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FI SMEP

Trial and service design document on FISMEP infra- structure

D2.1, part II

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ERA-Net Smart Grids Plus | From local trials towards a European Knowledge Community

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1 Introduction

This document reports on the development and technical implementation of an energy feedback system called ERO. The development of this system is part of the project FIWARE for Smart Energy Platform (FISMEP). FISMEP is a highly interdisciplinary project that involves advanced solutions in the area of energy, ICT and behavioral science. Concerning the energy scenario, FISMEP will focus on :

1. Advanced monitoring solutions applying the latest advances in the area of distribution grid monitoring based on PMU technology. PMU are widely used in transmission systems but a recent trend is showing a new role for this technology in support of distribution level state estimation. This is a new area developed in support of the concept of Active Distribution Network driven by the penetration of renewable energy sources.
2. Advanced automation solutions for multi-terminal MVDC grids. DC technology is seen as a key enabler in enhancing network capacity.

Concerning the behavioral science aspects, FISMEP will use as foundation the user-centered approaches developed at Chalmers, Sweden:

Insight and Appliance studies on the artefact landscape affecting the user level energy consumption behavior

System architecture and existing infrastructure for energy monitoring on single household and habitation Living Lab resolution

Design and implementation of user-centered feedback systems as well as analyses on generated data and user experience.

The FISMEP platform can be seen as an overarching scientific result able to capture the knowledge from these three different fields in a software ecosystem flexible and open and then ready for the exploitation in completely new and innovative business models.

The first part of the reports describes the design of ERO including the functionality and features of the system. Furthermore, a number of usage scenarios are described that give a more detailed impression on how ERO operates, these scenarios will be used as a foundation for further user testing with ERO in the HSB Living Lab at Chalmers.

The second part reports on the technical implementation of ERO and how it connects to FIWARE.

1.1 Problem definition

There is an urgent need to unlock Smart Grid Technologies and Services by means of a standardized software platform that can support intEROperability. To achieve this goal, FISMEP leverages activities performed at European and local level in the last few years. Main pillar is the result of the EU Project FINESCE funded within FI-PPP phase 2. As result of that project first steps have been performed towards a cloud-based, service-oriented, open-source middleware platform, the Smart Energy Platform, capable of supporting business models of different Smart Energy actors. While this platform has been demonstrated in 7 field tests within FINESCE, main goal of FISMEP is to expand the experience in breath and locations adding experiences from other countries such as Romania, Sweden and Germany. The goal is to enrich the set of use cases in the platform and to exploit different media, including the Knowledge Community, to raise awareness, adoption and support in Europe.

1.2 Description of ERO

ERO is a front-end user-interface that enables monitoring, controlling and planning of energy consumption. It addresses the end-user perspective in energy management and creates flexibility by engaging consumers in their energy consumption. The consumer is initially engaged through setting a Personal Energy Threshold (PET) which consists of a boundary that is based on a variety of factors such as the source, CO_2 footprint and price of energy. In relation to this PET, the energy consumption can be planned and controlled through active choices by the user and assessment of real-time energy data. It gives consumers awareness and insights on their energy consumption and through offering control allows for more conscious decisions. ERO also serves to monitor and to analyze end-users' energy behavior. It creates a direct pathway between the energy system and the end-user and enhances extended controllability. The interaction, which ERO enables, creates flexibility within the energy system, which could be used to achieve greater penetration of renewables and lower end-user consumption.

1.3 Features of ERO

1.3.1 Personal Energy Threshold

When setting the PET, the users can select between three different energy profiles. The first one allows the users to select their preferred energy sources for both electricity and district heating. Short facts about each energy source is available to guide the users in their choice. With the sources selected, the users then get to adjust the minimum share of the total energy production that they would like their selected energy mix to have. A simple visualisation shows how this adjustment affects not only the momentary PET value but also the parameters which are the focus of the two other energy profiles: CO_2 footprint and cost. When selecting one of these profiles instead, the principle is overall the same, allowing the users to adjust either the maximum carbon intensity or cost per kWh of both electricity and district heating.

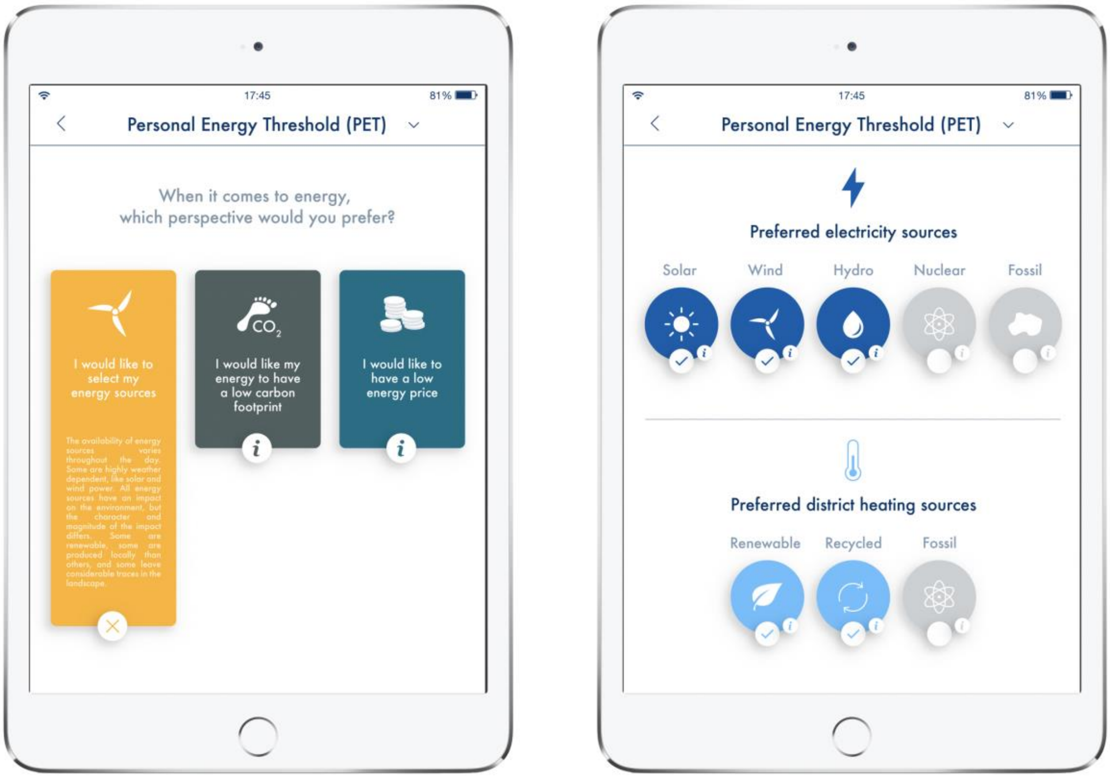


Image 1: Setting up the Personal Energy Treshold

1.3.2 Home screen

The home screen is divided into two main sections. The above section has three different views which the user can slide between showing (1) the current consumption of electricity as well as district heating in relation to the PET, (2) the current energy mix of both energy types and (3) the current status of the local solar production in HSB Living Lab as well as its battery storage. The lower section shows all active as well as planned energy consumers in the common space or the private room, which the user can switch between at the very top of the screen in the personal interface. The common interface only shows activities in the common area. The activities are placed on a timeline with a circle in the colour of the energy type and a radius corresponding to the magnitude of the consumption.

When the PET is exceeded for either of the two energy types, the consumption above the limit and the activity circles of that energy type turns red, to catch the users' attention and urge them to turn off the highest consumers. When there are instead favourable conditions to consume energy, for example when the solar production is running high, the consumption and activity circles turn green to encourage the user to use energy at a good time.

Image 2: The home screen with the three different upper sections

1.3.3 Options

The ERO button at the lower right of the screen shows available options such as *Favourite modes, Add activity, PET settings* and *Profile*. In Profile, the user can access a progress report, which will be sent to the user each week to give feedback on to what extent the PET has been sustained, the average energy mix and a retrospective view of the energy consumption.

1.3.4 Activity planning

The two tabs *Electricity* and *District heating* in the bottom tab bar give the user an overview of both energy consumption forecast and history and keeps the lower section of the home screen showing ongoing and planned activities. Clicking on one of the activities reveals three alternative actions: to cancel the activity, edit the activity or add another time slot of the same activity. The two later options take the user to a planning page where he or she can set the start and end time of the activity and in some cases, such as for floor heating, also set the desired temperature. The user can in some cases choose to repeat the activity on the same time for certain days and get a notification before the activity will start.

Image 3: The two bottom tabs Electricity and District heating and the expanded options menu (right)

1.3.5 Energy availability

The fourth tab takes the user to a page visualising the energy availability of the electricity and district heating grid as well as the local solar production. The upper section shows the current status, just like in the home screen, while the lower section shows a forecast and history of the energy mix and price.

Image 4:The energy availability tab inside the ERO app

1.3.6 Messages

In the final tab, *Messages,* the users will get notifications about for instance when there are favourable or unfavourable energy conditions and each week receive a progress report. This tab is also supposed to work as a chat for the residents where they for instance can plan shared energy activities such as cooking or the washing machine.

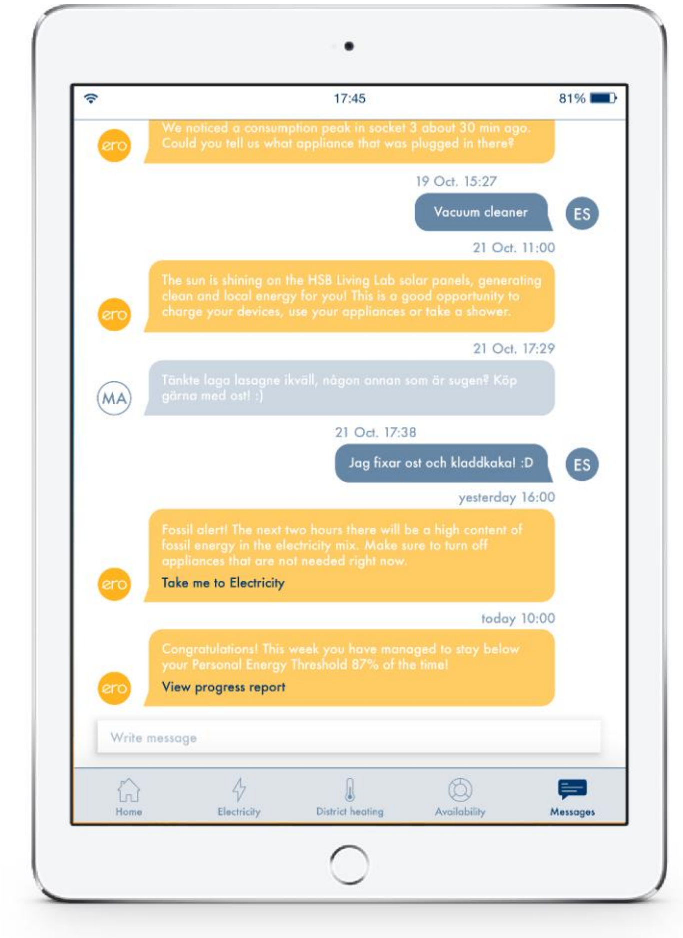


Image 5: The messages tab that enables more direct feedback to the user

1.4 Use case scenarios

1.4.1 Temperature control

This scenario illustrates how an ERO user could interact with the heating system in their apartment and more thoroughly control their energy consumption trough indoor temperature management.

Description of user scenario

Elon sleeps best in cold temperatures and has therefore used his ERO app to make a custom temperature setting for the bedroom. On workdays, the temperature in the bedroom is set to minimum 17°C and maximum 19°C between 11 pm and 6 am. When he gets up at 6:30 and eats his breakfast, he prefers it to be slightly warmer and has therefore set a temperature span of 19-23 degrees between 6 and 7:30 am. After that, he leaves for work and doesn’t really care about the temperature in his apartment. Since Elon has not bothered to make any setting himself, ERO has suggested a temperature span of 17-25 degrees for the rest of the day to allow for the Energy Manager device to optimize the power control and avoid consumption peaks.

Value contribution from user scenario

EON perspective

The ambition with this user scenario is to investigate whether end-user interactions could enable useful flexibility in the energy system. CESO normally operates with boundary conditions not to affect indoor climate which limits the potential of the technology. If the end-user could interact with CESO trough the ERO application this could partly attenuate this limitation. From the role as DSO of district heat it is of great value to investigate the quantity of flexibility achievable trough this strategy, but even more important is what time of the day this additional flexibility could be available.

Chalmers perspective

The outcome from this user scenario is strongly dependent on human behavior and acceptance. It put high demands on the end-user to be interactive with the ERO application and be anticipative about their heat demand. Chalmers ambitions are mainly research related and include areas such as application use patterns, functionality testing and activity management. The end-user experience from this user scenario is of great importance since it high-lights the relation between the energy system and human acceptance which has great investigational value for future research.

City of Malmö perspective

The ambition for city of Malmö is mainly to visualize values from made efforts within the municipality. These could be environmental or financial values which can be used as status update in the progress towards reaching settled climate-work objectives.

Implications for implementation

- Customer enrolment for installation of the CESO solution.

- Customer enrolment of at least 50 ERO users, where large majority must be in the same building.
- Establish agreements with users on installations and participation.
- Installation of Energy managers in concerned buildings
- Hardware instalments to make regulation of radiator systems in individual apartments possible. At least one installation per apartment.
- Temperature sensors inside every apartment.
- Hardware for steering radiators must be integrated in the ERO application.
- The ERO application must be able to aggregate relevant data and communicate this to the CESO system.
- The CESO system must be able to translate incoming data into useful flexibility.
- The CESO system must be able to determine and send information on "required" flexibility.
- Enabled flexibility must be forwarded to DSO interface.

1.4.2 Energy compensation

This user scenario illustrates energy compensation and how the ERO application could interact with the user to create flexibility and compensate for earlier consumption.

Description of user scenario

"It is a gray and rainy Sunday, a perfect day to stay indoors and bake bread, at least according to Alva. She checks her ERO app but discovers that her energy consumption is already close to the Energy Threshold. Without sun or wind, the ET is expected to stay low until the next day, but Alva will not have time to bake tomorrow. She starts preparing a dough anyway and after a while turns on the oven. Then she hears a tone from her phone. It is the ERO app, asking her for permission to lower the indoor temperature with two degrees for the next six hours in order to reduce her energy consumption and save a certain amount of CO_2. Alva accepts and feels pleased about finding a way to compensate for the energy she uses to bake the bread."

Value contributions from user scenario

EON perspective

This user case could be of great interest for peak shaving and to handle bottle-necks in the distribution system. During situations when production and distribution is stressed this could be an alternative to release flexibility in the system. A strategy could be that some users compensate for earlier peak hour consumption and then have this measure rotate among the users. This would over time decrease the general consumption during peak hours and release pressure on production and distribution.

Chalmers perspective

This user scenario would allow the ERO application to send requests to the user which of course is an interesting functionality. This makes the ERO application even more interactive and increases the potential of catching the attention of the user. It is also a scenario where ERO could support decision making which is interesting from behavioral and acceptance perspectives.

Implications for implementation

- Customer enrolment for installation of the CESO solution.
- Customer enrolment of at least 10 ERO users in each CESO enrolled buildings.
- Establish agreements with users on installations and participation.
- Installation of Energy managers in concerned buildings.
- Hardware instalments to make regulation of radiator systems in individual apartments possible. At least one installation per apartment.
- Temperature sensors inside every apartment.
- Individual measurement of energy consumption for each apartment with relatively high granularity. (Maybe not necessary).
- Potential solution could be to generate made-up CO_2 forecasts which could be used to realistically simulate scenarios and create requests based upon those. This solution does eliminate the need for individual measurement.
- Hardware for steering radiators must be integrated in the ERO application.
- The ERO application must be able to aggregate relevant data and communicate this to the CESO system.
- The CESO system must be able to translate incoming data into useful flexibility.
- Enabled flexibility must be forwarded to DSO interface.

1.4.3 Progress report

This user scenario describes how progress in the ERO application could be presented. It also shows how the ERO application could give suggestions to the user on how they should change their settings in the application.

Description of user scenario

"Ellen and Isac open the ERO app for the first time. They are asked to fill in their household profile, set their Energy Threshold and a temperature span which they are willing to accept for either the entire apartment or for each room individually. They are informed that the household profile, Energy Threshold and temperature settings can be changed at any time. One week later they receive their first progress report. It shows that their household uses 11% less energy than the average of all households in the building, but 23% more than the average when compared only to the two-person households in the building. They have managed to stay below their Energy Threshold (ET) 94% of the time for electricity but only 62% for district heating, with an average energy mix that consists of 30% fossil energy. Based on this result, ERO suggests a lowering of the maximum preferred carbon intensity in the ET settings for electricity and a larger temperature span acceptance for the district heating."

Value contributions from user scenario

Chalmers perspective

This user scenario describes how the awareness of the user could be reached through the ERO application. This is of course an important functionality which helps the user make more environmental friendly choices and become even more interested in using services in the application.

City of Malmö

The progress report contains information that could be useful for the city of Malmö. A possible value could be created if progress reports are aggregated and relevant information visualized for the city of Malmö. It could be useful since the city of Malmö could proceed mapping over the general progress and try to identify actions which can be made to maintain or increase progress.

Implications for implementation

- Requires enrolment of end-user willing to use and be interactive the ERO application.
- Establish agreements with users on installations and participation.
- Requires installment of energy measures in each apartment.
- Alternatively, we have smart plugs that measures electricity loads in the apartment and/or a progress report for the whole building.
- ERO platform must be able to access energy measures from each apartment alternatively from the building.
- Requires information on the average energy mix from producers of district heat and electricity.

1.4.4 Appliance scheduling

This user scenario focuses on "smart appliances" and how these could be managed through the ERO application.

Description of user scenario

"It is Thursday morning and Peter is the last family member leaving home for work. He has just finished his breakfast and is about to put his dishes in the dishwasher, when he notices that not only the dishwasher but the whole sink is full of dirty dishes. Coming home to this mess and starting tonight's dinner with washing the dishes does not feel very tempting, so Peter opens his ERO app to schedule an automatic start of the dishwasher. ERO suggests a time slot between 11 am and 2 pm, which according to the forecast from the energy company would cause the lowest CO_2 footprint. Peter accepts and ERO reminds him to add detergent, close the dishwasher door and set it on standby to prepare for the automatic start."

Value contributions from user scenario

E.ON perspective

As an energy company it is of course desirable if consumption was more strategically planed since this enables more efficient use of production and distribution systems. Within the framework of CESO this user scenario has no direct connection since CESO focuses on district heating/cooling while home appliances typically use electricity. It could however be of great interest for future work since including electricity management in CESO is possible.

Chalmers perspective

This user scenario specifically enlightens activity management functionalities within the ERO application. Chalmers is interested in investigating what type of devices that can be controlled by ERO and to what extent this could be done. They are especially interested in finding out what devices end-users actually want to be able to steer via the application and to what extent they are willing to actively manage connected devices. They also want to investigate what this additional controllability does for energy consumption and how this is related to behavior and acceptance from users.

Implications for implementation

- Requires enrolment of end-user willing to use and be interactive the ERO application.
- Establish agreements with users on installations and participation.
- Identify what "smart appliances" and loads we can work with trough the ERO platform.
- This could be done by using be built in "smartness" in appliances or application of smart plugs.
- Install necessary equipment for "smart appliances" in apartments.
- Establish connectivity between installed devices and the ERO platform.
- Establish forecasts on CO_2 emission profiles to make possible CO_2 footprint adapted steering of appliances.

1.4.5 Solar production

This scenario illustrates how the ERO application could be useful if buildings install their own energy production units such as solar panels.

Description of user scenario

"The Nilsson family have decided to base their Energy Threshold for electricity mainly on the availability of solar power from their own PV panels placed on the roof. In order to stay below their rather fluctuating Energy Threshold, they need to check their ERO app frequently and plan ahead for their energy use. Whenever there is plenty of solar power produced, ERO reminds the family members to charge their devices and run appliances such as the dishwasher and the washing machine. Energy that is available from the family's additional battery storage is shown as an additional dashed line above and in parallel with the ET curve in the ERO app. Battery power will automatically be used when the solar production is lower than the family's current energy use. The additional battery curve is lowered and eventually disappears when energy from the battery is used up."

Value contributions from user scenario

Chalmers perspective

Including interaction with production units is naturally interesting for ERO due to the ongoing trend where more decentralized energy production is becoming significantly more common. ERO could be useful for managing and utilizing small production units more efficiently in the future. This user scenario would work as an investigation on how interaction between solar production and end-user consumption could be managed and what possibilities/limitations this entails.

Implications for implementation

- Requires enrolment of end-user willing to use and be interactive with the ERO application.
- Establish agreements with users on installations and participation.
- Requires solar production units on enrolled buildings.
- Data on production from solar panels must be forwarded to ERO continuously.
- Requires battery storage and accessibility to battery storage management systems.
- Alternative solution: There could also be electric car chargers which could be adapted trough the ERO application with solar production.
- Alternative solution: There is neither battery or car chargers; then push notices could be sent to users reminding the end-user that production is high or low and suggest adaptive energy consumption behavior.

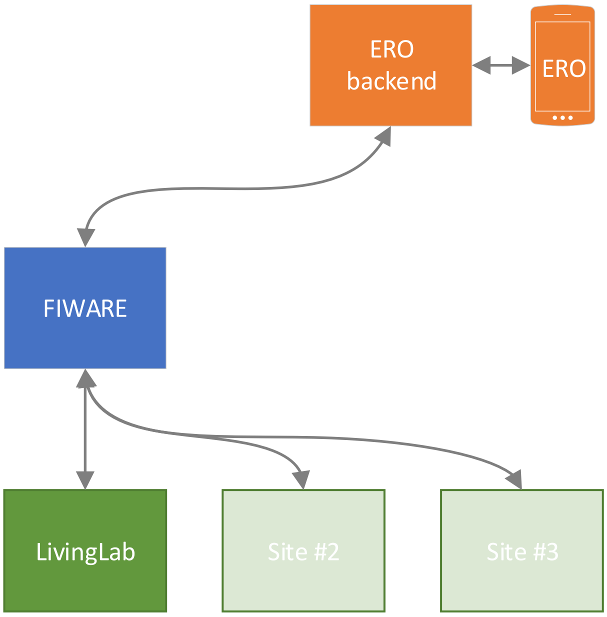
1.5 User research HSB living lab

The HSB Living Lab on the Johanneberg campus of Chalmers University of Technology is used to perform further user testing with the smart energy system ERO. The aim of the tests is to learn about the user’s opinion and everyday life as part of a smart energy system as well as enable users to control and plan their energy use in relation to their own Personal Energy Threshold.

Image 6: The HSB Living Lab at Chalmers

Image 7: Setup for the user testing at the Living Lab

2 Technical implementation ERO



ERO will be implemented in these layers:

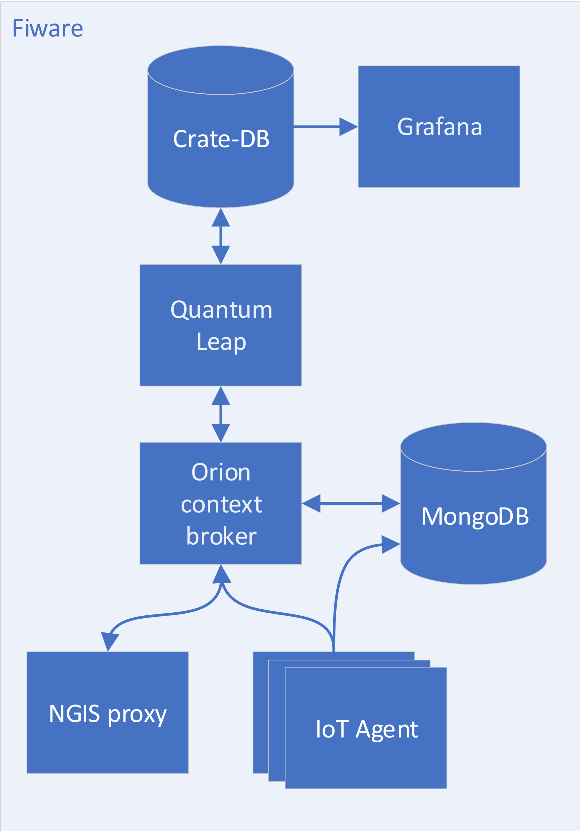
- The mobile app itself, it will preferable only implement the user interface and have as little logic as possible. This will make it easier to maintain and easier to implement on both Android and iOS.
- The ERO backend, that contain the business logic of ERO. It will provide the app with all the necessary information hide all underlying systems from the app. For the LivingLab we will use FiWare to mediate data between the app and the IoT devices, but at other sites we may for economic reasons be forced to accept whatever interface they can provide and connect directly to that interface from the backend.
- The FiWare platform will provide an easy interface to real time data and time series data required by the app, it will also provide the means to send information or commands from the app to the energy provider. The FiWare platform will partition data so the end user only can access her own data. It will also hide the multitude of different IoT devices and other data sources that the app communicates with.
- At the bottom of the stack are the actual data sources such as IoT-devices or existing platforms such as CESO.

Much of the communication between different layers will be implemented as RESTful services communicating data in JSON format.

The FiWare platform will be implemented inside a Docker swarm to make it possible to deploy in various environments such as local datacenters or as a cloud service. This will also make it easier to set up a robust installation with high availability and geographic redundancy if needed.

All communication inside the system will be encrypted except for communication with IoT devices and external services outside our control, where we must accept whatever measures of security they have implemented. The servers running the services will be hardened and not run any unnecessary services and will have firewalls to make them opaque on the internet.

2.1 The FiWare set up



Our FiWare platform contains the following components:

- The Orion context broker, this is responsible for transferring information between publishers and subscribers of information.
- MongoDB for data from the publishers and configuration data.
- IoT Agents are a collection of agents provided by FiWare to communicate with various protocols such as MQTT.
- NGIS proxy makes it possible to delegate information from the Orion broker to other data sources.
- Quantum leap populates the time series database and provide an interface to read time series data.
- Crate DB is a database optimized for time series.
- Grafana is a visualization tool.

2.2 Progress Report on Use case derivation from a technical perspective

In the Swedish field test, as part of work package 2, RWTH/EBC collaborates closely with Chalmers the development and implementation of use cases in the building energy sector. The focus here is always on the solution using a central IT platform, which is set up with the help of FiWare components as part of the project.

Based on IEC/PAS 62599 five different user stories were formulated, which consider the different research objectives of the project partners involved in the Swedish field test. Based on the user stories developed on base of user insight studies conducted at Chalmers, three use cases could be derived, which are to be implemented and investigated during the course of the project. These are briefly described below and simplified in Unified Modeling Language (UML) diagrams.

Use Case 1 (User defined Flexibility):

The end user can specify a temperature range via a user interface within which he accepts fluctuations in the interior temperature. All collected data of all users are transferred to the energy system operator. The operator can then adapt the boundary conditions of his system optimisation based on the flexibility provided by the users. The energetic effect of the input is returned to the user as response. At the same time, the overall system status achieved by the optimization is visualized and returned to the operator.

Use Case 2 (User requested Flexibility):

Requests are continuously sent to the end user via a user interface which asks whether he agrees to a variation of the interior temperature for a limited period of time (3 to 6 h). The requests also contain information about the consequences for the energy system depending on the respective user feedback. The queries are based on the generation and distribution strategy of the grid operator; this can be, for example, the avoidance of fossil energy supply. The flexibility thus requested by the end user can be considered in the production strategy of the grid operator. If the end user rejects the request, its flexibility potential in the optimisation process is rated at zero. Communication should take place via a central platform.

Use Case 3 (System State Visualization):

The data flow between network operator and end user is logged and analyzed in order to filter out relevant information and to monitor and evaluate the performance of the overall system. Furthermore, third parties should have the possibility to evaluate the data for other tasks. The required communication will take place via a central platform.

Based on the developed use cases, the actors of the respective use cases and expected requirements have already been derived. At this point in time, however, these have not yet been formulated more precisely in terms of IEC/PAS 62599. Work is currently underway to define and present the data exchange required for the implementation of the individual use cases. The requirements are then specified more precisely. As part of the last two points, RWTH supports the implementation in the field test Sweden and is currently investigating which data exchange is necessary between the already existing subcomponents and how this can be incorporated into the requirement specifications for the central IT platform. Here it is also examined to what extent existing reference data models, such as Smart Appliances REFerence ontology (SAREF) and the domain-specific extensions, are suitable as supporting tools for the description of data flows and whether these might have to be extended domain-specifically within the scope of the catalogue of requirements for the use cases.

2.3 Progress report on platform setting-up at HSB Living Lab

FiWare platform described above has been installed inside Docker on virtual machines at the Chalmers site. The installation is stable and maintainable. It is possible to publish and subscribe to messages via the Orion broker.

We have begun developing adapters that will publish information from the LivingLab into FiWare. Cooperation between Chalmers and E.ON is underway to install another instance of the FiWare system at E.ON and to transfer data from CESO into that FiWare instance.

The FiWare platform has not been installed as a high availability cluster because we need to solve how persistent storage shared between the virtual machines should be implemented. To solve this without any single points of failure has proven to be hard. Solving and documenting the installation process of FiWare seems rather important to lower the barrier for third parties to implement similar solutions in the future.

The next step is to decide how the data should be structured in FiWare, most likely using SAREF (Smart Appliances REFerence) ontology. Then to feed FiWare with production data and test it. In parallel with testing we will start the further development of the ERO app and its backend for extension of functionalities and for the applicability on a larger scale on two sites in the smart city district of Malmö.