instructed to refer to the D3.8 Revised Automated Flexibility Management module and its upcoming final version D3.9 for details on the AFM interface.

4.3 Single flexibility platform

Single flexibility platform is developed in the OneNet project. The platform includes modules such as TSO-DSO coordination platform, flexibility register, grid model, and optimization module. The platform is the core of the OneNet's research and development effort.

4.4 Flexibility Register

The Flexibility Register is envisioned as one of the key building blocks of the future flexibility markets of power systems where the same flexibility assets can provide services to multiple actors. The flexibility register facilitates information exchange related to the overall flexibility market framework and conducts processes related to asset information management and flexibility verification and settlement. [D7.2]

Flexibility Register's process flow is shown in Figure 4-2.

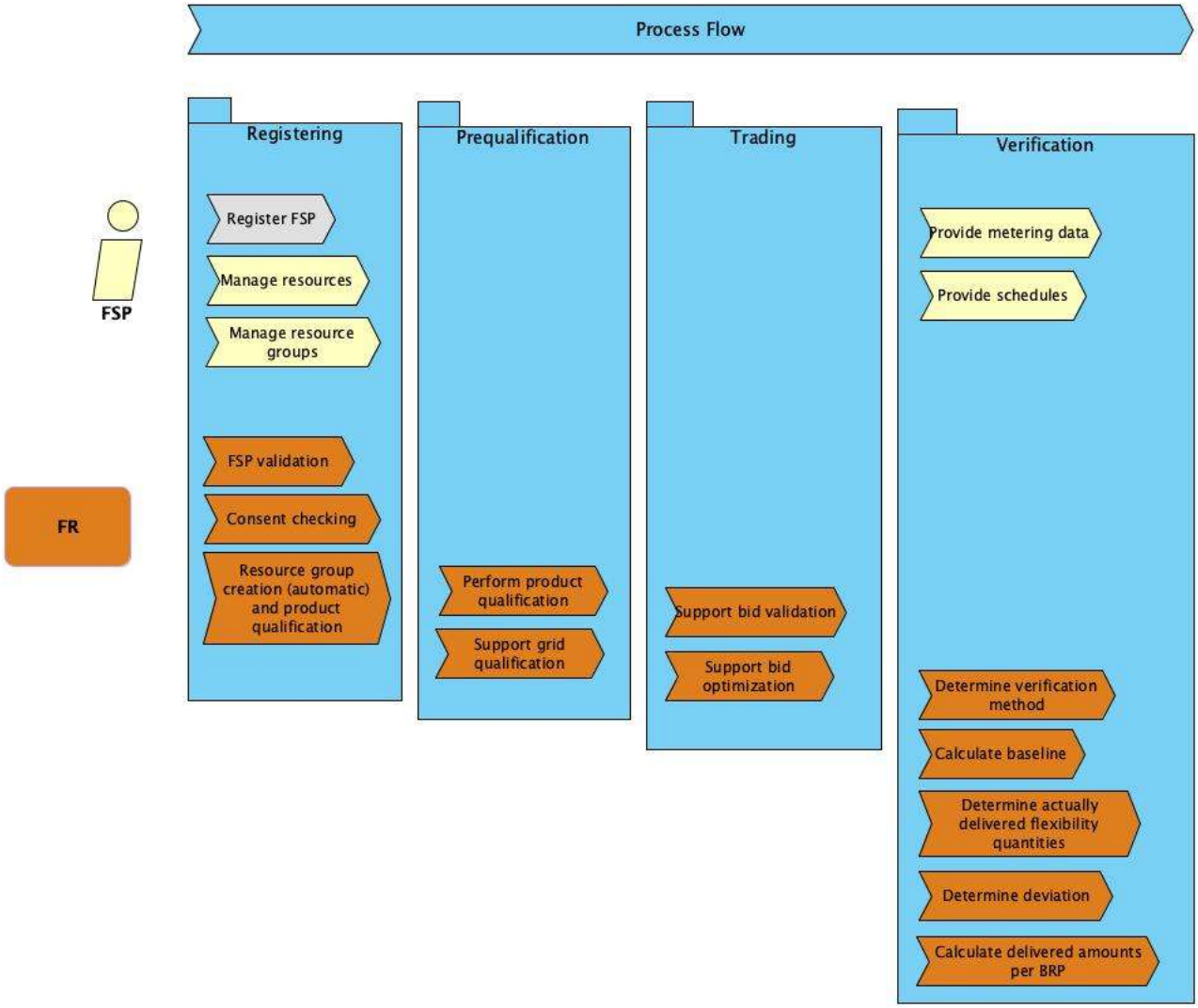

Figure 4-2: Process flow of the Flexibility Register [D7.2]

Key functionalities of the Flexibility Register are:

- Flexibility Service Provider registration and qualification
- Resource registration
- Flexibility contract management

- Flexibility resource group management and product qualification
- Verification process
- Determination of remuneration and penalties.

A flexibility resource is registered to the flexibility register by the FSP. This information is exchanged with SOs for the purpose of initial grid check, i.e., a step used to ensure that activation of the resource acts to mitigate the targeted congestion and does not further lead to violation of grid constraints at any point in time. Based on that, the resource is assigned the status 'qualified' or 'not qualified'. FR then pools resources into groups based on product definitions / requirements communicated by market operators. Here, product qualification routine is initiated. The resource group characteristics are evaluated against the product requirements and the results are stored in FR. This evaluation is necessary to offer a resource group to the relevant marketplace. During the trading phase, FR provides support and exchanges data with relevant entities including the TSO-DSO coordination platform which determines the bid qualification status. It is enabled through metering point ID linking the asset / resource group to the grid topology. All this information including network topology, bids, flexibility purchase offer etc, is fed to the OneNet platform to perform bid optimization. During this phase, the flexibility bids and purchase offers are matched in the most economical way considering costs borne by SOs and grid limitations. The results of optimization are sent to relevant market operators and registered into FR for the purpose of verifying delivered flexibility and conducting financial settlements. FR can perform verification of activated flexibility either by establishing baseline using metering data, or through receiving schedule information from the FSP. Based on the delivered flexibility and activation order, deviation is calculated. Finally, FR calculates remuneration and penalties for flexibility resources and communicates to relevant SOs and MO.

4.5 Aggregator and market interface

Enerim's aggregation platform has been developed and used in different National and International European R&D projects namely INTERRFACE, OneNet, TIoCPS, RESONANCE, and iFLEX to name a few. The platform is developed to perform market integration of (distributed) resources, so as to enable resource owners to provide different services to energy system as well as to gain more benefits from their investment. Since the capacity of the resources does not usually fulfil the market entry requirements, the platform aggregates them in a way the aggregated service can be offered to the market. To maximize the benefit of the resource owners, the platform optimizes the offering value and price against the product requirement. Since the offered service is provided by different resource owners, allocation of the cleared volume / service to the resources and sharing the received profit among the owners are also done by the platform.

According to the above descriptions, the platform has different functionalities which are described in the following:

- Interface with resource owners: The aggregation platform uses the interface to mainly receive information about available services from different connected resources, send service activation signal to the resources and receive acknowledgment (activation feedback) from the resources.
- Aggregation and market integration: The platform aggregates service potentials offered by different resources and prepares the optimum offer for the market. An offer includes price and volume. This functionality needs to be further developed since resources can provide services to different energy and flexibility markets simultaneously, which can be translated to a need for an advanced optimal bidding model in a multi-market environment.
- Interface with the market: The platform uses the interface to submit the prepared bids to the market. The main market target is Nord pool now. The platform can also submit bids to the Finnish national mFRR market (i.e., VAKSI) which is the most important tool for managing the exchange of trading data between flexibility providers and the Finnish national TSO (i.e., Fingrid). The interface is also used to receive activation signal from the market including the service that has been purchased or cleared in the market.
- Service and profit allocation: The platform calculates the allocation of the sold services between the connected resources. It also calculates the share of each resource from the revenue earned from selling the service in the market.

The platform has been developed in a micro-service architecture where there are two micro-services namely resource handling micro-service and aggregation micro-service. The resource handling micro-service handles connection to resources and aggregation micro-service handles aggregation and bidding models.

4.6 Marketplaces

Flexibility as a demand response can be traded at marketplaces like ancillary services marketplace operated by TSO or physical electricity marketplace Nord Pool. In the OneNet project, demand response of the iFLEX building is offered to both Fingrid's (Finnish TSO) held balancing power market and Nord Pool intraday market. The marketplaces offer different type of flexibility products based on activation and gate closure time-frames.

For Fingrid's balancing power market, the compatible product is specified as Near real-time active energy (NRT-P-E) and in Nord Pool intraday the product is Short term active energy (ST-P-E). This harmonized flexibility products delivery need is specified by the SO by initiating a purchase offer in the market of interest. Each product has its own technical characteristics and timeline that affects the flexibility procurement procedure. For instance, the gate closure time for receiving bids in case of ST-P-E is one hour before the physical delivery.

Nord Pool facilitates flexibility trading by utilizing Intraday platform. This is achieved by enhancing the intraday market orders with a flexibility asset ID which, apart from the locational information, indicates information on connected network topology and type of asset etc. The orders can then be activated to fulfil any flexibility need of the TSOs or DSOs. Flexibility asset owners can also offer the same asset on the intraday market with the same order which will help them to commercialise the asset more as they have a broader possibility to trade the flexibility.

Fingrid's ancillary services markets include a marketplace called mFRR which can receive regulation bids until 15 minutes before the delivery hour. In the OneNet project, the product for real-time power balancing is harmonized enabling market-driven flexibility uptake by networks irrespective of the location of the resource. The product is designated as NRT-P-E. Fingrid as a market operator facilitates the trading process for the flexibility providers. This includes also the information exchange required for the processes, i.e., submitting bids, sending activation signals, and possibly exchanging metering data for monitoring the activations. Similar to Nord Pool's market, flexibility asset ID is provided with the market offer.

5 Demonstrated Scenario and use case

The iFLEX project is collaborating with the OneNet and MAKING-CITY projects by sharing piloting cases. In this initial phase, collaboration demonstration was arranged with the OneNet project. The iFLEX provided the HOAS building as the flexibility resource and the iFLEX Assistant as the interface. OneNet provided the marketplace integration to the OneNet platform. As mentioned in sub-section 4.6, multiple products are available to fulfil the needs of SOs. Depending on the product, the optimization model of the OneNet platform is different to take into account the requirements of the SO during procurement. Moreover, the optimization is performed for each market session and for each call to purchase offer for flexibility. In this demonstration, the purchase offer and the iFLEX HOAS building flexibility is targeted at Nord Pool intraday market within ST-P-E framework and activated accordingly.

The demonstrated scenario is illustrated in Figure 5-1 which displays a simplified model of the Fingrid transmission network at two different voltage levels portrayed using red and blue colours.

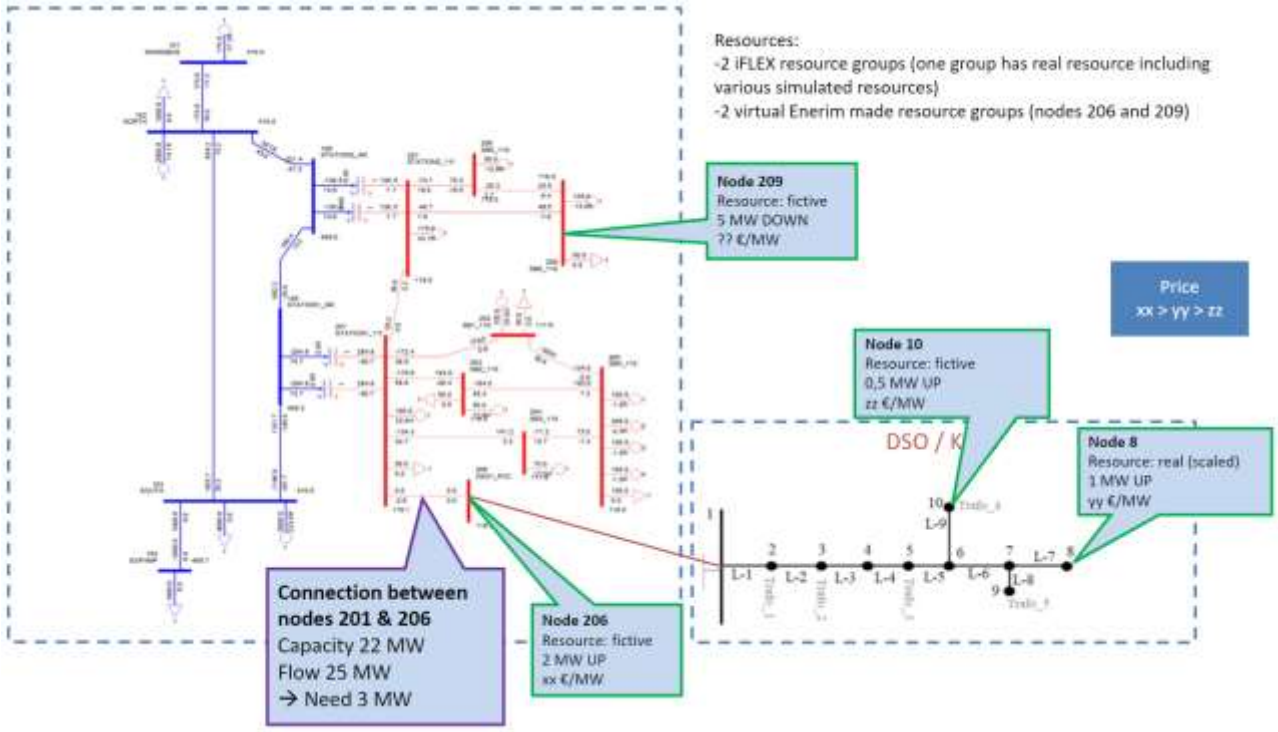

Figure 5-1: Scenario of the iFLEX-OneNet demonstration

In this scenario, Finnish TSO network has a power congestion of 3 MW in the line connecting nodes 201 and 206. The node 206 also represents a DSO network. The real iFLEX building is located in the KSOY (DSO) network behind node 8 along with simulated resources as an aggregated asset. Furthermore, a simulated iFLEX building (digital twin) is located at node 10 of the KSOY distribution network and other virtual resources are located at nodes 206 and 209 of the Fingrid network. The flexibility resources available for trading are summarized in Table 2. It is to be noted that bid volume quantities (MW) are proportionately elevated to match the scale needed at the TSO level. Also note that the negative price for the asset located at node 209 of the FG network indicates that the flexibility provider is willing to pay to provide down-regulation. This is to ensure that imbalance position remains the same before and after the power congestion is optimally removed from the system. Further, for simplicity, the bids are assumed to be fully divisible, i.e., can be cleared between any energy quantity ranging from 0 to the offered maximum volume and does not involve any minimum bid volume requirement. However, other bid types such as indivisible or partially divisible bids can also be utilized in the framework.

Table 2. Flexibility assets and corresponding bids in the flexibility market

System ID	Node ID	Direction	Quantity offered (MW)	Offered price (€/MWh)
KSOYV	10	Up-regulation	5	700
FG	206	Up-regulation	2	900
KSOYV	8	Up-regulation	1	600
FG	209	Down-regulation	5	-700

5.1 Process flow

Different market participants and partners of the OneNet project were involved in the iFLEX-OneNet demonstration. Resource provider (RP) was VTT (building owned by HOAS). Enerim and Vattenfall were working together as the Flexibility Service Provider (FSP) and market interface. Nord Pool was acting as the Market Operator (MO). Cybernetica and VITO were monitoring the demonstration as the developers of the OneNet platform, and Fingrid acted as the System Operator (SO). Furthermore, KSOy (DSO) was present, but they did not have any operational role in this scenario.

FSP / Aggregator had registered and prequalified the flexibility resources before the demonstration at the Flexibility Register, which is not shown in the process flow.

Steps in the process in order:

1.a. SO created purchase offer to mitigate the TSO network congestion.

1.b. RP is providing continuous forecast of flexibility potential.

1.c. FSP created bids according to flexibility potential of the resources available.

2. MO forwards bids to TSO-DSO CP.

3. Optimization module runs the optimization with the included bids in search for congestion clearing outcome.

4. After optimization, TSO-DSO CP recommends probable solution, and SO buys bids required.

5. MO clears purchased bids from the marketplace platform.

6. Aggregation platform sends activation command for the purchased hour.

7. RP activates the purchased potential and recalculate future potential.

8. RP provides FSP the metered data.

9. FSP forwards metered data to TSO-DSO CP.

10. TSO-DSO CP verifies activation and calculates renumeration.

Process flow of the demonstration is shown in Figure 5-2.

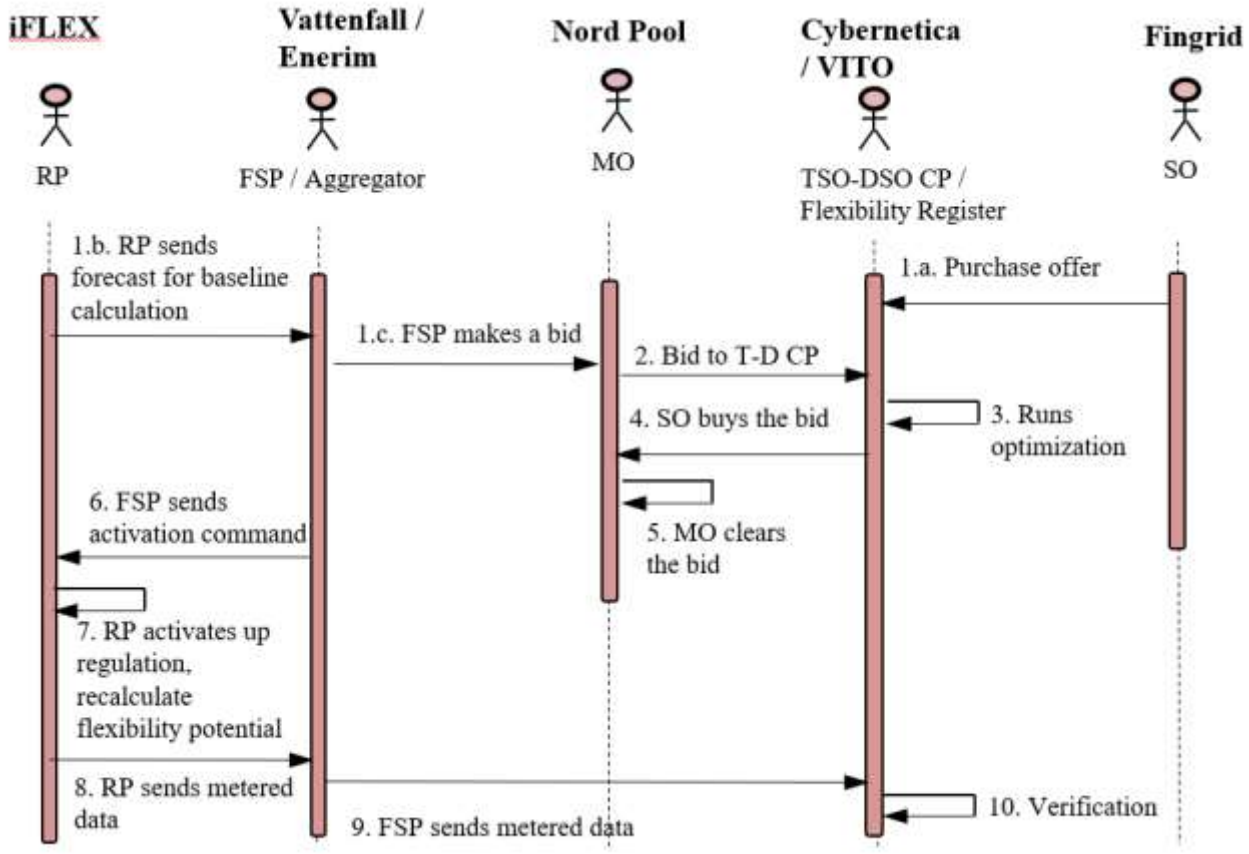

Figure 5-2: Process flow of the iFLEX-OneNet demonstration

5.2 Trading phase

The demonstration focuses on the bid optimization system use case which automatically includes the grid and product qualification system use cases. The demonstration was launched on March 24, 2023, at 9:25 EET.

5.2.1 Specification of purchase offer

The market-driven flexibility uptake process is initiated when SO identifies or forecasts a possible power imbalance or power congestion issue in the network in any following point of time. In the initial phase, TSO forecasts network state and recognizes a congestion of 3 MW in the line connecting nodes 201 and 206 for the time stamp 14:00 – 15:00 as illustrated in Figure 3. Accordingly, SO specifies a purchase offer in the OneNet platform. This purchase offer is a data set with the necessary information to launch the market clearing optimization process. It comprises the desired market product to be procured, delivery hour or timestamp, congestion (if any), imbalance position of the network (marking if balancing needs to be included) and cost cap of the market session to mitigate the issue. The purchase offer is summarized in Table 3 below. Note that the flexibility is needed several hours after registration of the purchase offer, therefore the market product ST-P-E is chosen being the most suitable under given conditions of the demo.

After passing this info to the OneNet platform, the trading phase is initiated.

Table 3. Purchase offer

Type	Timestamp	Imbalance Position (MW)	Congestion	Total Cost Cap (€)
Nord Pool Intraday ST-P-E product	• Start: 2023-03-24; T14:00:000 • End: 2023-03-24; T15:00:000	Unchanged. Optimisation uses default values	3MW excess flow in Line 201 – 206	Not provided. Optimisation assumes total cost is unlimited

5.2.2 Bid submission, matching and acceptance

Any market participant can provide the available flexibility within the stipulated time. Enerim's aggregator and market interface module is continuously keeping an eye on the marketplace. Moreover, it continuously receives updated baseline consumption and flexibility potentials for the following time slots from the iFLEX Assistant as well as other flexibility resources, located at node 206 (KSOY network). In this respect, Figure 5-3 presents a specific instance of the forecast of heat demand fed by heat pump in case of the iFLEX building. It is important to mention here that the forecasted flexibility is to be harnessed by sacrificing thermal comfort levels, i.e., slightly altering the indoor temperature from the preferred set point in the pilot building. It is supported by pre-heating or pre-cooling the well-insulated building envelope depending on the electricity, district heat tariffs and self-consumption of solar panels yield. Such a building thermal inertia dynamics result in significant reduction of energy procurement costs. The said end-user flexibility potential is realized through deep reinforcement learning routine integrated to the iFLEX framework.

The market interface module optimizes the flexibility potentials in terms of price to forms bids that does not lead to liquidity being reached. As summarized in Table 2, 3 individual bids from 3 resources are submitted by the market interface module to the Nord Pool intraday market few hours before the delivery need. Note that these bids have a locational / metering ID associated with them along with other attributes. Figure 6 shows an instance of API of Nord Pool Intraday market illustrating the submitted bids. Besides demand flexibility bids, generation flexibility bids proposed by TSO Fingrid can also be seen in Figure 5-4 for power balance management. The Nord Pool then forwards the bids to TSO-DSO coordination platform which fetches necessary information from the FR to perform mandatory checks before proceeding to actual bid optimization.

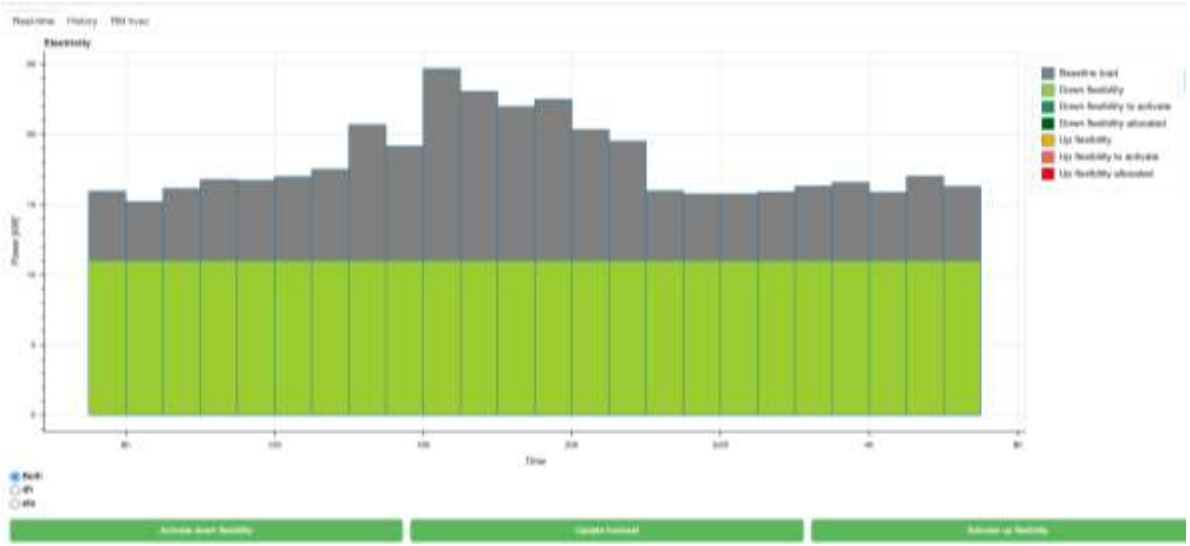

Figure 5-3. Schedule forecast of iFLEX building before flexibility activation

Figure 5-4. An instance of Nord Pool Intraday market

The objective of optimization is to match purchase offer with flexibility bids at minimum costs, and avoiding further issues in the neighbouring grids involved, enabling value stacking. The optimization needs to be repeated if bids become unavailable during optimization and there is sufficient time before physical delivery, particularly in case of long-term capacity products. Based on the optimization results, the OneNet platform

proposes MO to procure bids against the purchase offer as summarized in Table 4. Note that the energy quantities are in kWh and the price is given in €/kWh. The MO, i.e., Nord Pool clears the bids, or volume of bids according to the optimization results, provided the bid still exists, which was the case in this demonstration. If, for some reason, bids would have become unavailable during optimization due to matching or contracting by other parties, the whole optimization routine has to be performed again considering the available bids and the SO might need to update the purchase offer depending on the time remaining to physical delivery.

The 3 MW congestion is optimally removed by activating the 03 Nos. up-regulation bids, i.e., demand decrement. However, such an action could impart 3 MW power imbalance in the network, which is not acceptable according to the purchase offer listed in Table 3, hence 3 MW of generation at node 209 is downregulated to restore the actual / initial power balance of the network. The fully cleared bids are removed from the market while the uncleared volume of partially cleared bids remains at the marketplace till expiry time or acceptance by a participant, whichever is earlier.

Table 4. Bid optimization results

SystemId	NodeId	Sense	Price	Quantity Offered	Cleared
KSOYV	10	UPWARD	0.7	500	500
FG	206	UPWARD	0.9	2000	1500
KSOYV	8	UPWARD	0.6	1000	1000
FG	209	DOWNWA	-0.7	5000	3000

5.2.3 Activation of flexibility

After the marketplace, i.e., Nord Pool clears the bids, it sends an activation command to the ‘aggregator and market interface module’ which calculates the amount of flexibility need to be activated for each participant. Since the submitted bids in Table 4 demonstrate individual entities / assets that were not aggregated at the bidding phase, the market interface module reflects the same activation signal to respective individual entities. In case of the real building located at node 8 of the KSOY network, the iFLEX Assistant receives the activation order. The iFLEX Assistant schedules the activation of the cleared volume of flexibility and submits the updated schedules to the ‘aggregator and market interface module’ as depicted in Figure 5-5 below. The figure illustrates the forecasts for hourly base-load consumption, available down-ward flexibility potential and the scheduled flexibility to be activated during the targeted time stamp, i.e., 14:00 – 15:00. Upon activation of the ordered flexibility, the TSO’s network congestion is resolved while retaining the balance position, such that the network transitions to a new state with no technical violations.

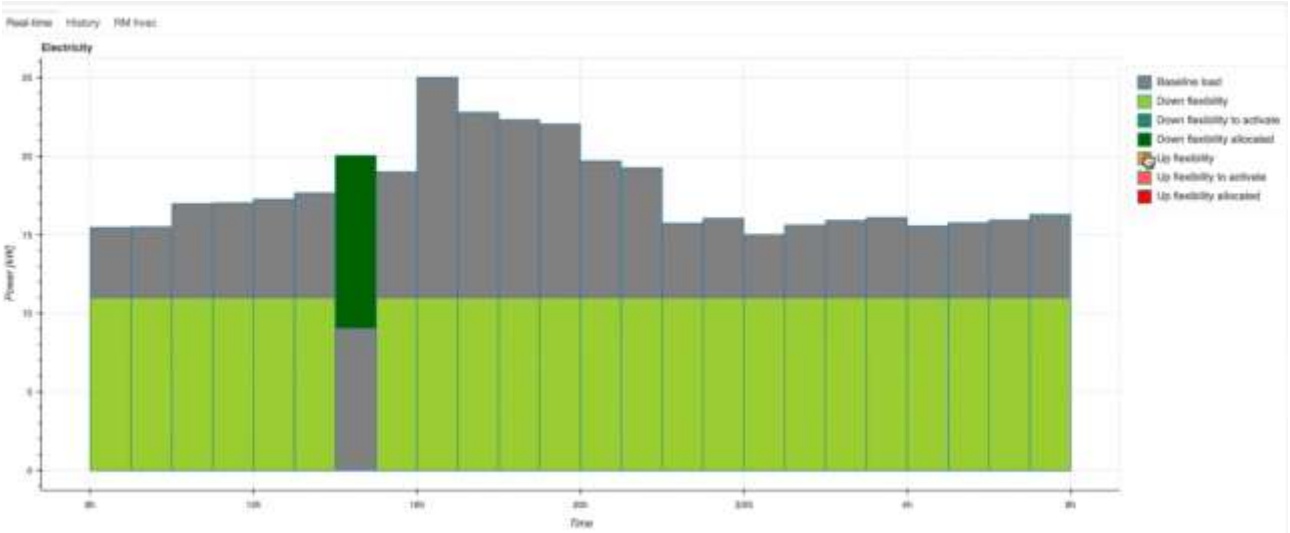

Figure 5-5. Scheduling of flexibility activation

5.3 Measurement, and verification

After the physical delivery hour, the FR initiates the verification process. FR gathers information about activation commands in relation to the cleared bids, by market operator and the actual delivered flexibility by the flexibility resource. FR assesses whether each asset provided the desired amount of flexibility in accordance with the activation order. To do so, FR uses metering data provided by FSP, accesses datahub, or establishes a reference (baseline) value based on the historical metering data. Baseline calculation method often requires lot of historical metering data, which can be an issue in case of a newly qualified flexibility resource. However, the baseline method works quite accurately for resource that has a repetitive consumption profile. Once the quantities are determined, FR delivers the committed energy volume quantities and the associated deviations to the respective MO who then proceeds for financial settlements in terms of remuneration and penalties. This information is also shared with concerned SOs for possible flexibility procurement in real or near real-time, if needed.

In this demonstration, the activation of flexibility was found in accordance with the submitted bids and corresponding activation orders. In other words, the heating demand of the iFLEX building was down-regulated (to match the scale of the submitted / cleared bid) during time stamp 14:00-15:00 as depicted in Figure 5-5. Practically, it was achieved by optimizing the operation of district heat and heat pump together with indoor thermal comfort management. The iFLEX Assistant provided the metering data which was submitted to FR (integrated to the OneNet platform) through market interface platform. Baseline method was utilized for calculations. Afterwards, the measured flexibility is shared with the MO and TSO Fingrid respectively. We conducted a validation of the results by measuring the impact of flexibility activation on district heating power and electricity power during our test. The pilot integration test was successful as evidenced by a noticeable decrease in electricity power level, allowing us to effectively trade real flexibility. However, we encountered a forecasting error during the test that was larger than expected, as shown in Figure 5-6. This error was attributed to a defect in the model training data pre-processing procedure. After some corrections, we repeated the flexibility activation procedure at the same time of day and obtained significantly improved results, with forecasts closely aligning with actual measurements as depicted in Figure 5-7.

Lastly, this deliverable discussed the activities of the federated iFLEX pilot with the OneNet platform. The activation of flexibility indeed results in reduction of energy procurement costs of the pilot building. To this end, the small and large-scale pilot deployment and validation of the iFLEX Assistant will be carried out separately in deliverables D7.6 and D7.7 respectively.

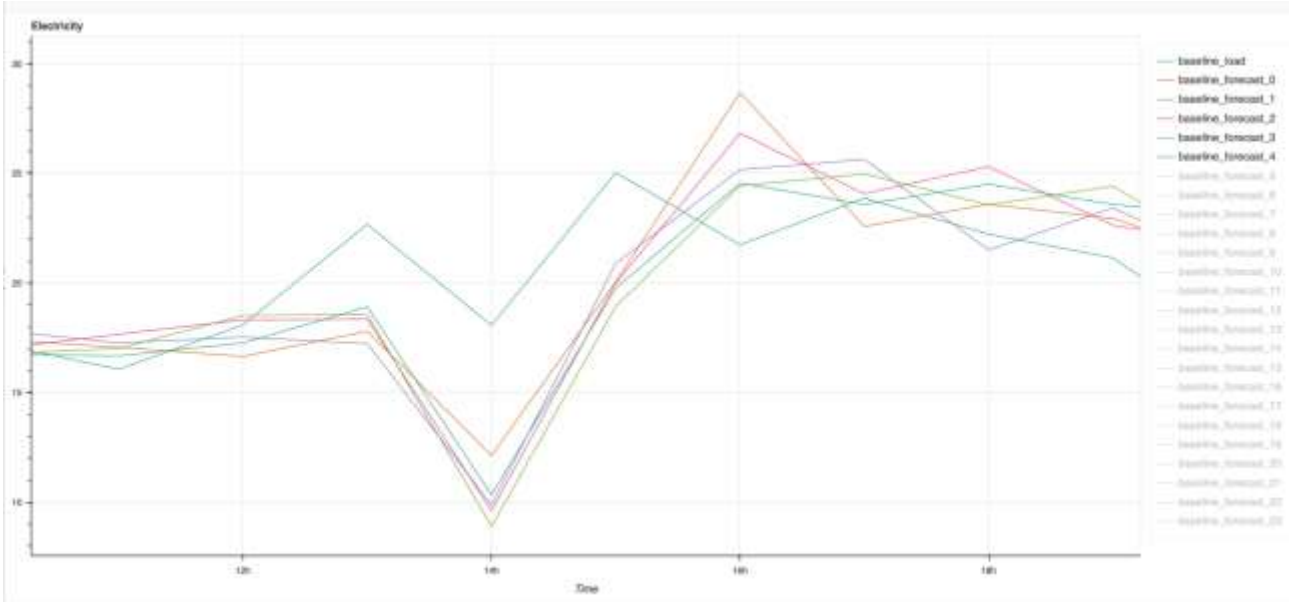

Figure 5-6. Forecasted electricity, initial version

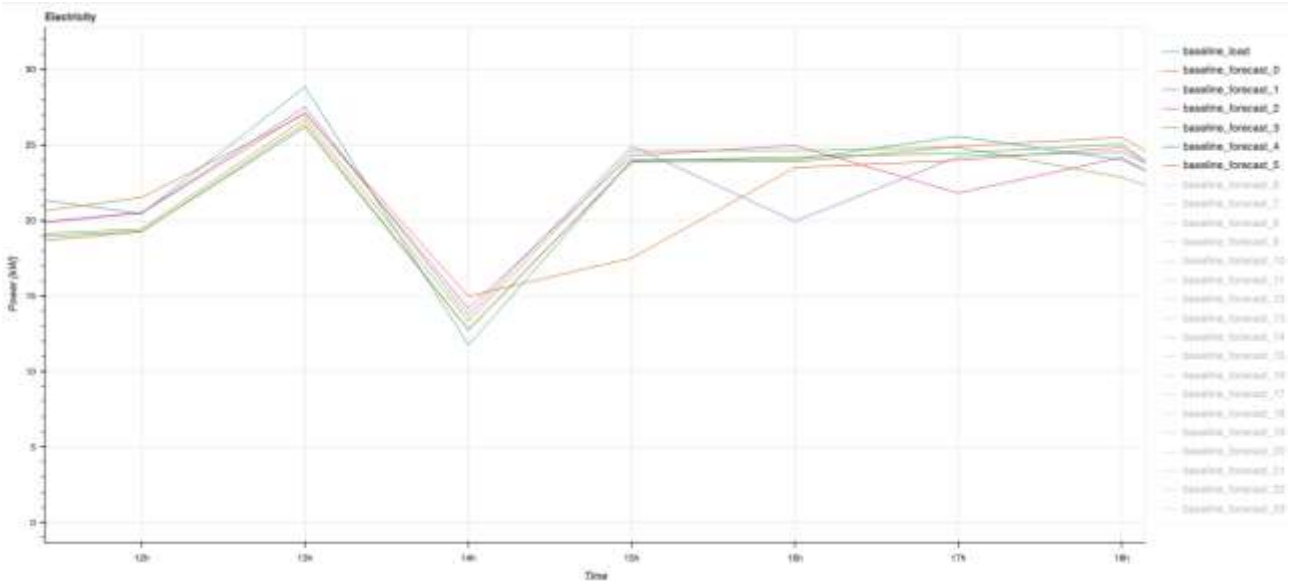

Figure 5-7. Forecasted electricity with corrected modeling approach

6 Conclusion

This deliverable outlines project's federated Finnish pilot's evaluation and validation. Collaboration with the MAKING-CITY projects, in Oulu PED area, is also explored by designing an joint pilot, as iFLEX and MAKING-CITY are both end-consumer centric. As a result, iFLEX Assistant adds significant value in the energy value chain, hence it offers comprehensive solutions. In addition, the deliverable explores the collaboration with related European Commission (EC) Horizon projects, providing integrated solutions that would not be feasible otherwise. The value that iFLEX Assistant adds is clearly addressed from both the end-user and grid perspectives.

iFLEX Assistant's main concept is an intelligent agent that can communicate with local energy systems, other market participants, and grid system stakeholders on behalf of consumers with the goal of maximising benefits through automated local energy management. When the iFLEX Assistant is incorporated into the local energy management system, it adds the most value from both end-users and grid, since it effectively analyses consumer's behaviour and enables load control, automated DR and cost savings.

For the joint Finnish pilot, based on day-ahead power costs, district heating rates and end-user comfort levels, the iFLEX Assistant optimises local energy consumption. According to this, iFLEX Assistant makes recommendations for baseline consumption and the flexibility potential which can be provided to the network from the pilot building. The market interface and aggregation module receive the flexibility profile and then the aggregator sends bids to the appropriate market, which are subsequently sent to the OneNet platform for the suitable energy network optimisation. The findings are afterwards transmitted to the appropriate market operator, who decides whether to accept or reject the offer based on them. If the bid is accepted, the iFLEX Assistant will produce and deliver the instruction to activate the flexibility. For the purpose of calculating compensation or penalties, the active flexibility is finally evaluated against the bid and the baseline usage.

As a final remark, the iFLEX Assistant is first integrated to the pilot building's BEMS and then linked to aggregation and TSO/DSO market platforms in the OneNet. The ability to view the entire flexibility chain, starting with the end user and ending with numerous markets, with respect to incentive mechanisms and competitive procurement becomes feasible by this cooperation. Sustainability, energy cost reductions, congestion, and network management are among the motivations. The collaboration with OneNet also verifies the iFLEX Assistant in a widespread market setting, i.e., universal adaptability, indicating future market demands that may be utilised to establish a business strategy. Finally, iFLEX Assistant is designed to be utilised in constantly evolving market structures as well as under potential conflicting incentive conditions in order to secure its replication at the EU level, as it serves management of consumers' incentives and flexibility to be used for the grid.

7 List of figures and tables

7.1 Figures

7.2 Tables

8 References

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