Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX)

D8.3 Report on the System Prototype Implemented in the Field – Use Case 2

October 2018

Imprint

Contractual Date of Delivery to the EC:		**31 October 2018**
Actual Date of Delivery to the EC:		31 October 2018

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Project: Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX)

Work package: **WP8**
Confidentiality: Public
Version: **5**

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The project Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731232. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Innovation and Networks Executive Agency (INEA) or the European Commission (EC). INEA or the EC are not responsible for any use that may be made of the information contained therein.

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Executive Summary

This document (D8.3) reports the activities of Task 8.2 of the GOFLEX project.

The goal of GOFLEX project is to demonstrate the possibility to harvest flexibility in electrical consumption at prosumers levels. There can be different types of prosumers, such as: households with some standard controllable electrical appliances, factories with industrial processes and charging stations for electric vehicles. The GOFLEX system is tested in 3 different demo sites across Europe, representing different contexts.

The implementation of the system prototypes in the demo site of ESR area is presented in this report. At the time of this report, corresponding to the Milestone 4 of the project, the representative systems of the different types were all installed, and this demonstrates the proper operation in the field of the whole system. Over the next months, a scale up of the number of connected systems will be done:

- Direct Control: the proposed equipment is installed and operational at 60 prosumers; the scaling up goes to 200 prosumers. The direct control system is normally installed in a house and the controlled flexible loads are a heat pump, a water heater or a direct electrical heating appliance.
- Factory Energy Management Systems (FEMS): 3 industrial processes are installed and connected at the time of this report and the scaling up goes to 10 factories.
- Home Energy Management Systems (HEMS): 2 homes were connected at time of this report, one of it being a CDHEMS, and the scaling up will go up to 20 HEMS in the next weeks.
- Charging energy management systems (CEMS): 2 CEMS are currently connected, encompassing 4 charging stations. More charging stations will be installed and connected.

The report will present technical aspects of the prototype as well as wider aspects such as installation routines and problems, interaction with local inhabitant, information provided to the client, etc.

Document History

Version	Date	Status	Author	Comment
0	26.09.2018	Draft	Moix P-O	Copy of project notes in the Canvas
1	04.10.2018	Draft	Moix P-O	ESR part added
2	07.10.2018	Draft	D. Gabioud	Draft version of paragraph 3.2.5.
3	08.10.2018	Draft	Various	Multiple input from HES-SO
4	11.10.2018	Draft	P. Roduit	Version ready for review
5	24.10.2018	Ready for submission	P. Ferrez	Full reviewed version

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List of Acronyms and Abbreviations

Abbreviation	Definition
CA	Consortium Agreement
CDEMS	Charging/discharging Energy Management System
CEMS	Charging Energy Management System
DHW	Domestic Hot Water
DOMS	Distribution Observability and Management System
EMS	Energy Management System
EV	Electrical vehicle
FEMS	Factory Energy Management System
FMAN	Flexibility Manager
FMAR	Flexibility Market
FOA	Flexibility Offer Agent
GA	Grant Agreement
HEMS	Home Energy Management System
IoT	Internet of Things
SP	Service Platform

1 Introduction

1.1 Purpose

This document provides a progress report regarding the situation and the accomplished work of WP8 – System Deployment & Evaluation – Use Case 2 after 24 months (November 2016 – October 2018). It provides the reader with the description of the Swiss Pilot deployment phase, explaining how the prosumers were found and how the different systems were installed.

A deeper analysis of the value of flexibility used for ESR business cases was described in D8.2, whereas D8.4 (M36) will describe the global results of the Swiss pilot.

1.2 GOFLEX System

The GOFLEX system manages energy production and consumption at the local level, from the bottom up. In this way, consumers can participate actively in the future energy system by offering to be flexible in their energy production and/or consumption. In GOFLEX, end users of energy place offer to sell or activate discrete amounts of energy flexibility on a market. In the project demonstrations, the distribution system operator (DSO) accesses this flexibility by submitting a buy-offer to the market. Technology is also provided to for the DSO to automate and optimize use of flexibility in the grid. Figure 1 illustrates these concepts.

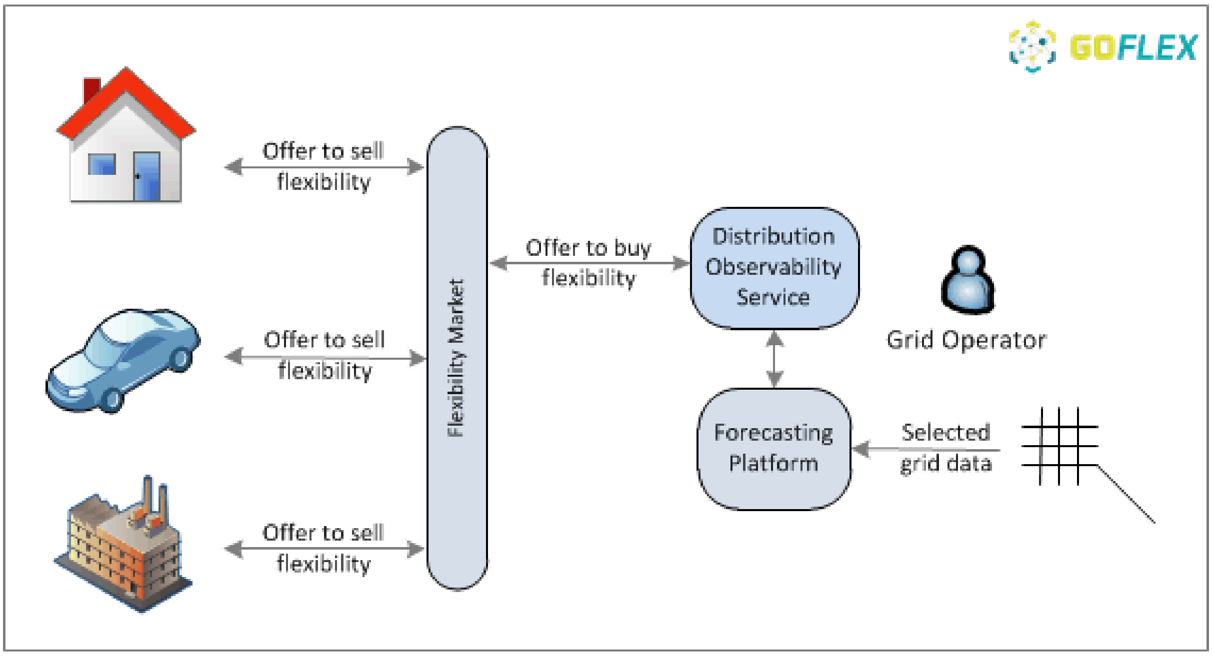

Figure 1 - Illustration of GOFLEX Concept

Carrying out automatic trading of energy flexibility requires an integrated suite of technological components. Working from the bottom upwards, energy users such as factories, homes, and electric vehicles each require a suitable energy management system to physically control the energy loads that deliver flexibility. Thus, a Factory Energy Management System (FEMS) controls factories and commercial buildings; a Home Energy Management System (HEMS) controls residential locations; a Charging Energy Management System (CEMS) controls electric vehicle charging stations; a Charging/Discharging Energy Management System (CDEMS) controls an electric vehicle capable of discharging to the grid. Other types of energy management system such as smart plugs or direct controls are also used. The energy management systems communicate available flexibility to a FlexOffer Agent (FOA). The role of the FOA is to transform information on available flexibility into a standard format and provide it to a centralized Flexibility Manager (FMAN). The FMAN places the offer on a Flexibility Market (FMAR) and receives notifications about whether the offer is accepted. When an offer is activated, the FMAN notifies the energy management system via the FOA. Collectively, the FMAR, FMAN, and FOA comprise an automatic trading platform (ATP). The DSO accesses energy flexibility by trading on the market. From the DSO side, a Distribution Observability and Management System (DOMS) receives grid data and forecasts from the Service Platform (SP). DOMS then optimize where and when flexibility is needed to meet operational needs. The required flexibility is expressed as a buy-offer and sent to the trading platform. Figure 2 summarizes the technological components of GOFLEX systems.

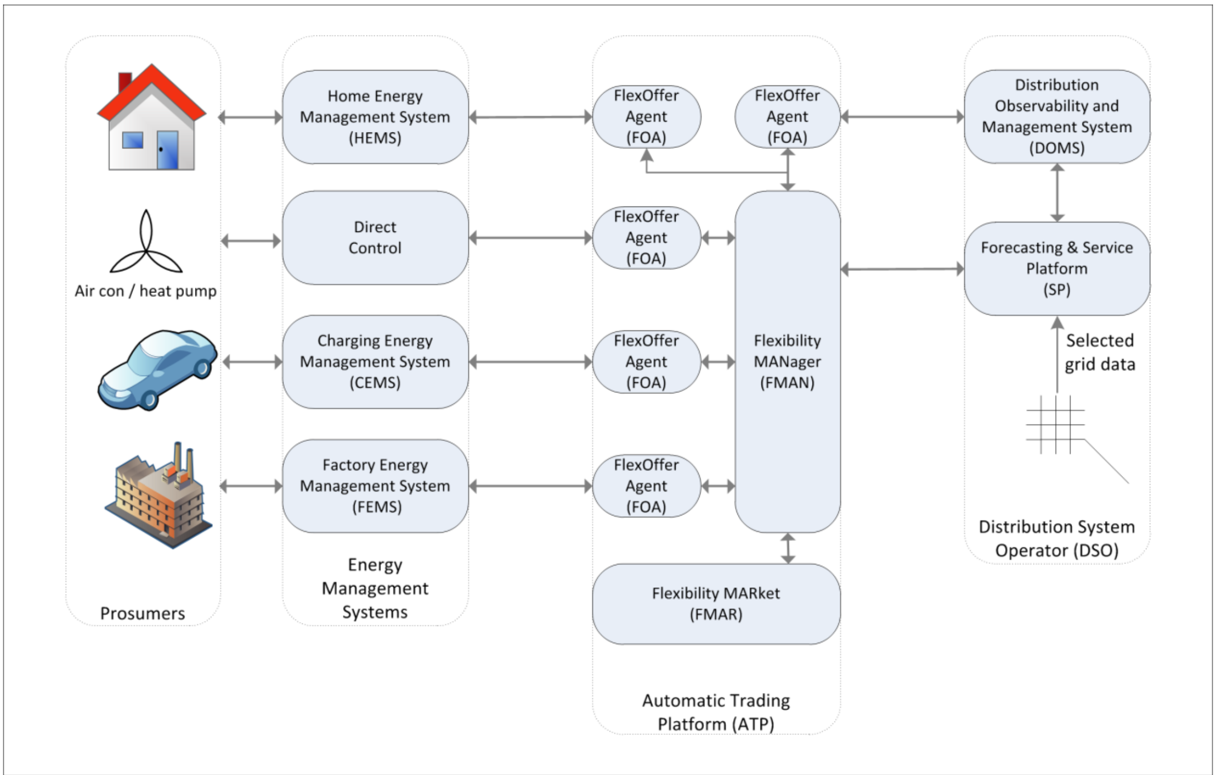

Figure 2 - GOFLEX System Components

1.3 Related Documents

This document is related to the similar deliverables of the other WPs. It is also directly linked to D8.1 and D8.2.

1.4 Document Structure

This report explains the elements implemented in the Swiss demo case. To facilitate the understanding of the demo case, Figure 3 presents the scope of the demo with the different technical solutions that must be deployed.

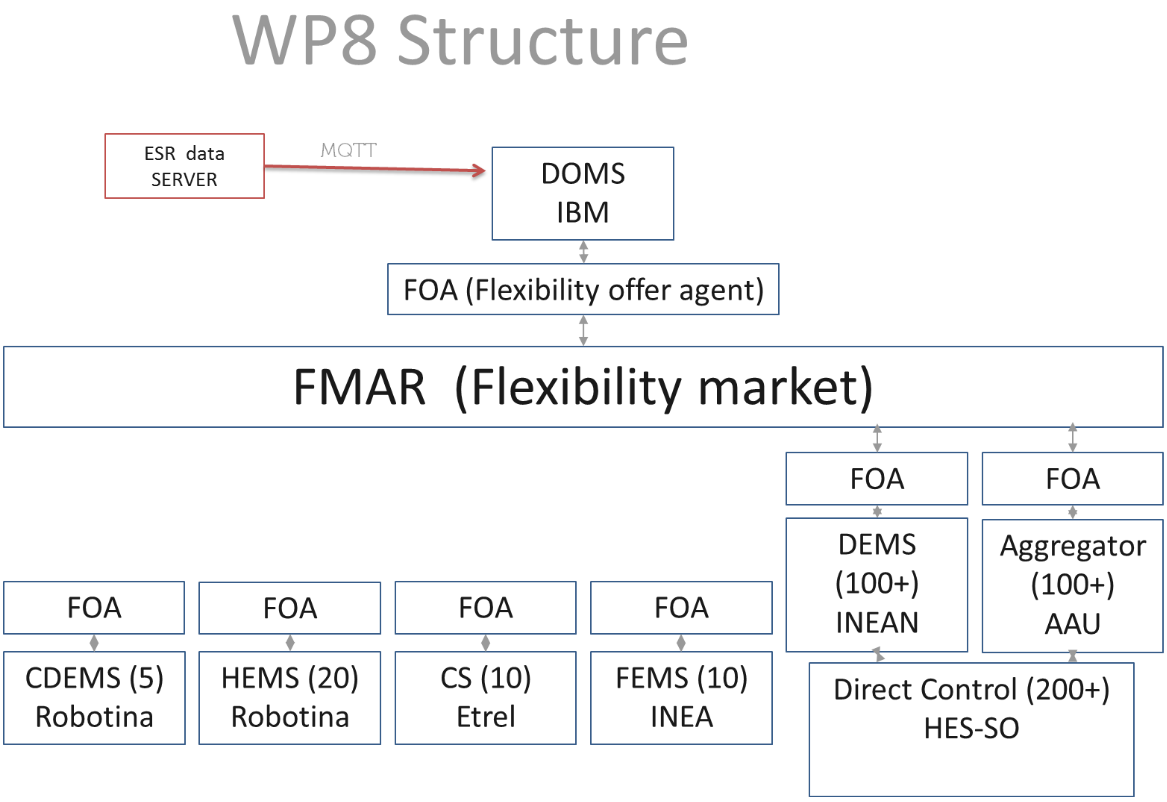

Figure 3 - Structure of the Swiss pilot

After a brief introduction on the purpose of this report in Section 1, Section 2 will follow with the description of the interaction with the prosumers. Section 3 will then describe the installation of the technical solutions in the field, followed by a short conclusion in Section 4.

2 Prosumer Participation

This section describes the prosumers participating in the demonstration by trading mode and type of energy management system. Copies of information provided to the prosumers are included.

2.1 Direct trading prosumers

2.1.1 Factories (FEMS)

The selection of partners as FEMS was carried out based on the list of large consumers known by ESR. During this first stage, 45 companies were selected. Then, we analysed the process that took place in those companies with the goal to identify the most interesting partners for GOFLEX project. 39 companies have thermal processes (warm or cold) linked to thermal storages and therefore the flexible ones have been selected. These thermal processes are often just one part of the overall activities that take place on an industrial site. At the end, only 31 sites with predominant thermal processes have been selected.

Table 1 - List of FEMS

N°	Description	Electrical power	Flexibility		PV plant
			Winter	Summer	
01	Asphalt base	100 kW	Middle	High	-
02	Cold storage for food	75 kW	High	Middle	1’150 kW
03	Semi industrial bakery	50 kW	High	Low	140 kW
04	Wine cellar	105 kW	High (except harvest)		500 kW
05	Swimming pool and skating ring	160 kW	Middle	High	-
06	Private services building and public swimming pool	125 kW	Middle	Middle	250 kW
07	Microparts producer	90 kW	Middle	Middle	-
08	Public building (library and restaurant)	80 kW	High	Low	-
09	Public building (school and 2 sport hall)	30 kW	High	Middle	250
10	Public building (museum)	40 kW	High	None	-
	TOTAL	**855 kW**			**2'290 kW**

HES-SO maintains close links with the local companies and this was a great help to make this selection but not enough to convince all partners with the most potential. In total, twenty companies were approached, and participation agreement was signed with ten of them (Table 1).

A classification of flexibility has been estimated:

1. **High:** The consumer should always react to a cut-off or switch-on command (probability > 90%)
2. **Middle:** The consumer should most of the time react to a cut-off or switch-on command (probability >50% and < 90%)
3. **Low:** The consumer does not react most of the time to a cut-off or switch-on command (probability < 50%)
4. **None:** There is no flexibility and no consumption (e.g. heating installation of a building during summer time).

This general classification was established following our discussions with facility managers and our experience in the operation of the controlled installations. They must be confirmed by tests during the pilot phase.

An agreement has been signed with each company. It has no real contractual value, but it sets the framework of the required collaboration to participate to GOFLEX project. The document states that:

- There is no charge for the companies for the installations of the systems and of the different required meters,
- The installed FEMS installed will make possible the visualization of the energy consumption and will propose analysis tools during the project,
- A complete analysis of consumption and a report will be done at the end of project, including possible detected problems as well as advices on optimization,
- If the use of flexibility generates a demonstrated financial interest, a fair remuneration will be discussed with ESR,
- The company is free to communicate about its participation in GOFLEX, for marketing purposes, company-positioning, image towards the energy transition, etc.,
- The technical risks are low as the current installation will always keep all its functionalities and the final decision to accept or refuse incentives from the FEMS belong to the local control system,

- The HES-SO and ESR, are committed to providing all technical support to solve any problems. If modifications are suggested, they will be made with the agreement of the partner and will be carried out by professionals,
- GOFLEX is a research project, there is no guarantee of financial or energy gains,
- If the company would like to continue using the system at the end of the project an arrangement will have to be found for the continuation of the service. Otherwise, we will undertake to uninstall all the system,
- The confidentiality of the data is guaranteed. They will be stored by ESR and managed by HES-SO and ESR. In parallel, part of them can be forwarded to GOFLEX project partners for research, development of optimisation solutions, economic interest calculation and load management. In all cases, these data will be made anonymous before being transmitted to the partners. The link between the company name and the data will only be known by HES-SO and ESR. No public communication mentioning the names of the companies will be made.

In October 2018, the deployment status is as follows: FEMS 02, 08 are running since August 2018 and FEMS 07 is running since October. Installations of FEMS 03, 04, 06 and 09 are planned during October and they will be commissioning successively. FEMS 01 has been abandoned due to difficulties to find an agreement with the subcontractor who oversees the plant's control system. The costs involved to bring the current control system compatible with GOFLEX system were disproportionate and unjustified. We are currently in search of a replacement company.

For FEMS number 05 and 10, problems related to communication with current control systems needs to be solved with the concerned subcontractor.

Among the 10 companies with whom the project was able to enter in deployment phase, 8 of them had existing links with HES-SO which was mandated for previous projects. In fact, it has been much more difficult to convince bigger companies with other interests in other part of the country or outside the country. One of the principal difficulties was to establish a contact with the right person inside the company able to support and defend the project to decision-makers. Among the ten refusals we had, nine concerned multiple level companies in which such decisions are not taken at the local level. It has been easier to work with local companies, with no external link.

The second big difficulty, once an agreement had been established with a company, was to convince their subcontractors in charge of the automation and control systems with whom we want to interact. For FEMS 01, this element has been prejudicial for the implementation of the project, even if the final customer had given his consent. For FEMS 02, we finally found a way to collaborate and the fact that this subcontractor has ongoing projects with the HES-SO was significant. Control systems of 6 out of the 10 demo sites are performed by the same international automation company. It allowed us to present GOFLEX project in a different way to this subcontractor, with more weight and importance. When six of your clients want to participate in the same project, it is more difficult to deny collaboration. In addition, the development made for one is useful for the following five. These arguments have enabled us to establish a good collaboration with this sub-contractor. If we had to negotiate one by one each implementation of FEMS, the result would not have been as positive, resulting in much more rejection. This is exactly what makes the implementation of FEMS 05 and 10 slower and more difficult.

As other difficulties frequently encountered, we could mention the fact that companies and people in general have internalized and understood the concept of energy efficiency. GOFLEX approach is different and goes one step further in the decarbonisation of electricity by proposing to increase the overall efficiency of the power system and maximize the consumption of renewable energy at a higher level. This point was and is not easy to explain to non-specialist. The reflex is “I will consume more, so I will pay more”. We had to ensure that if consumption and costs will increase throughout the test phase of the project, these costs would not be charged by ESR. Finally, some big consumers are connected to ESR grid, but are not client of ESR. These companies have access to the liberalised electricity market and we decided to exclude them.

2.1.2 Homes (HEMS)

2.1.2.1 Selection of HEMS

For the installation of HEMS, a first list of possible participants was drawn up based on households' characteristics, searching to have the most complete prosumers, equipped if possible with solar panels, smart grid ready heat pumps and charging station for electrical vehicles.

A list of the most promising houses where to install a HEMS was created and the owner were then contacted. The main arguments that were used to convince people to participate to GOFLEX were the following:

- The possibility to monitor the whole consumption and production of the building,
- The system will boost the use of solar panels for self-consumption,
- The possibility to actively participate to the energetic transition to allow for a better use of renewables.

However, some demands received a cold welcome. Based on the major difference of price between injected and purchased electricity, some people were more searching for a solution to get off the grid. In all cases, proximity with the clients was a clear plus to convince them.

2.1.2.2 Installation principle

Controller and linker

1. The controller (Figure 4) collects the inputs and allows the piloting of the loads via internal and wireless relays.
2. The linker (Figure 4), materialized as an industrial PC, insures the link between the controller and the Robotina server.

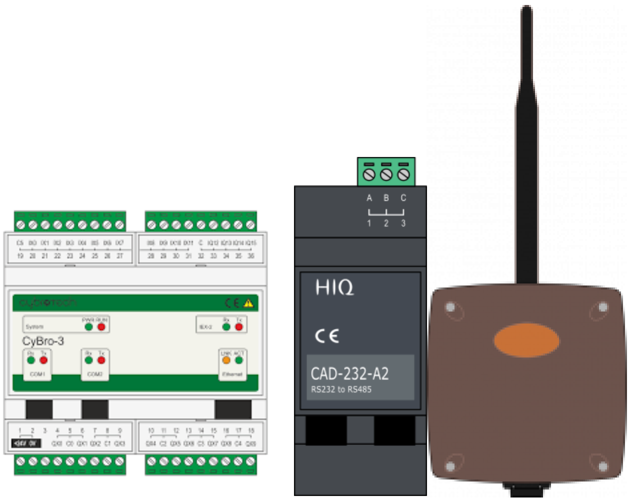

Figure 4 - Illustration of the controller and linker

Measurements

1. Electrical power

   The consumed or produced power can be measured through three-phase power meters (Figure 5). We decided to measure separately the general consumption of the house, of the heat pump, and of the electrical vehicle. Finally, the production of the solar panels will also be separately measured.

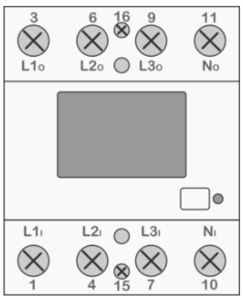

Figure 5 - Illustration of the three-phase power meter.

The power meter is powered through its connections to the grid and it communicates with the controller via Modbus. Most appliances use three phases, even if sometimes electrical vehicles can be charged using only one phase.

2. Room temperature

   We plan to equip the living room of each household with a temperature and humidity sensor (Figure 6). The communication with the controller is made via Zigbee wireless protocol.

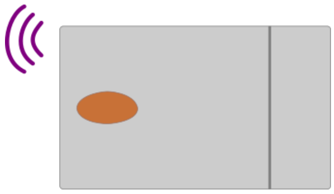

Figure 6 - Illustration of the room temperature sensor

3. Temperature of hot water storage

   For the measurement of hot water temperature, we plan to install an NTC measurement probe (Figure 7) in contact with the tank, wherever possible. It is also possible to measure two points. So, if another tank for sanitary water exists, it will be possible to measure it separately.

   Like for the room temperature sensor, the communication with the controller is made via Zigbee wireless protocol.

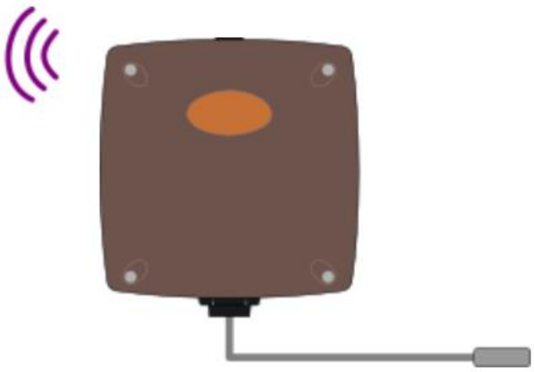

Figure 7 - Illustration of the NTC measurement probe

Piloting

1. Relays on controller

   The controller includes some I/O (Figure 8) that can be used to give inputs to heat pumps if they can be installed close to each other.

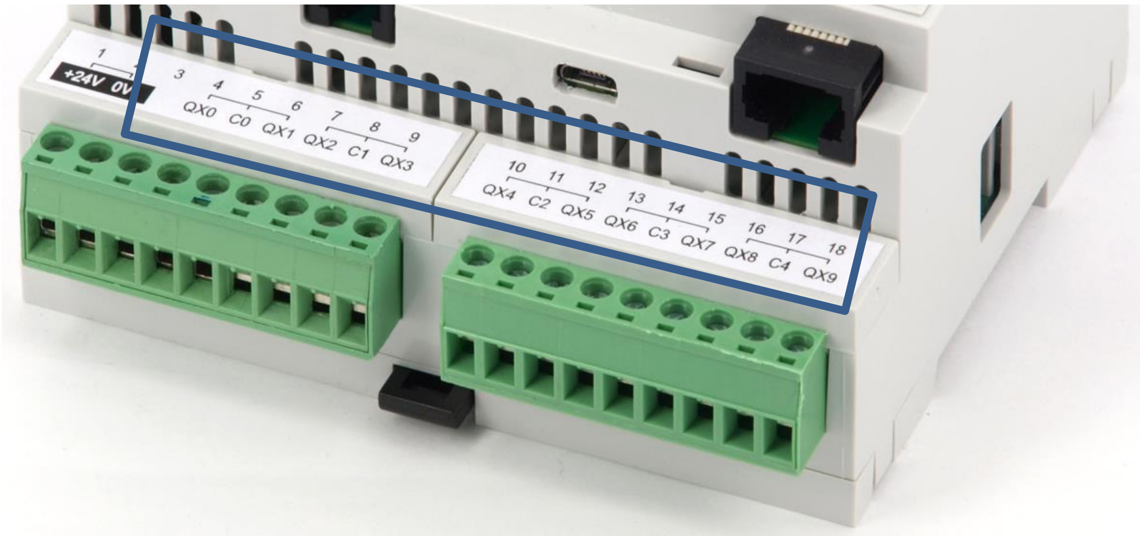

Figure 8 - Illustration of the relays

2. Single-phase power relay and consumer measurement

   The single-phase wireless relay (Figure 9) is, as its name indicates it, connected only on one phase. It allows cutting the connected load as well as measuring its consumed power.

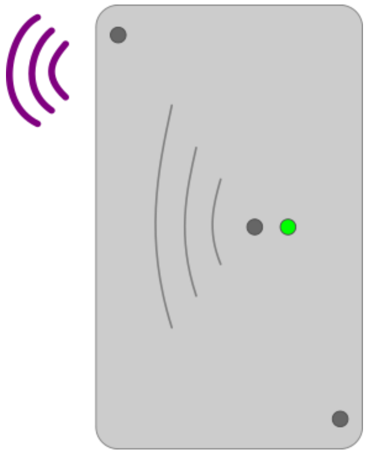

Figure 9 - Illustration of the single-phase power relay

2.1.2.3 Assembly schematic

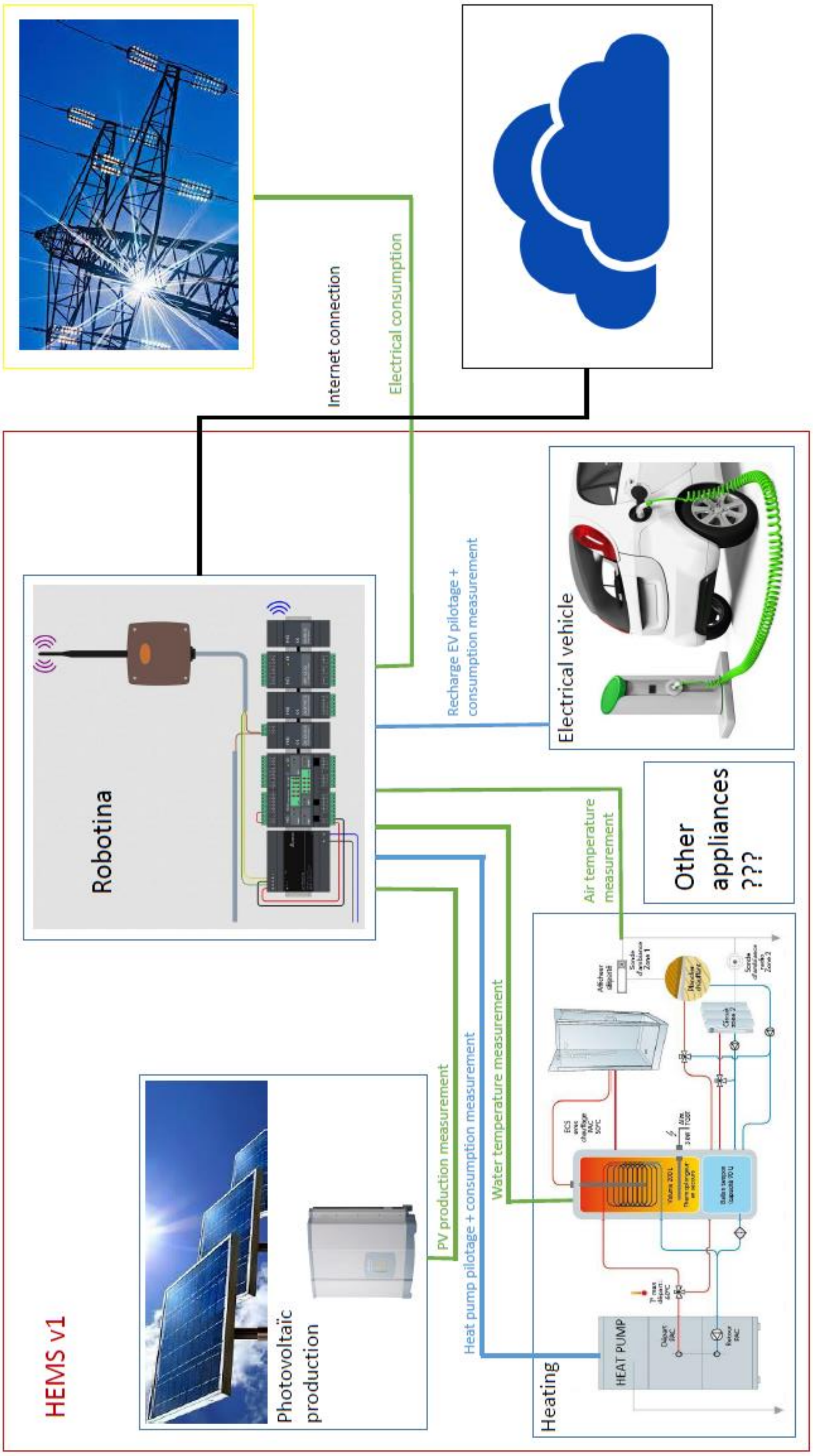

Figure 10 - HEMS assembly schematics

2.1.2.4 Test setup

Before starting installations in real households, we decided to install one HEMS in our laboratory (Figure 11) to test the devices sent by Robotina. This step was mandatory to know how to connect and configure all the appliances. Many difficulties were met because the development of the software (i.e. configurator, GOFLEX GUI) was not finished. With the help of two Robotina's employees who came to Switzerland, it was possible to solve the remaining problems.

Figure 11 - HEMS lab test setup

The picture below shows more details of the connections between the controller and the other appliances

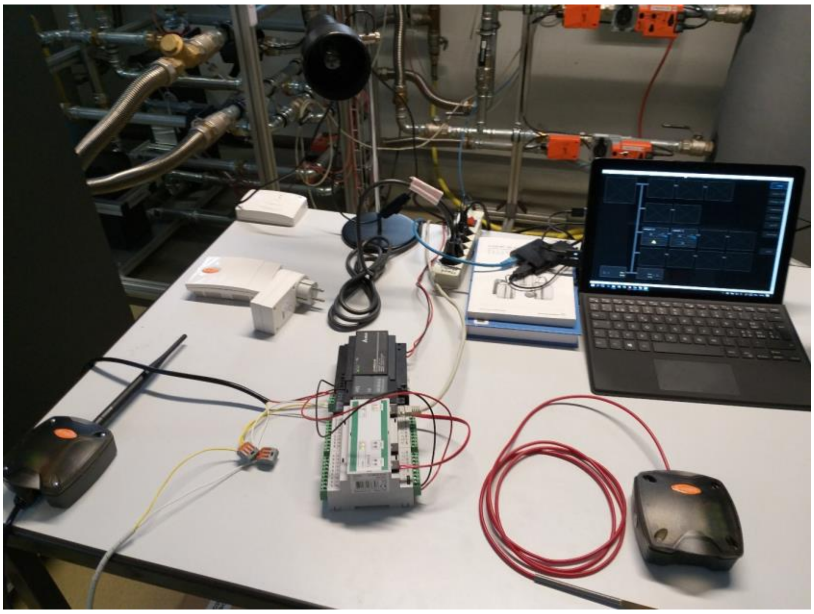

Figure 12 - HEMS lab test setup with focus on communication

2.1.3 Charging Stations (CEMS)

The hunt for existing Etrel compatible charging stations for electric vehicles on the domain served by Energies Sion Région (ESR) started mid-2017. The selected charging stations must be Etrel compatible, since Etrel's dashboard will be used for their monitoring and control. A few existing public and private charging stations were considered as candidates for CEMS. Most of these charging stations are manufactured by Green Motion (www.greenmotion.ch), the charging stations market leader in Switzerland, and are unfortunately not Etrel compatible (no open communication standard such as OCPP are included in those stations). Figure 13 illustrates one of these Green Motion charging stations installed in ESR's car park. This non-compatibility means that most of the existing public charging stations located on the domain served by ESR are not an option for CEMS.

Figure 13 - Green Motion charging station installed in ESR's car park.

Based on this, it was decided to focus on private (e.g. households) or semi-private (e.g. access-restricted car parks like companies' car parks) possibly existing, but mainly new Etrel compatible charging stations. Thus, so far, we have installed four Etrel charging stations in two different CEMS. Three charging stations are operational at the University of Applied Sciences and Arts Westerns Switzerland (HES-SO) and the fourth one is installed in the parking lot of a private individual in Sion.

2.1.4 Charging/discharging Stations (CDEMS)

Recruitment of CDEMS was done jointly with the recruiting phase of HEMS. A first observation was that no electrical vehicle able to discharge was found, like in the other two pilot sites. As a result, it was decided to use 3 kWh battery packs to emulate the discharging mode of the vehicles. A specific search was still performed to have existing electrical vehicles were CDEMS must be installed.

The first tests on CDEMS were made in laboratory (Figure 14). The outside communication did work, and it was possible to put or remove power from the battery.

Figure 14 - CDEMS battery pack in the lab test setup

2.2 Delegated trading prosumers

2.2.1 Homes with Single Load Controllers (Direct Control)

Energies Sion Région SA has already about 11'600 customers equipped with ripple control receivers. This basic load control system was largely deployed in Switzerland in the 70's and it is still in operation. The definition of ripple control is: (Wikipedia 2017[1]) "*Ripple control is made of a central system adding a signal generally between 400 and 1000Hz on the 50Hz sinewave. This signal can be read by all receiver connected on the grid and those connect and disconnect loads in function of coded messages".* It is a basic demand side management (DSM) system without much flexibility. The ripple control was mainly installed for peak shaving purpose.

The customers with a ripple control receiver already installed were selected first, as they have already controllable loads with the wiring done to the ripple control receiver. This wiring is simply redirected to the GOFLEX Direct Control gateway (Figure 15). The old receiver is left in place in case of the necessity to set everything back to the original state at the end of the project.

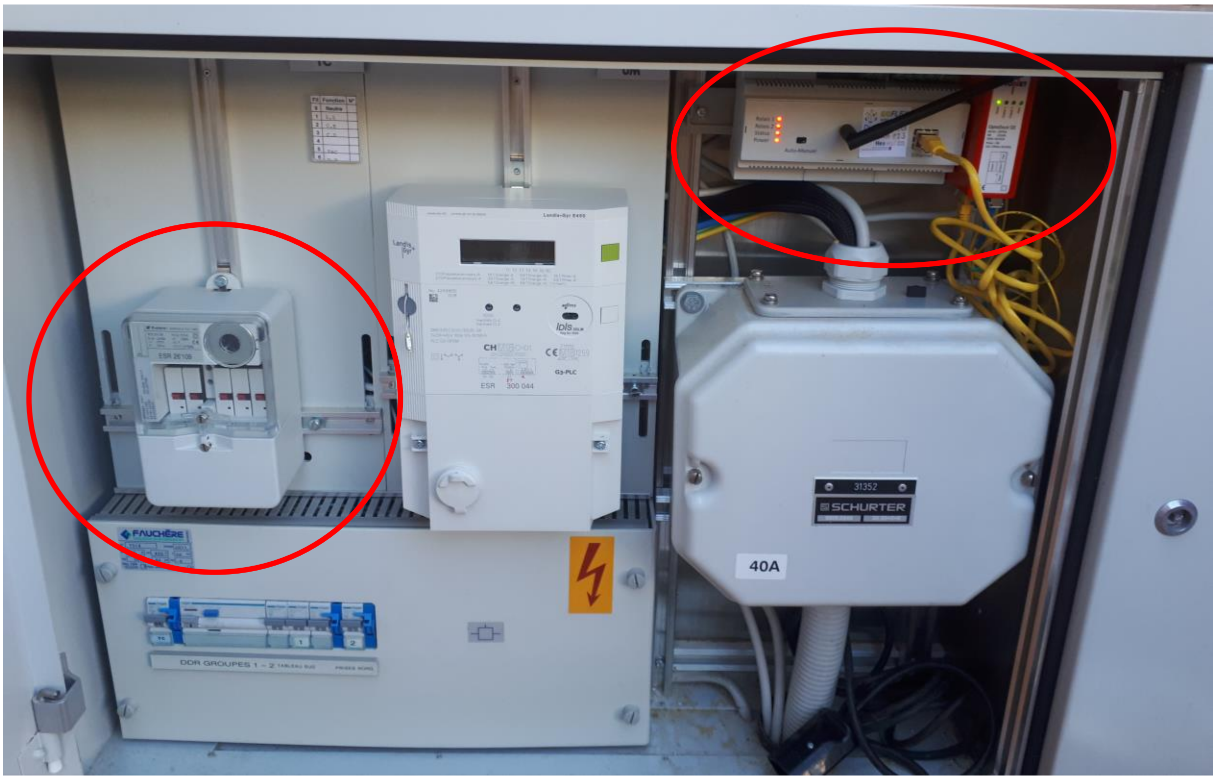

Figure 15 - Standard electricity main introduction to a house: the ripple control receiver (left) replaced by the GOFLEX Direct Control Gateway (top-right)

[1] https://en.wikipedia.org/wiki/Load_management#Ripple_control

2.2.1.1 Potential of flexible consumers

In the GOFLEX project, we focused on customers with the following flexible loads:

- Water heater: easy direct control
- Direct heating: in floor or with thermal storage
- Heat pumps: cannot be switched on and off as wanted

Loads used for heating purpose are interesting as they present a natural storage, with the volume of water or thermal inertia of buildings. Such heating loads can be interrupted momentarily without impact on the end user. He will not even notice any change in temperature before a certain time.

When an electrical installation is commissioned, the electrician must communicate if there is a large power electrical appliance and it is generally connected to the ripple control system. Therefore, normally, a database of controllable load is available.

However, on the 11’687 ripple receivers, we have only 1562 with loads explicitly registered in our database.

Heat pumps

There are 1287 customers with heat pumps in the ESR database. The rated power of most heat pumps is above 2kW. The total installed capacity is 3.66MW. The first 200 largest heat pumps represent an installed capacity of 1.04 MW.

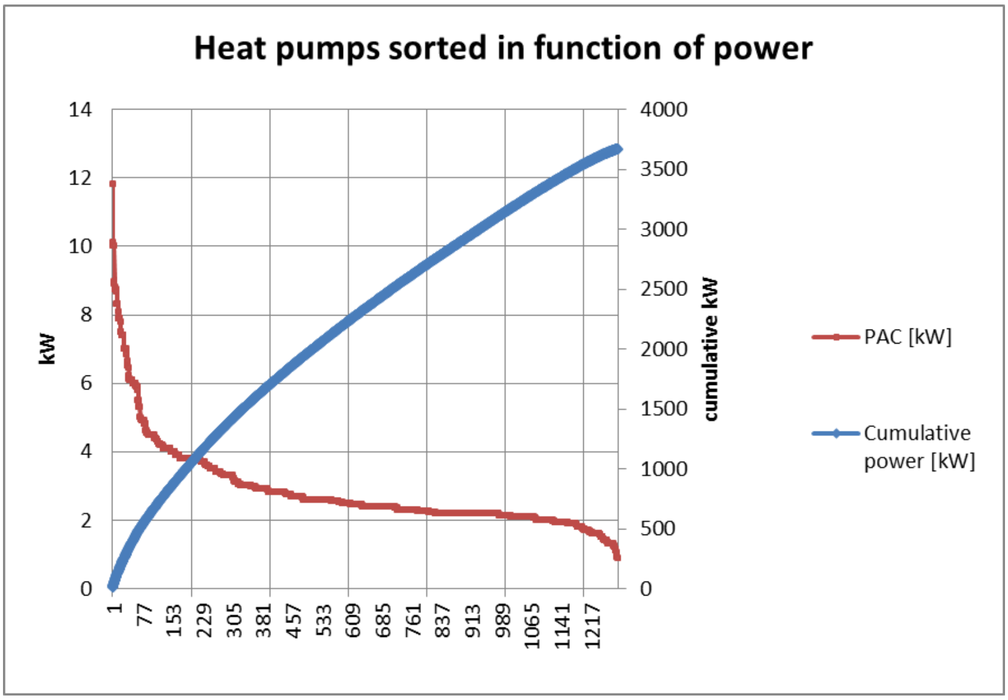

Figure 16 - Listed heat pumps at ESR

Boilers

There are 759 customers with boilers in the database. Most boilers are rated at 6kW. The total installed capacity is 3.89MW.

The first 200 largest boilers represent an installed capacity of 1.31 MW.

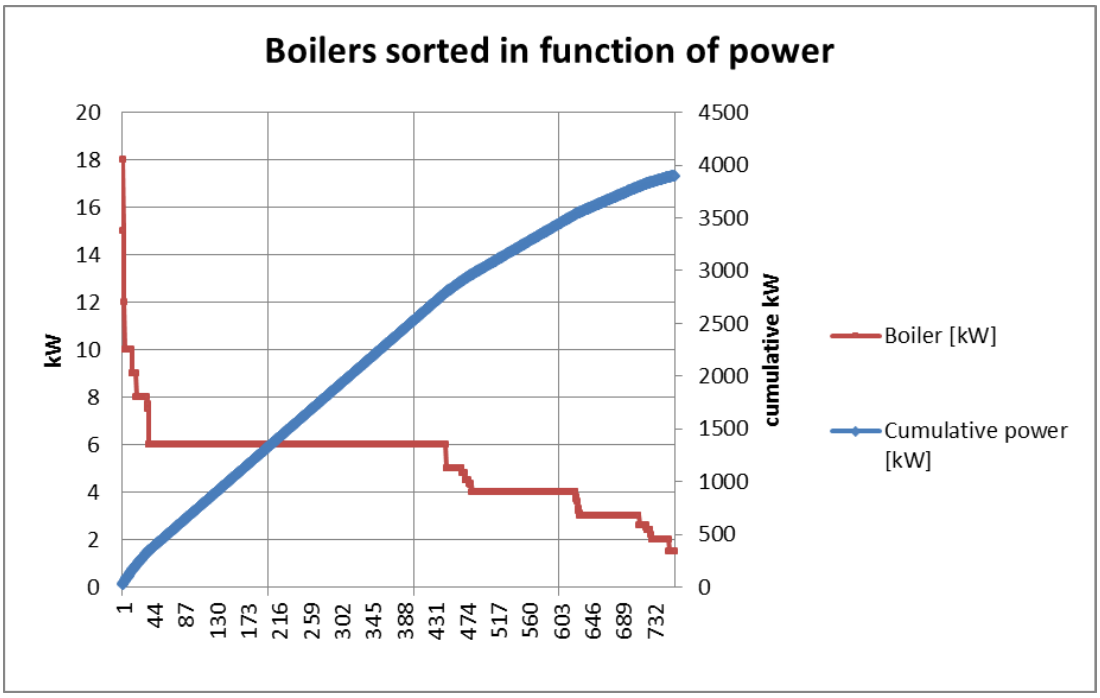

Figure 17 - Listed water heaters at ESR

Quite often, boilers are installed as a complement to heat pumps. In order not to oversize the heat pumps, resistive elements are added as a secondary source of heat, for example, in case of a very cold weather during a long period, making the heat pump insufficient. That means that most of the time, they will not be used.

A second thing to consider is the potential of installed systems. On a 6kW rated boiler, an electrician has the option to wire two or three heating elements (Figure 18). It is not sure that the whole 6kW is always wired.

Figure 18 - Example of a boiler's consumption details

Heaters

There are 1076 customers with heaters in the database. The total installed capacity is 3.7MW. The first 200 largest heaters represent an installed capacity of 1.26 MW.

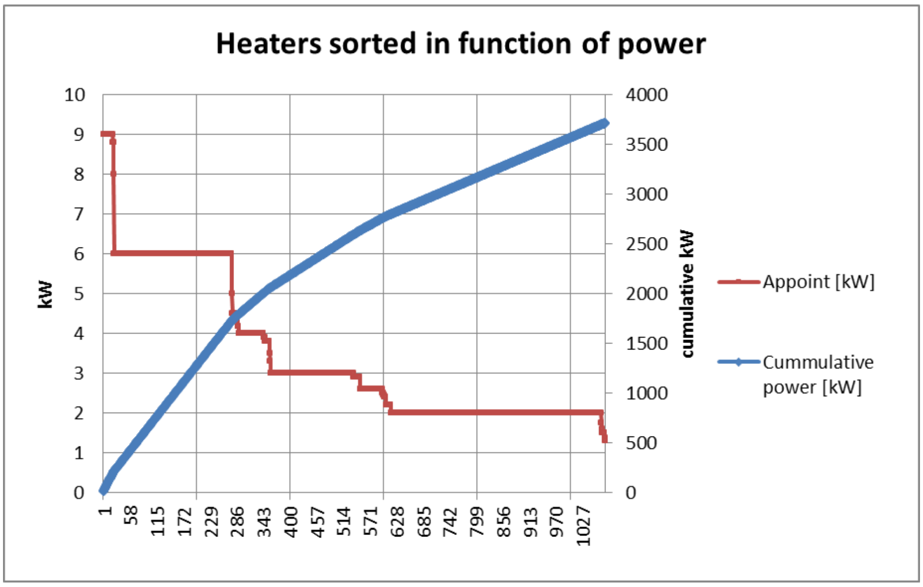

Figure 19 - Listed heaters at ESR

Sum of interruptible loads

Some houses have at the same time heat pumps and boilers. The sum of available power is considered. There is a total of 11.25MW of loads (3.7+3.89+3.66). There are 1'562 prosumers with flexible loads.

The first 200 prosumers have a cumulated power of 2.9MW. If we could get all the best prosumers and if their loads are all controllable, we would reach this maximal power of flexible loads.

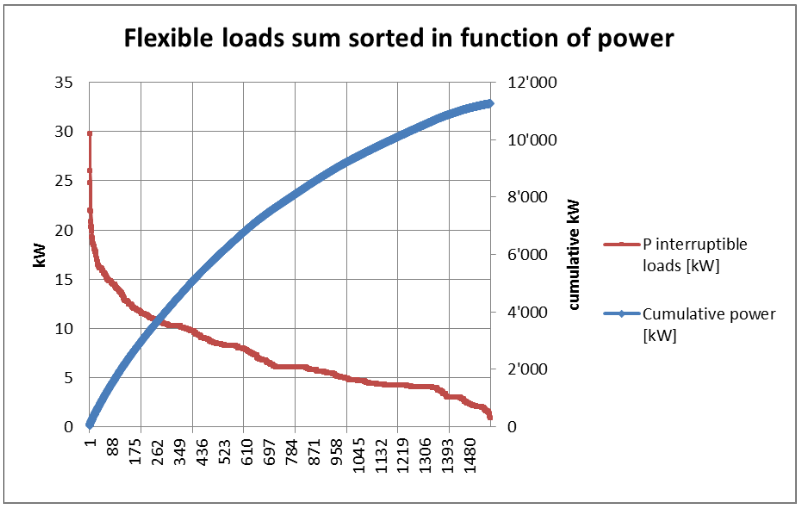

Figure 20 - Listed flexible loads at ESR

Total potential

There are 11687 users with a ripple control receiver. It is reasonable to suppose that all of those have also flexible loads even if it is not recorded in our database. Otherwise, they would not have a receiver. With a mean installed power of 7.2 kW this represents 84MW of loads.

Very often all the loads in a house are not working at the same time. Typically, when there is a heat pump, the water heater is added in the water tank in case the heat pump is insufficient. That means that most of the time some of the loads will not be usable.

If half of the loads are available a quarter of the time, this represents 10.5 MW of flexibility. It would be enough to fully control the forecast error (see chapter 3.3 about DOMS goal). However, at this stage, we have no real idea if it is a quarter or a tenth of time of availability and of the real power connected.

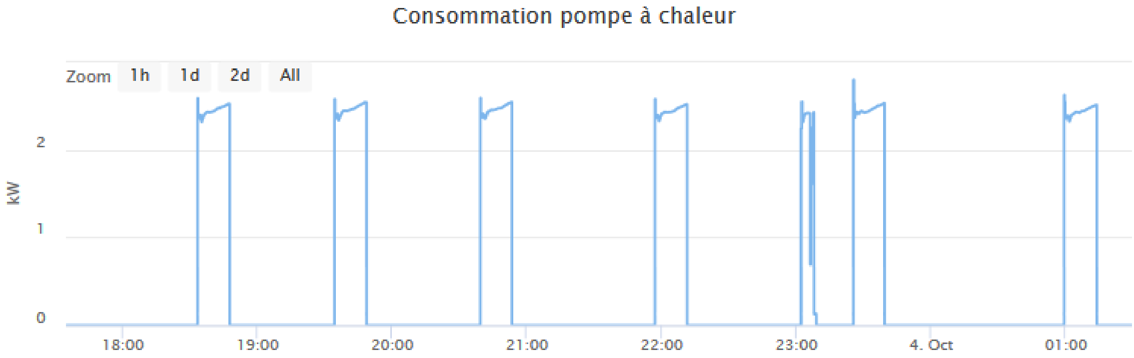

Figure 21 - Typical load curve of a heat pump on a cold evening. It is on only part of the time, meaning that the load cannot be turned off whenever wanted

The trial period and the assessment of measurements will help us understanding what is really connected and thus estimating the ratio between max theoretical power and real flexibility achieved.
In deliverable 8.2, two KPIs are defined for direct control (for the service 4: Individuals).

- Energy shifting flexibility for each load.
- Usability of aggregation.

These KPIs will be determined at the end of the project and allows better projections of the potential of flexibility that could be harvested by all the prosumers of ESR grid.

2.2.1.2 **Value proposition to the prosumers**

Already explored with the business model description in the first phase of the GOFLEX project (see deliverable 8.2), the value proposition must be presented to the prosumers in the selection phase.

Figure 22 - The value proposition to the prosumers:

The main points that were identified in the customer wishes:

- People have a great willingness contributing to the energy transition.
- They are proud to participate in innovative projects.
- They can be interested if there is a direct compensation or a special price on bought energy.
- They want to understand their energy use.
- They want to decrease their consumption
- They can be interested if there is another advantage/service offered → New product/services, energy visualization
- They want to keep control of their system
- They are afraid to be disturbed (cold ambient temperature, water)
- If they have PV already installed: optimize self-consumption

Web interface

It was decided not to go toward special energy prices or rewards in money. First reason is that ESR won't earn direct money during the GOFLEX pilot phase. ESR will gain knowledge and have a better idea of the potential benefits of the GOFLEX system at large scale. Second point: talking money kills the good will and enthusiasm of participating freely in an innovative project. The value of flexibility for a single house could be only of a few cents or francs per year (to be determined during the GOFLEX project) and this is not relevant for a prosumer.

The value proposition to the customer is then centred on the message of participating in energy transition. The web-interface where they can see and understand their electrical consumption is also central part of the proposition. Showing how and when flexibility is used and letting them have a way to disable their appliance control is essential in soothing their fears.

2.2.1.3 Communication

Between months 12 to month 24 of the project, various publications were done to support the project and communicate it to our local audience as well as to the potential prosumers.

Initial communication started in November 2017 with a press release. It was relayed by local press and the ATS press agency giving an audience at the level of the French speaking Switzerland (Romandie).

The information on our website was set up in April 2018 when the recruitment for installations was ready to start (www.esr.ch/goflex). This was associated with social networks communications: Facebook, Twitter and ESR news webpage.

In May 2018, the interview of our first test customer was released to rise interest and confidence in the participation (see appendix 3).

About the same texts were reposted at the end of the summer.

Figure 23 - Typical publication as posted on Facebook, Twitter and ESR's website

There have been a few weaknesses in the communication to the prosumers:

- In some cases, a few months have gone between the subscription of the prosumer and the installation. When the installation team re-contacts the prosumer, he sometimes does not remember exactly what he signed for.
- During the installation, it became clear that the prosumers understand very little about flexibility and renewable integration. Most of them only understand the general concepts about the necessity to switch to renewable. However, some people are real specialists.
- House owners are not all used to the digital tools: a web-interface seems complicated to some of them.
- Understanding the graphics showing energy consumption is not easy. It should come with some explanations. The first version of the web interface gave only graphics with raw data.

Lessons learned:

- The prosumers should be kept informed regularly of the advancement of the project.
- A more detailed description of the system available should be available. The communication should have at least two level of complexity:
    - General public
    - Details for interested people.
- A substantial effort must be done to make user-friendly visualization accompanied with some explanations.

2.2.1.4 Consent form

As the prosumer is sharing data with ESR and other participants of the project, this must be explicitly explained to the prosumer and he must give his consent. An example of the consent form is given in Appendix 2.

2.2.1.5 Selection of flexible consumers

The flexibility harvesting requires a special infrastructure. We need flexible loads but also a communication network to the prosumer. To have a “real world” demo site that helps us to understand what it means to deploy the GOFLEX system at large scale, the choice of ESR is to implement the communication independently of the prosumer private internet connection. It is impossible to rely on this connection. It may work for a small demo on a voluntary basis, but that could not be scaled up. The choice was done to use the existing optical fibre network.

The selection of potential volunteers for the GOFLEX project was done crossing the information about flexible loads and possibility to connect them to the optical fibre network.

With this methodology, the number of potential prosumers was quite low. It allows us to have a first batch of 311 peoples. Letters were sent to them (see appendix 1) and we had a return of about 40 subscriptions.

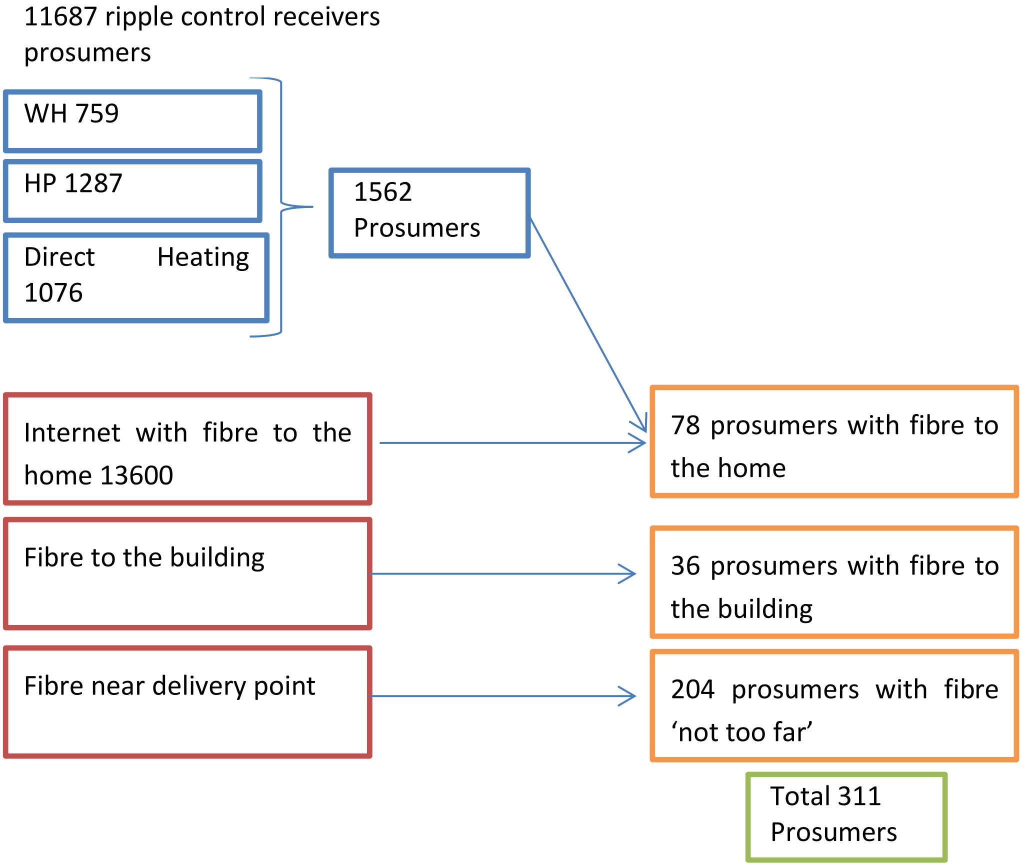

Figure 24 - Selection of the first prosumers

In the end, the selection of 200 prosumers required three rounds of letters to about 700 people and a campaign on social networks that gathered about 50 volunteers. We had to open the selection to houses with coax TV cable and not only optical fibre.

The volunteers contacting ESR because of the social networks' communications were often people with PV installations that are already very interested in energy. Those were very positive and ideal test-prosumers but sometimes it was difficult to connect to the GOFLEX system because of the lack of optical fibre or coaxial cable. Unfortunately, some of them had to be rejected.

3 Prototype Installation

Each of the following sections describes the work steps carried out to install and/or configure components of the prototype and prepare or adapt the environment – installation project documentation.

3.1 Automatic Trading Platform

3.1.1 Flexibility Market (FMAR)

The virtual machine containing FMAR and provided by INEA was deployed on ESR servers. The deployment worked perfectly.

3.1.2 Flex Offer Agent (FOA)

No hardware FOA were currently installed as they are integrated in the different solution (FEMS, HEMS, Delegated control, CEMS, etc.) as software FOA.

3.2 Energy Management Systems

3.2.1 Factories (FEMS)

The Factory Management System is composed of the following equipment:

- Electrical cabinet provided by INEA,
- Electrical meter on the general introduction of the site (in addition to the ESR meter),
- Electrical meters on each controlled appliance.

Added electrical meters are connected to the existing control system. Those data are supplemented by data of the site (e.g. outside/inside temperature, temperature of storages, and status of the heaters…) and pushed to GOFLEX system through the FEMS cabinet (Figure 25). An exchange table is defined for each site.

Figure 25 - FEMS cabinet installed at FEMS 8

Installation and electrical wiring of the cabinet and the counter is carried out by ESR electricians. The installation of current transformers on general introduction is the most problematic and electricity must be cut off most of the time to do this work. To reduce this inconvenience not well appreciated by operators, split-core current transformers have been used when possible. The use of Rogowski's probes are unfortunately not compatible with the selected industrial counters. Figure 26 presents the installation of a power meter at FEMS 8.

Figure 26 - A power meter installed at FEMS 8 with the split-core current transformers

The modification of the local control system is the second step and is carried out by the usual subcontractor of the enterprise and mandated by HES-SO. New values of the meters are added to existing control system.

Once this task is completed, communication between FEMS cabinet and local control system is tested as well as the connexion between FEMS Cabinet to the GOFLEX server hosted by ESR. In some cases, IT services must modify specific parameters and give the right to establish this connection. Some companies have a strict control of IT accesses and this point could lead to a dead end. We imagined others IT solutions (GSM connection, new internet subscription for FEMS) for those cases but fortunately, it was not necessary to implement them since we found a final agreement with the IT teams.

3.2.2 Homes (HEMS)

The first HEMS was installed in a household possessing a smart-grid ready heat pump as well as a roof PV installation. The controller part of the HEMS was installed in a small dedicated electrical cabinet, like presented in the pictures below. The pictures show also the installation of the hot water tank temperature sensor, the installation of the power meters to track the consumption and production of the PV installation, of the household, as well as the consumption of the heat pump.

The heat pump controller had to be reconfigured, to be able to access the smart-grid ready mode.

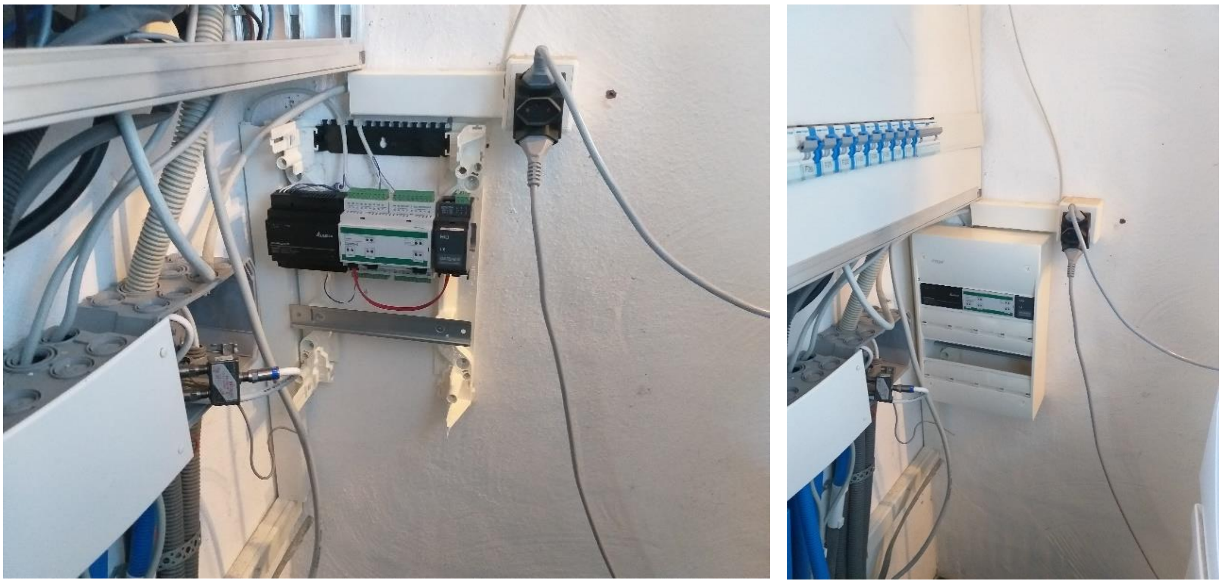

Figure 27 - HEMS controller installed in its dedicated cabinet

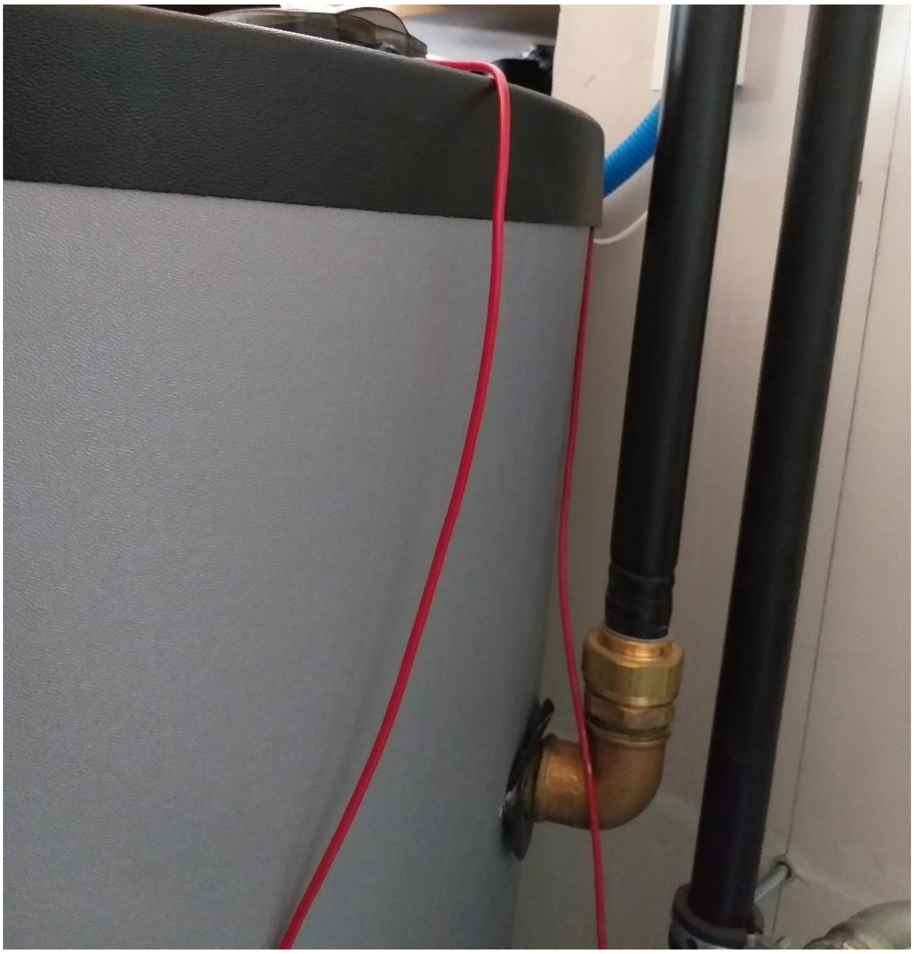

Figure 28 - Hot water tank temperature sensor

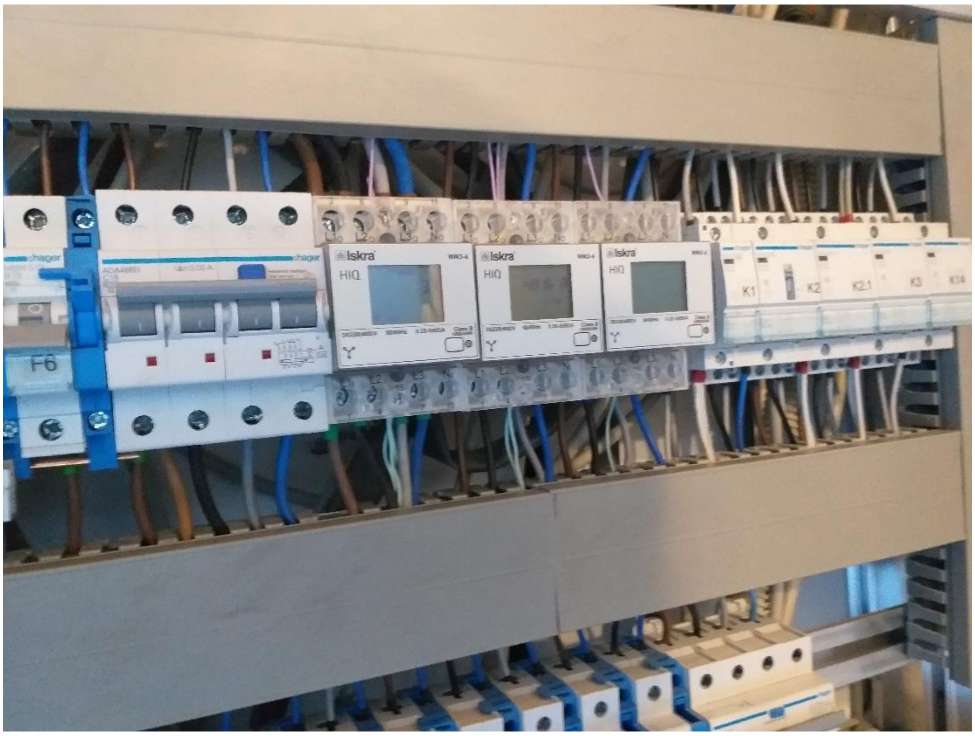

Figure 29 - Power meters installation in electrical cabinet

Figure 30 - Smart grid ready heat pump and its controller

3.2.3 Charging Stations (CEMS)

Etrel's G6 charging stations provide the user with two sockets for simultaneous AC charging. These charging stations feature single or three-phase seven pole IEC62196-2 Type 2 Mode 3 sockets. The output power of each socket is up to 22 kW and the output current is up to 32 A per phase. These charging stations also contain embedded smart energy meter for each socket and communication with the charging station can be made via Ethernet or GSM. Finally, user identification uses RFID 13.56 MHz cards and the charging stations supports smart cards compliant with ISO/IEC 14443 A and ISO/IEC 15693 standards. Etrel's G5 charging stations show similar characteristics but only feature a single socket. Figure 31 illustrates both the G6 (left) and the G5 (right) charging station.

Figure 31 - Etrel's G6 (left) and G5 (right) charging stations for electric vehicles.

So far, four Etrel charging stations for electric vehicles have been installed in two CEMS on the domain served by ESR. Two G6 and one G5 charging stations are operational in the car parks of the University of Applied Sciences and Arts Western Switzerland (HES-SO) in Sion (CEMS 1) and one G5 charging station is installed in the parking lot of a private individual in Sion (CEMS 2). Figure 32 illustrates the two G6 installed in the car parks of HES-SO (top), the G5 (bottom left) installed in the car park of HES-SO and the G5 (bottom right) installed in the parking lot of a private individual. These four charging stations all use Ethernet for communication to and from Etrel's dashboard. The three HES-SO charging stations use public IP addresses and are connected in a demilitarized zone (DMZ) for security purposes. The fourth charging station is connected in a home private network and network address translation (NAT) as well as port forwarding are used for communication to and from Etrel's dashboard.

Etrel's dashboard, shown in Figure 33, is used for monitoring and control of the charging stations. It is also used for energy management, assets management and user's management and identification. Several application programming interfaces (APIs) are available to get and set relevant information about the charging stations and the users such as location, status, charging sessions, identification and son on. These APIs will be used to retrieve the consumption data of each charging station.

Figure 32 - The two G6 (top) and the two G5 (bottom) charging stations installed in Sion.

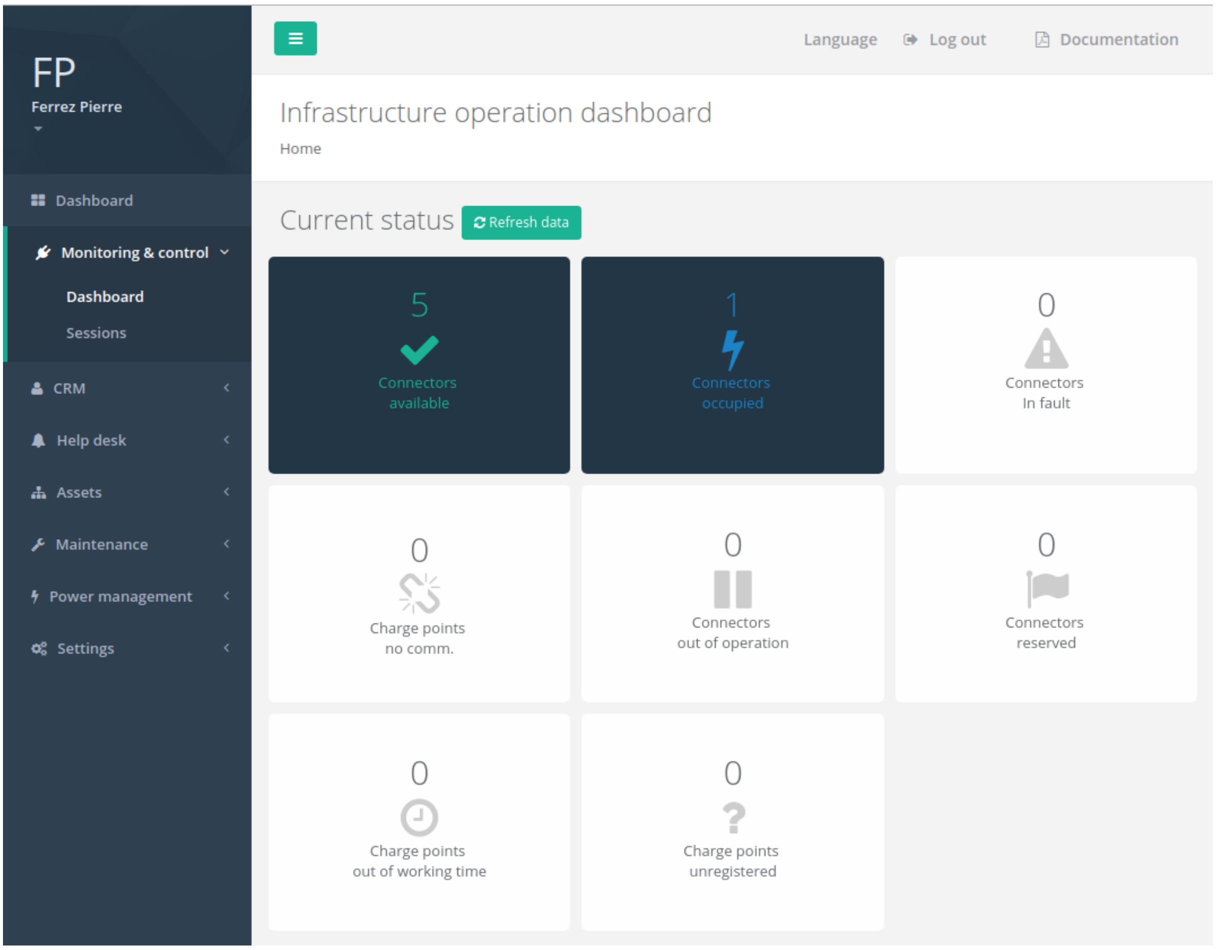

Figure 33 - Etrel's dashboard used for monitoring and control of the charging stations as well as for the users' management.

3.2.4 Charging/Discharging Stations (CDEMS)

The first CDEMS to be installed was HEMS 3. The household is equipped with a heat pump (Figure 34) that produces both space and hot water heating. The inhabitants possess also a Tesla car that is charged with a standard plug in the garage. Moreover, the installation of roof PV panels is planned, and the installation will be adapted as soon as it will be installed. The installation was done in a very similar way as with HEMS (Chapter 3.2.2). A battery storage (eStore) of 3 kWh was installed to emulate the behaviour of charging and discharging electrical vehicle.

Figure 34 - The first installed CDEMS including a heat pump (left), two water tanks for space and water heating (right) and the deployed battery (right)

3.2.5 Single Load Controllers

3.2.5.1 Status

The GOFLEX Description of Work indicates that single load controllers should be deployed in 200 buildings owned by the delegated trading prosumers. At the date of the present deliverable (end of October 2018), 50 buildings are fully operational. Deployment is late, mainly because of the lack of capacity for the installation of the high-speed telecom link (optic fibre or cable TV) required for each participating building. Measures have been taken to speed-up the deployment.

3.2.5.2 Direct control model

Sites with single load controllers use the so-called Direct Control model: local sensors and actuators are connected to a local device acting as a gateway (i.e. without local intelligence) to a remote EMS or aggregator service including a FOA. Such a gateway is naturally named "Direct Control gateway".

3.2.5.3 Types of houses

Some of the criteria used to differentiate the households are the following:

1. use of electricity for space heating, domestic hot water or both;
2. use of common or separate heating system for space heating and domestic hot water;
3. use of either direct resistive heating or heat pump as technology for each heating systems;
4. local PV installed or not.

The individual setting for each building is recorded in the meta-data (see 3.2.5.11).

3.2.5.4 Monitoring and control parameters

The following rules indicate which parameters are monitored or controlled:

1. All participating houses are equipped with an online smart meter.
2. Houses with electrical space heating are equipped with a temperature sensor in the main room (typically living room).
3. Houses with electrical domestic hot water are equipped with a temperature sensor located on the external wall of the hot water tank. Sensors may be missing if access to the wall is not possible.
4. Heating systems, independently of their technologies, are equipped with an electrical sub-meter.
5. Heating systems, independently of their technologies, are equipped with a relay that can enable (relay is closed) or disable (relay is open) heating generation. When the relay is open, heat generation is turned off. When the relay is closed, the controller integrated in the heating system controls heat generation without any restriction.

Target sample periods for monitoring are indicated in Table 2.

Table 2 - Measured value with target sampling periods

Sensor	Measured value	Acquisition
Room temperature sensor	Ambient temperature	Once per 15 minutes or on temperature change (dead band 0.5 K)
Water temperature sensor	Domestic hot water boiler temperature	Once per minute or on temperature change (dead band 0.5 K)
Sub-meter	Power	15 seconds (if changing)
	Phase L1, L2 and L3 voltages	15 seconds
	Phase L1, L2 and L3 currents	15 seconds (if changing)
	Energy	15 seconds

Values to be acquired by the smart meter are listed in Table 3.

Table 3 - Monitored parameter by smart meters

Group "Technical" Acquisition period: 5 seconds	**Group "Energy"** Acquisition period: 5 minutes	**Group "Billing"** Acquisition period: 30 days
Logical name push setup consumer information 1	Logical name push setup consumer message	Object list push setup consumer information 2
Device ID 1 (utility serial number 1, ID 2.1)	Device ID 1 (utility serial number 1, ID 2.1)	Logical name push setup consumer information 2
Device ID 2 (utility serial number 2, ID 2.2)	Device ID 2 (utility serial number 2, ID 2.2)	Device ID 1 (utility serial number 1, ID 2.1
Active power import +P	Clock	Device ID 2 (utility serial number 2, ID 2.2
Active power export -P	Active energy import +A (QI+QIV)	Active energy import +A (QI+QV) rate 1
Reactive power import +Q	Active energy export -A (QII+QIII)	Active energy import +A (QI+QV) rate 2
Reactive power export -Q	Reactive energy +Ri (QI)	Active energy import -A (QII+QIII) rate 1
Current L1	Reactive energy +Rc (QII)	Active energy import -A (QII+QIII) rate 2
Current L2	Reactive energy -Ri (QIII)	
Current L3	Reactive energy -Rc (QIV)	
Voltage L1		
Voltage L2		
Voltage L3		

3.2.5.5 **In-house setting**

Figure 35 represents the monitoring and control infrastructure of a fully equipped Direct Control building. The gateway features an Ethernet interface and is connected to the ESR private data network through an external modem (optical fibre for most sites, cable TV for some of them).

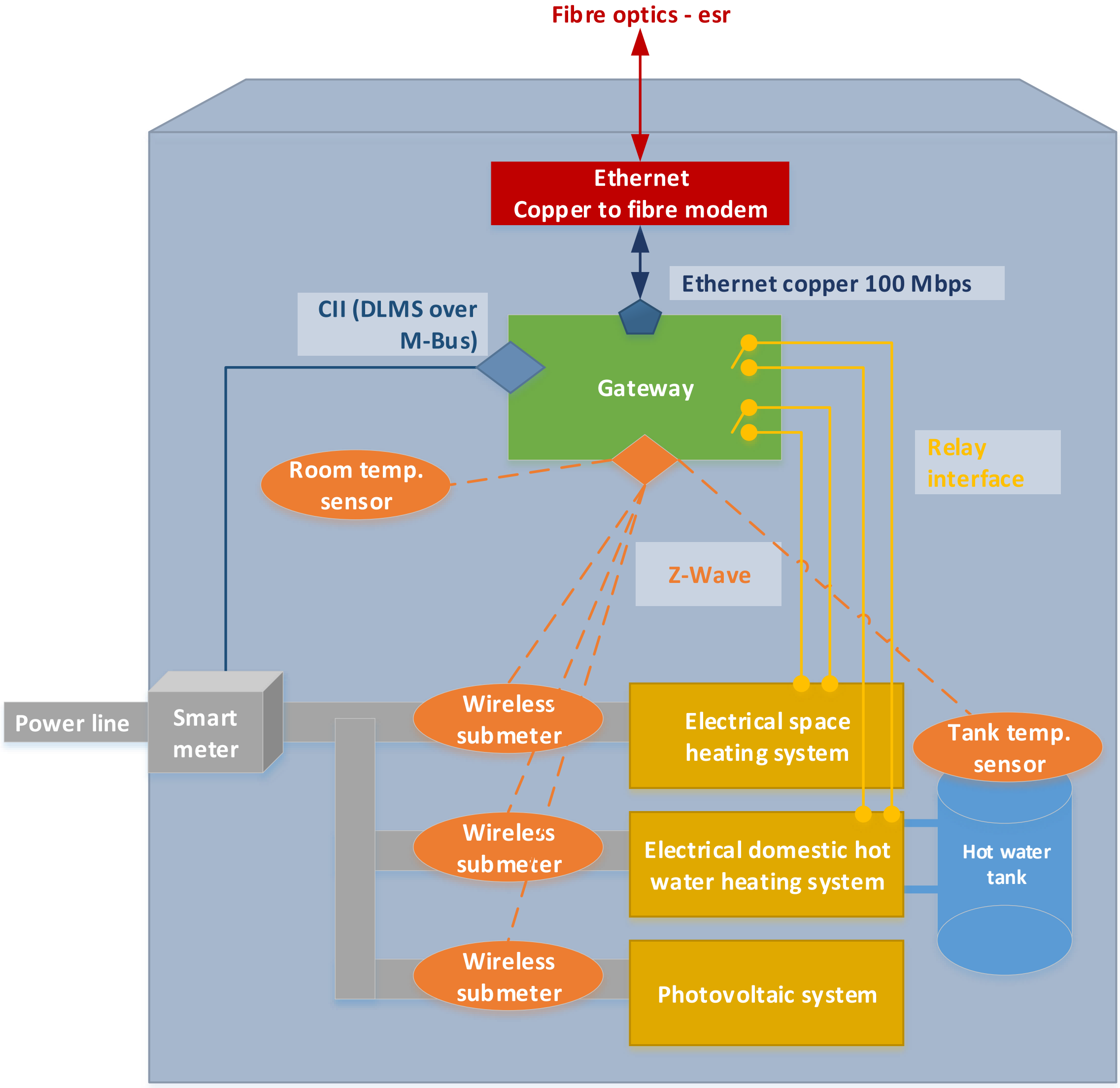

Figure 35 - Schematic view of a fully equipped Direct Control building

Sub-meters and temperature sensors (both hot water and ambient) are connected to the gateway over Z-Wave wireless links. Enable / disable relays are integrated in the gateway. The smart meter features a digital wired link to the gateway.

3.2.5.6 Direct Control gateway architecture

The Direct Control gateway is based on a Raspberry Compute Module[2]. It has been designed by HES-SO specifically for this project and has been manufactured and mounted by a company mandated by HES-SO.

The gateway connects to the internet over an internal USB to Ethernet hub, controls the relays and LEDs and reads the state of the "On-Auto" switch. This switch allows an inhabitant

[2] https://www.raspberrypi.org/products/compute-module-3/

to disable remote relay control (i.e. to manually force the relays to close, if she believes that the temperature of the domestic hot water or the ambient temperature is too low). It is meant as a last security feature in case of failure of GOFLEX.

To eliminate the need of an external power converter, the gateway can directly be powered with 230 Vac. To get the measurement data, the Raspberry Compute Module connects to the smart meter over a serial link (UART).

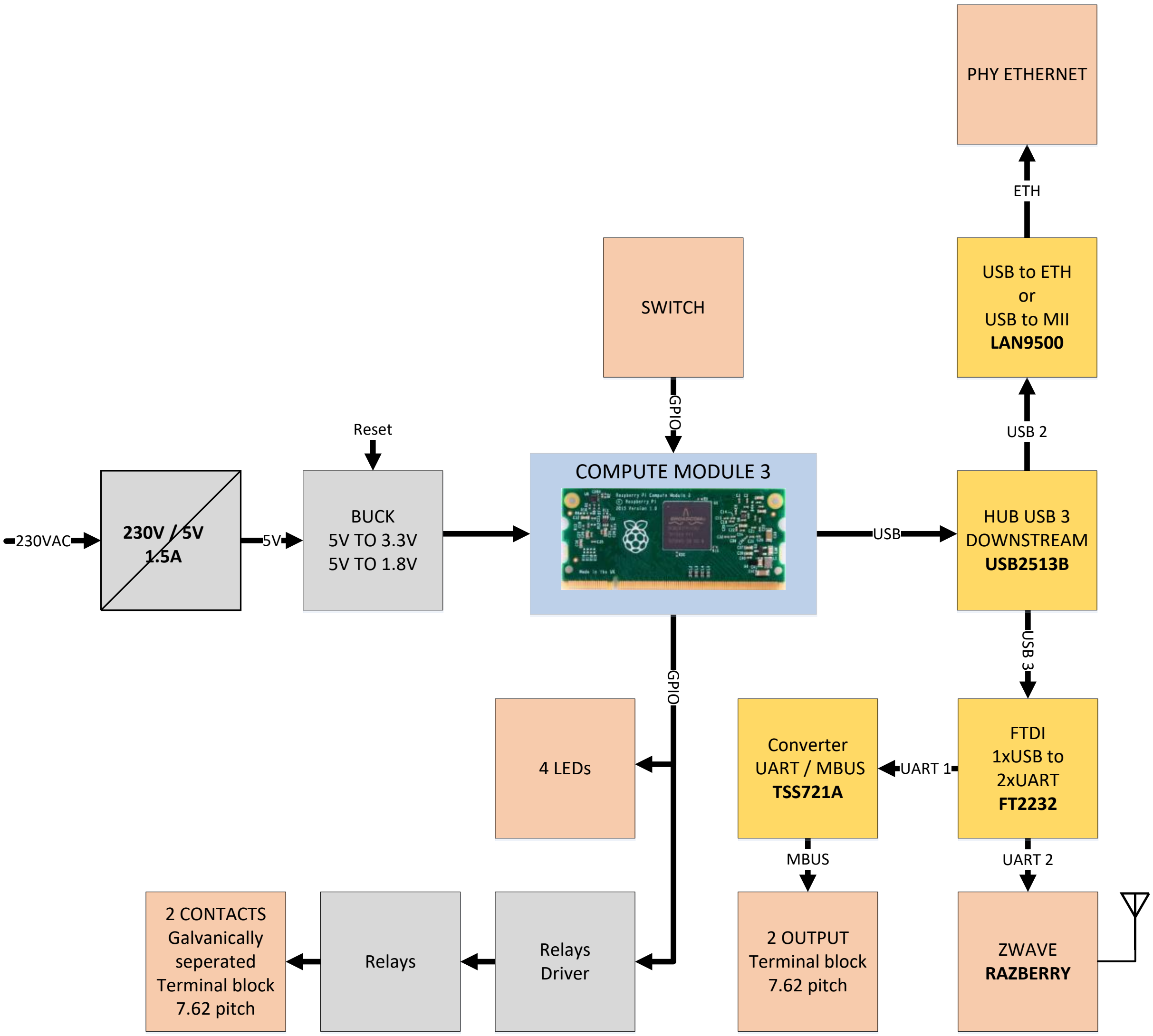

Figure 36 - GOFLEX Direct Control Gateway Architecture

The three field interfaces are:

1. The M-BUS / DLMS interface for connection with the smart meter.
2. The Z-Wave interface for temperature sensors and sub-meters.
3. The relay interface to enable / disable heating.

The remote interface is based on Ethernet –TCP/IP. It features an interface to the IoT system cloud.iO (see 3.2.5.10 and 3.2.5.10).

The only logic programmed into the gateway is to enable space and domestic water heating (close relays) when remote communication is lost.

3.2.5.7 Sensors and actuators

As explained in 2.2.1, control circuits are disconnected from the ripple control and connected to relays outputs of the Direct Control gateway. Control relays in the gateway are bi-stable relays providing a galvanic insulation between the gateway and the heating systems.

Table 4 lists the Z-Wave sensor types with their properties. Figure 37 displays a picture of these sensors.

Table 4 - Z-Wave sensor description

Measured parameter(s)	Sensor type	Comment
Ambient temperature	Philio PAT02-B	Battery powered
Boiler temperature	Qubino Flush On/Off Thermostat	Used with a 1m digital temperature sensor
Electrical sub-meter on heating / PV systems	Aeotec Home Energy Meter Gen5	Possess three clamps returning separate values

Figure 37 - Pictures of the Z-wave sensors (from left to right, ambient temperature, boiler temperature, and electrical sub-meter)

3.2.5.8 Smart meters

ESR, like all Swiss DSOs, plays three roles for residential consumers: DSO, metering operator, and electrical energy supplier. As indicated in 3.2.5.4, ESR chose to collect three groups of measured parameters – each group having its own acquisition period.

Smart meters are of the type Landis+Gyr E450. They feature three communication interfaces:

1. **Power Line Communication (PLC)**: low speed interface designed to let the metering operator collect daily the load curve, typically with a 15 minutes resolution.
2. **Optical serial interface**: This digital interface allows an installer to configure locally the meter and to retrieve energy indexes per tariff for billing.
3. **Consumer Information Interface (CII)**: This interface, defined by an association of smart meters manufacturers called IDIS[3], has been designed to allow a prosumer to access real-time data from her meter. For security reason, this interface is one-way: data flow only out of the meter.

None of these interfaces fits perfectly the requirement for direct control sites. PLC speed is an order of magnitude too slow for data acquisition as specified above. The optical interface requires an optical "eye" to be placed permanently on the meter. Costs are prohibitive for the project and prosumers could remove them (they are held in place only by a magnet). The CII fulfils the specification, but the metering operator cannot remotely address the meter (for configuration changes or for reading other data). The CII being the only interface to fulfil the requirements, it has logically been selected for direct control sites, despite the lack of bidirectional communication.

The CII interface uses the stack of protocols indicated by Table 5.

Table 5 - Protocol stack for the CII Interface

Physical layer	M-Bus: the smart meter takes the master role and the gateway the slave role
Data Link layer	HDLC
Application layer	DLMS "Push" model. List of pushed objects are configured in the meter. Each list has list own push period.
Security	According to DLMS Level of security selected: No encryption
Object classes	COSEM
Object identification	OBIS codes

[3] http://idis-association.com/

Each of the parameters listed in Table 3 is identified by an OBIS code. OBIS codes are loosely defined by the DLMS association[4]. Hence, all DLMS meter should use the same OBIS code for a given parameter.

3.2.5.9 The cloud.iO IoT framework

cloud.iO is an open source IoT framework developed and maintained by HES-SO[5] (IoT Architecture for Decentralised Heating Control in Households, 2018). cloud.iO orchestrates field-proven scalable internet open-source components to build a secure and flexible IoT framework.

The cloud.iO framework connects field devices called Endpoints and so-called Applications, which are computer programs with real-time read/write access to Endpoints parameters and read access to historical values of Endpoints parameters.

Some features of the framework are listed below:

- cloud.iO can support any data model (i.e. structure of data) for Endpoints.
- cloud.iO communication is based on a messaging service (and not on the client-server model), i.e. Endpoints and Applications can feed cloud.iO with data at any time.
- cloud.iO communication features state-of-the-art security (encryption and authentication).
- Access rights to Endpoints points by Applications can be managed centrally.

cloud.iO features three databases:

1. The Process Database stores the status of Endpoints. The status is composed of two types of data:
   - an image of the current values of the field data as captured by each HEMG, and
   - the list of on line and off-line Endpoints.
2. The History Database stores all past field monitoring data and provides access to them. The History Database has a companion web visualization portal based on Grafana[6].

[4] https://www.dlms.com/

[5] http://cloudio.hevs.ch, https://github.com/cloudio-project

[6] https://grafana.com/

3. The Access right Database holds the read and write access rights for Applications on Endpoints.

Through the Endpoint API, Endpoints can push new sensors values to cloud.iO at any time and receive new actuators values from cloud.iO.

Through the Application API, Applications can:

- query the Process and History databases,
- subscribe to get notified of any change of field sensor values,
- be notified in real time on changes on subscribed field sensor values,
- and update the set point of any actuator in real time.

Each field device connected to cloud.iO features an X.509 certificate signed by a (private) Certificate Authority (CA) and a corresponding private key. Links between cloud.iO devices are implemented by SSL/TLS connections based on mutual certificate-based authentication.

cloud.iO can enforce privacy rules by explicitly granting Applications read and/or write access rights to Endpoints.
Endpoints feature a tree-shaped data model, as illustrated in Figure 38.

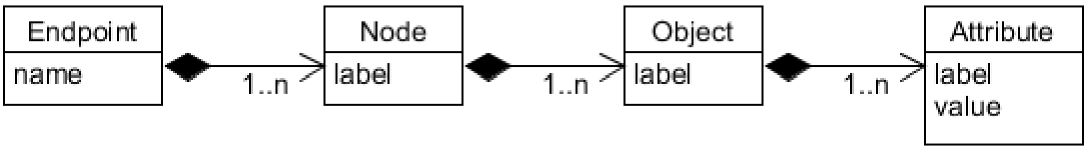

Figure 38 - cloud.iO data model

The **`Endpoint`** name must be unique in the cloud.iO system. It is the Common Name (CN) of its X.509 certificate.

The **`value`** of an **`Attribute`** holds a current sensor value or an actuator set point. A **`value`** may take all common types for a variable (integer, floating-point number, string of characters…).

Each **`Attribute`** is identified by a unique identifier called "attribute full label". The latter is built according to the following pattern:

<Endpoint_name>/nodes/<Node_label>/objects/<object_label>/attributes/<Attribute_label>

The core of cloud.iO is a message broker to which Endpoints, Applications and databases connect. Messages feature a topic and a content. In a cloud.iO system, there are two basic types of messages:

- Messages sent by **`Endpoints`** to publish a new value for a sensor **`Attribute`**:

  - Topic: "**@update/<attribute_full_label>**"
  - Content: JSON encoded message with the new sensor value and an optional time stamp.
- Messages sent by **Applicatons** to publish a new value for an actuator **Attribute**:
  - Topic: "**@set/<attribute_full_label>**"
  - Content: JSON encoded message with the new actuator value and an optional time stamp.

A component connected to the message broker can subscribe to message topics, possibly with a wildcard. When a component has subscribed to some topic, the message broker pushes to it all messages with that topic. In cloud.iO, the following subscription policy is applied:

- An **Endpoint** with name **<Endpoint_name>** subscribes to topics **@setup/<Endpoint_name>/#**, where **#** is the wild card character.
- An application may subscribe to any topic beginning with **@uppate/**, if permission is granted in the Access rights database.
- The Process database logs "everything". Hence, it subscribes to **#**.
- The History database logs all sensor values and therefore subscribes to **@update/#**.

This subscription policy allows:

- any Application to read any sensor **Attribute**'s **value**, as long as permission is granted,
- an Application to write any actuator **Attribute**'s **value**, as long as permission is granted,
- to store all sensor values in the History database, and
- to keep the cloud.iO system current topology up-to-date in the Process database.

Applications and Endpoint connect to cloud.iO either with the MQTTs[7] protocol or with the AMQPs[8] protocol.

---

[7] Secure version of the MQTT protocol (https://en.wikipedia.org/wiki/MQTT)

[8] Secure version of the AMQP protocol (https://en.wikipedia.org/wiki/Advanced_Message_Queuing_Protocol)

3.2.5.10 Cloud.iO for Direct Control

Direct Control gateways are cloud.iO Endpoints. Aggregators / EMS components with integrated FOA are cloud.iO Applications.

`Endpoint` names are built according to the following pattern: "**`goflex-dc-<###>`**", where **`<###>`** stands for a string made up of three digits indicating the house number (example "**`goflex-dc-004`**".

`Attribute` elements are defined for all sensor and actuator values in the two relays, in the smart meter and the Z-Wave devices. Attributes are logically groups in nodes, as defined in Table 6. Z-Wave sub-meters are the only devices that can be present multiple times in a given house. A given power meter is identified by a specific **Node** label corresponding to a given power meter unit contains the figure "**1**", "**2**" or "**3**". The figure does not indicate which process is measured; this should be defined in the meta-data (see 3.2.5.11).

Table 6 - cloud.iO Node objects for Direct Control

cloud.iO Node label	Description
goflex-dc-<###>/nodes/ambientSensor-#	Node for ambient room temperature
goflex-dc-<###>/nodes/boilerSensor-#	Node for probe temperature
goflex-dc-<###>/nodes/powerMeter-#	Node for the Aeotec Home Energy Meters
goflex-dc-<###>/nodes/SmartMeterBilling	Node for the "Billing" group of the smart meter
goflex-dc-<###>/nodes/SmartMeterEnergy	Node for the "Energy" group of the smart meter
goflex-dc<-###>/nodes/SmartMeterTechnical	Node for the "Technical" group of the smart meter
goflex-dc-<###>/nodes/gateway	Node used to assign relay set points

The complete list of **`Attribute`** full names is given in Appendix 4. Each smart meter COSEM object identified by its OBIS code is also a cloud.iO **`Object`**. The **`label`** of such an object is derived from its OBIS code.

Each house has its own Grafana web page that displays graphically the main indicators for a building. This page is useful for diagnostic. Grafana allows easily modifying time settings (start time and time scale).

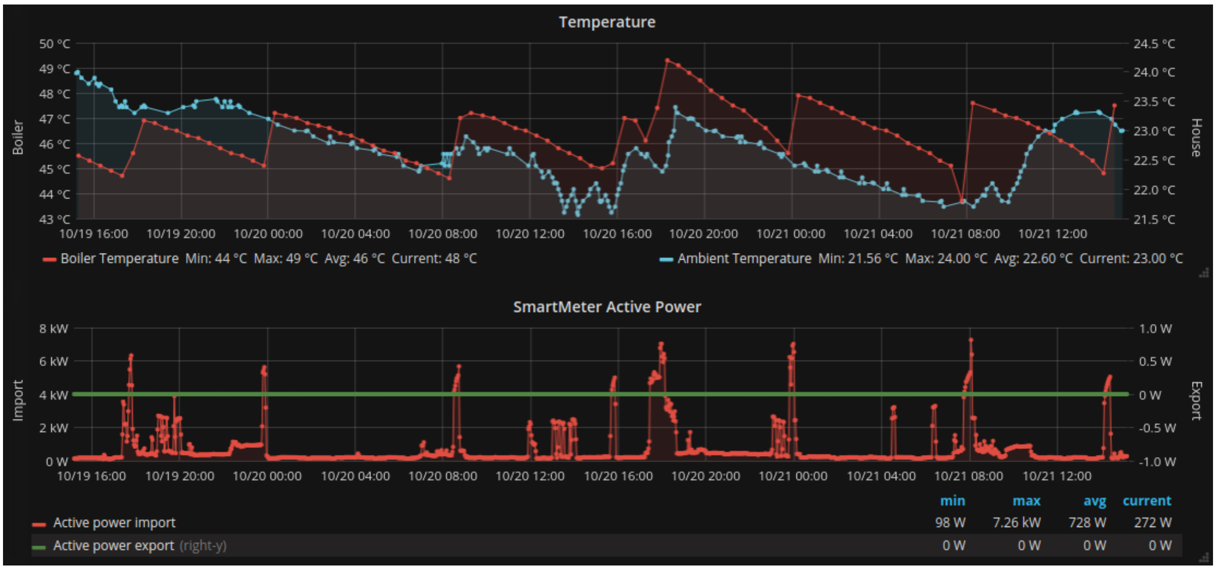

Figure 39 - Sample diagnostic web page for a house, from the History Database

3.2.5.11 **Meta-data**

cloud.iO addresses only measurement and control and does not provide any mean to manage and store associated meta-data. Hence, a separated database has been setup for meta-data. The cloud.iO `Endpoint` name serves as a common key between cloud.iO and the meta-data database.

The meta-data database contains six kinds of data:

1. Administrative data about the prosumer and its house.
2. Topology of the house and related sensors/actuators (especially which power meter and relay correspond to which process).
3. Energy relevant information on the building: type and size of building, heating systems technology, size of DHW boiler…
4. Information regarding the wiring in the building. The goal is to support maintenance and decommissioning.
5. The reference to the aggregator / EMS controlling the house.
6. Information about the building (year of build or major renovation, boiler volume ...) and the household (number of inhabitants).

For privacy reasons, the access to the meta-data database is restricted. To protect privacy, exports of relevant tables of the meta-data database can be performed on request.

Meta-data are managed by the system management tool (see 3.2.5.15).

3.2.5.12 Direct Control backend

The Direct Control back-end is made up of the servers and the software for the operation of the Direct Control demonstrator.

The Direct Control houses are connected to the Direct Control back-end with an ESR private network (i.e. not through internet). An overview of ICT system for Direct Control is presented on Figure 40.

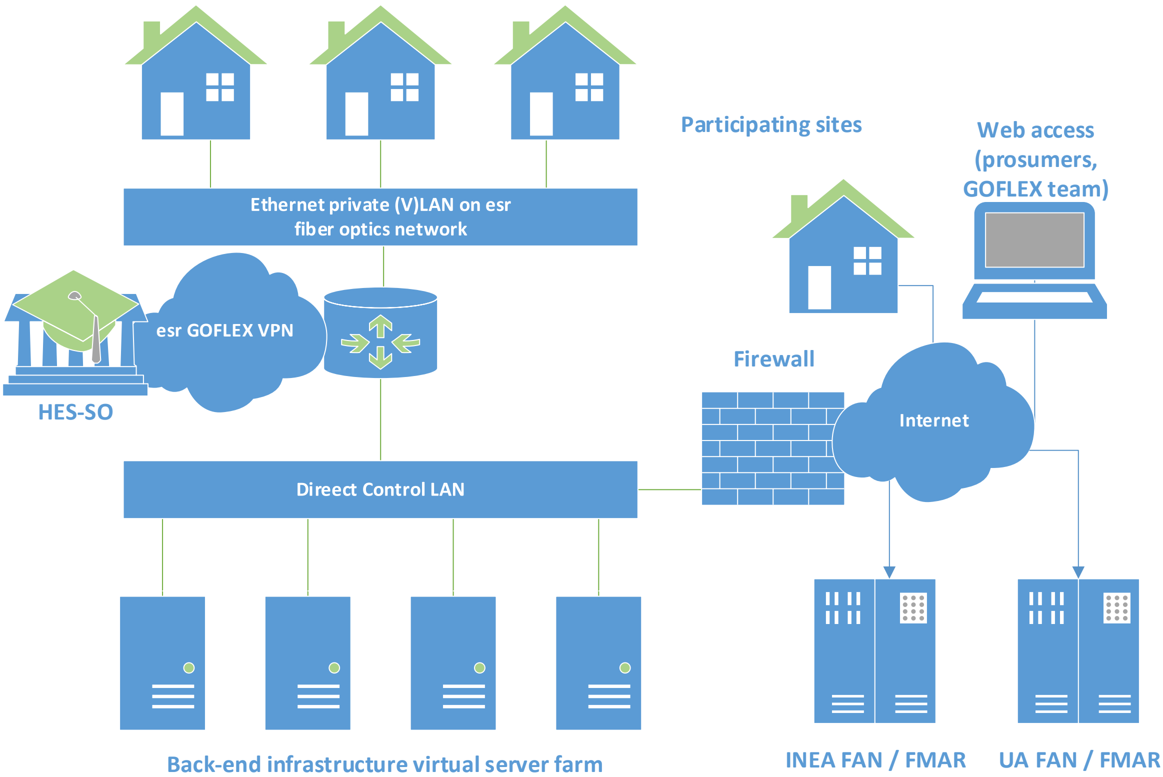

Figure 40 - ICT back-end infrastructure for Direct Control

The Direct Control back-end infrastructure is hosted in the private cloud of ESR, located in its premises of Sion, Switzerland. The EMS / aggregators connect to the cloud.iO message broker with MQTTs. Hence, they receive updated values for all subscribed attributes in real-time.

The back-end infrastructure is made up of four virtual servers (see Figure 41).

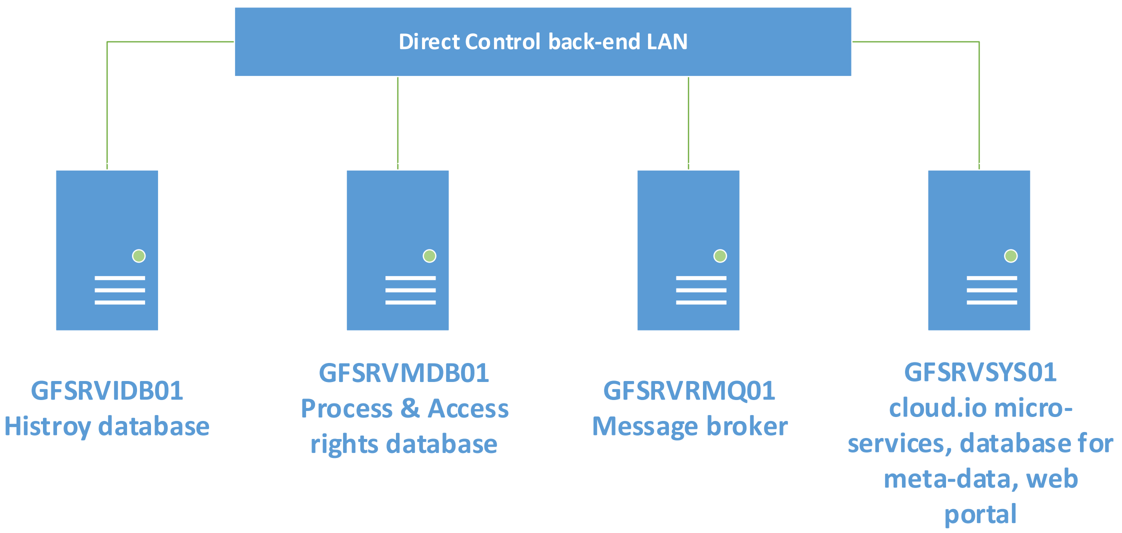

Figure 41 - Servers for the Direct Control back-end infrastructure

3.2.5.13 Provisioning

ESR has gathered a list of 200 customers, who are motivated to participate to the research project and feature an appropriate setup in their house (electrical space and/or domestic hot water heating). Each participant's house is identified by a number.

Administrative data for the participants is introduced in the system management tool (as part of the meta-data, see 3.2.5.11). On cloud.iO, a participating site is identified only by its cloud.iO Endpoint identifier ("`goflex-dc-<###>`", **#** being the house number).

The workflow for provisioning a new participant is summarized below:

1. ESR's multimedia team installs a fibre link to the house. It installs a fibre (or cable TV) link to the electrical cabinet of the target house and terminates it with a fibre (cable TV) modem.
2. The participant is contacted by email. The email explains the context and goal of the project, describes the infrastructure to be deployed in her house as well as the performed monitoring and control.
3. An employee of ESR's metering team replace the previous meter by a smart meter Landis+Gyr E450.
4. An ESR installer and an HES-SO engineer install the on-site infrastructure (see 3.2.5.14).
5. When on site, the HES-SO engineer collects technical information (also part of the meta-data, see 3.2.5.11) about the building and its heating system. The information comes from observation and from an interview with the participant.

6. The HES-SO engineer feeds the system management tool with the collected meta-data and launches the participant web portal (see 3.2.5.17).
7. The participant receives an email with the credentials to access the prosumer web portal.

3.2.5.14 **Procedure for on-site installation**

HES-SO engineers perform the following steps in the HES-SO premises, prior to an on-site installation:

1. Installing the firmware on the gateway.
2. Generating the cryptographic material and downloading it in the gateway: X.509 root CA certificate, X.509 gateway certificate with its own name "**<goflex-dc-<xxx>**", corresponding private key.
3. Adding a GOFLEX self-sticking label with the house name.
4. Pairing Z-Wave devices with the gateway.

Batches of configured gateway are handed over to ESR installers.

At the arranged time, an ESR technician and an HES-SO engineer go to the house at the same time.

While the HES-SO engineer mounts the gateway on a DIN rail of the cabinet and installs the paired Z-Wave devices, the ESR technician:

1. Mounts the GOFLEX Direct Control gateway and connects it to the fibre modem
2. Installs the wired link between the gateway
3. Disconnects the ripple control lines from the ripple control receiver and connects them to the gateway, and
4. Prepares power supply for the hot water tank temperature sensor.

Finally, the HES-SO engineer validates the installation with a battery of tests.

The following figures present pictures of installed settings.

Figure 42 - Very first installation with a prototype version of the gateway and an optical eye-based communication with the meter (instead of a cable M-bus connection)

Figure 43 - Picture of the first prototype version of the gateway installed in the electrical cabinet.

Figure 44 - Near final version of the Gateway connected to the optical fibre modem.

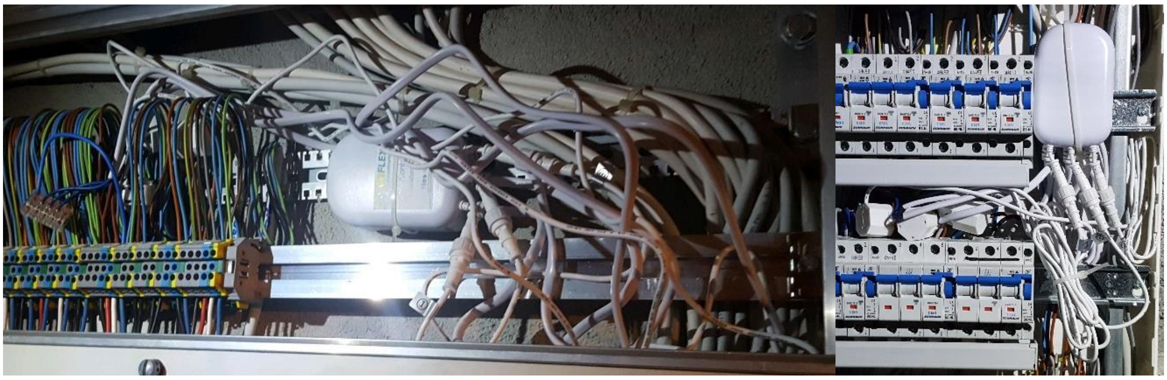

Figure 45 - Sub-meter for a heat pump

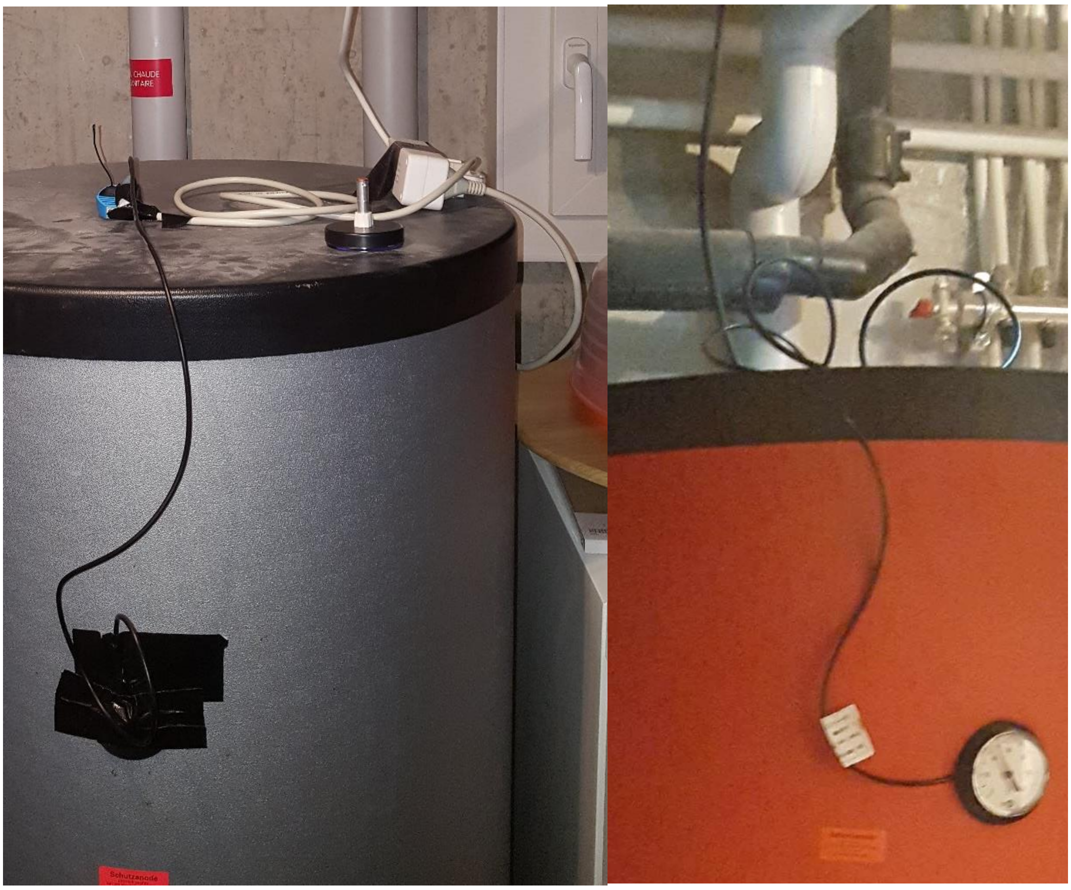

Figure 46 - Heat probes for boilers

3.2.5.15 Supervision

As explained above, the data measured by the smart meters, the sub-meters and the temperature sensors are pushed to a database. Every morning at 6AM UTC, an automatic system queries this database and reports on the quality of the data pushed to the database during the previous 24 hours for each installed house. Depending on the nature of the data (voltage, current, power, energy, temperature, etc.), checks about the quality of the data (sensible values) and/or the quantity of data (respect of the sampling frequency) are performed.

This data check allows us to monitor the collected data and to quickly solve hardware and/or software problems, to maximize the quality of the collected data.

3.2.5.16 System management tool

The system management tool aims to enter and to query meta-data as well as unstructured data (comments, pictures).

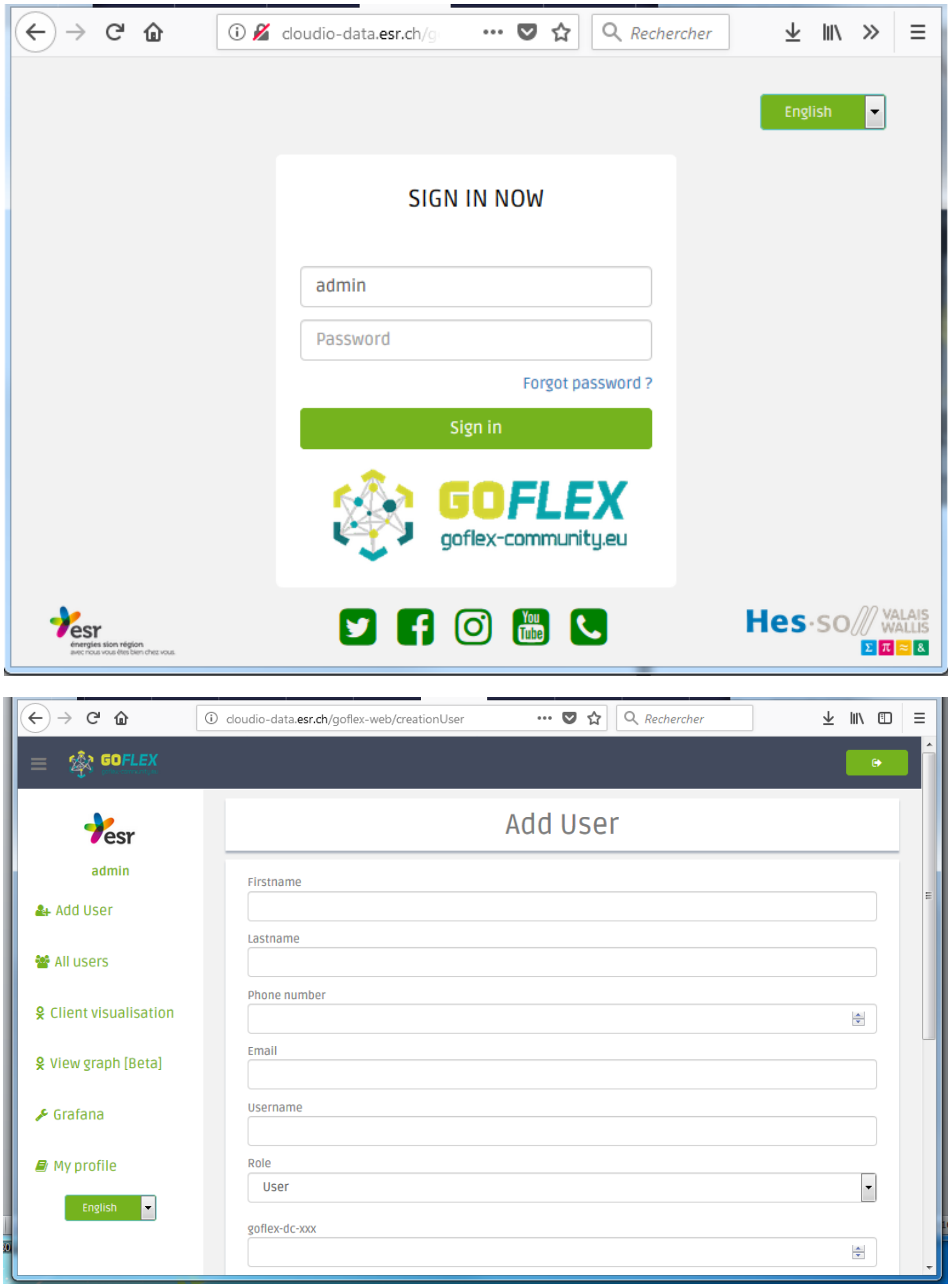

Figure 47 - Menu to add a new participant

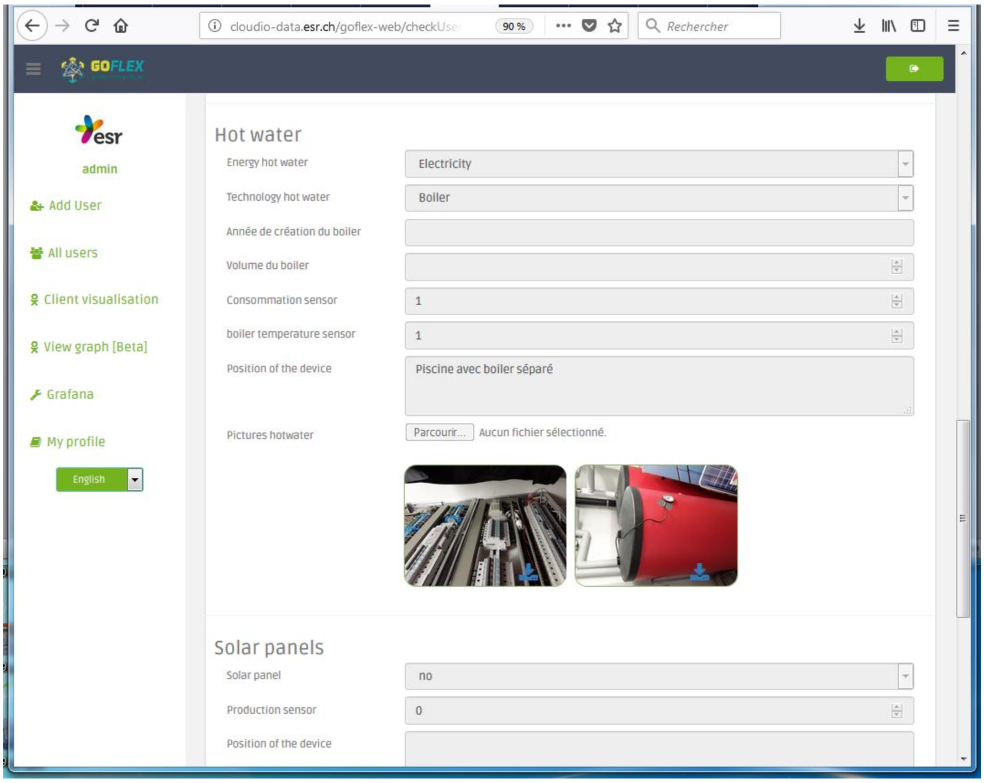

Figure 48 - Menu to input domestic hot water related meta-data

The admin interface allows the monitoring of all the installations.

3.2.5.17 Prosumer web interface

As a counterpart in participating in the project, the prosumers have access to their energy data on a web page. This interface raises the interest of the prosumers for the GOFLEX project and improves their commitment. This interface will show the use of flexibility and can soothe possible conflict about having appliances controlled by the DSO. This allows them to understand their energy use and it opens the door to:

- Potential improvement in energy efficiency.
- For the people having already PV panels installed, the visualization of the profile of the consumption and the comparison with the profile of solar production helps to improve the self-consumption. This helps renewable integration, which is a goal of GOFLEX.
- Possibility to have a PV self-consumption evaluation before a PV plant is planned and installed.

At time of this report, the user interface is available for the 50 test-prosumers in a first very basic version.

3.3 Distribution Observability and Management System (DOMS)

Data from ESR SCADA had to be fed to DOMS and description of the goals of the DOMS were defined by the ESR business cases as described in report D8.2. The main goal selected for the GOFLEX trial is the correction of balance energy, because this is perceived as a real case that can be useful already today. The final financial assessment of using flexibility for this purpose will be done at the end of the project after a few months of operations.

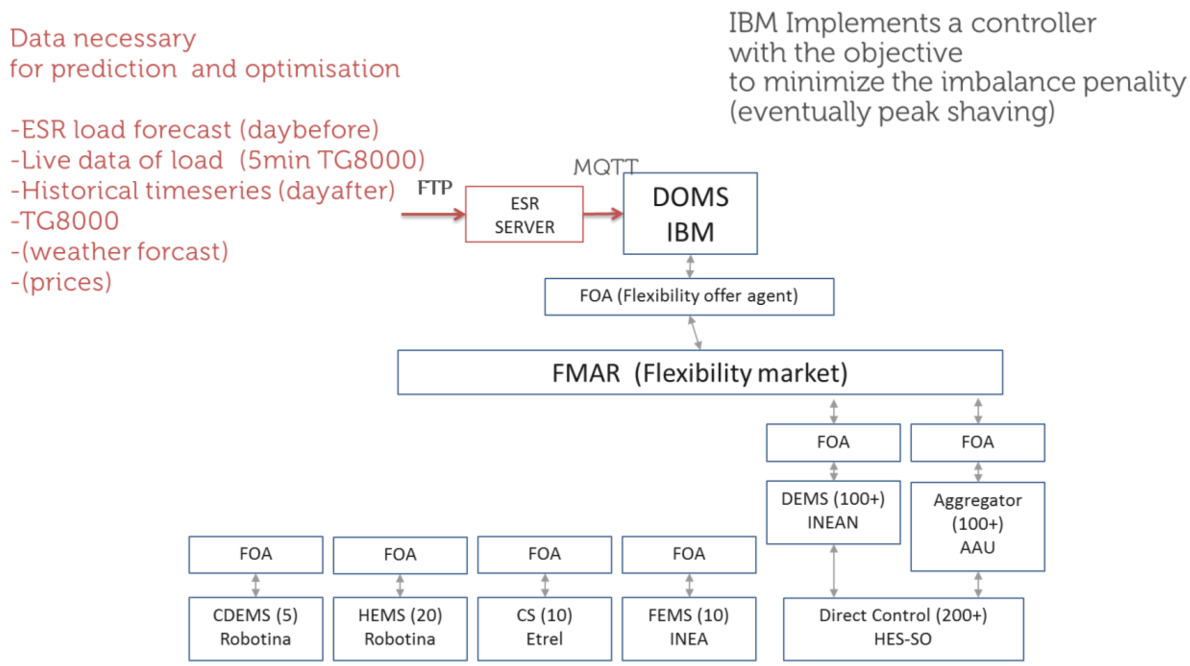

Figure 49 - ESR must feed the DOMS with data, so that the DOMS can make flexibility offers on the flexibility market

3.3.1 DOMS goal

The DOMS for ESR case must be able to compute the difference between load predictions and the real load of the distribution grid. Imbalance is the difference between forecasted power and real power.

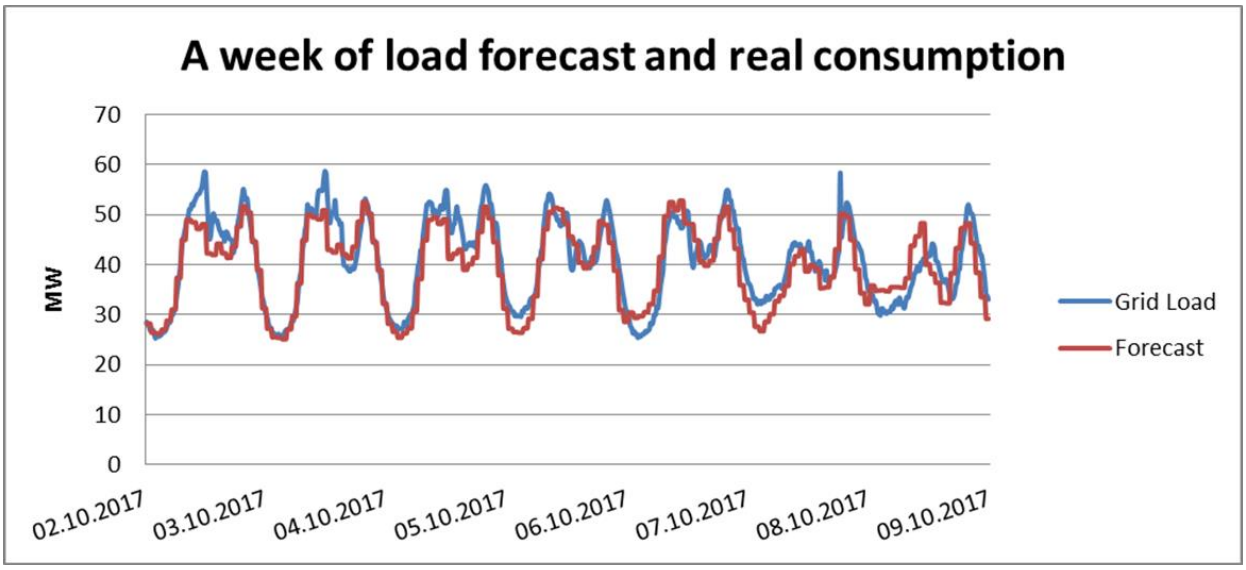

Figure 50 - Example of load and forecast of the ESR grid

The cost of this prediction error is published by Swissgrid (TSO).

A more detailed study of the prediction error was performed on historical data. The year 2016 has 35136 quarters; there are 28881 quarters with prediction error between -5 and 5MW (82%).

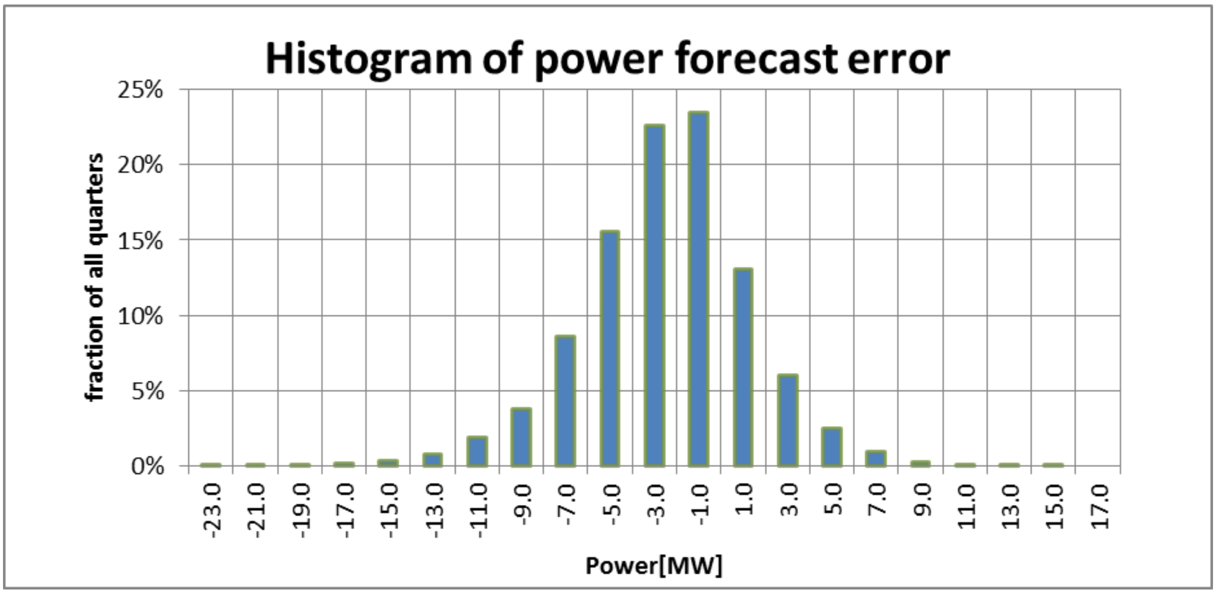

Figure 51 - Distribution of the forecast error on year 2016

The duration of an error (for example during how much time a load prediction is long before going short) and the energy it represents was also assessed.

There are 4980 errors (same sign of forecast error consecutively). Within them, there are 3844 errors (77%) between -2 and 2MWh.

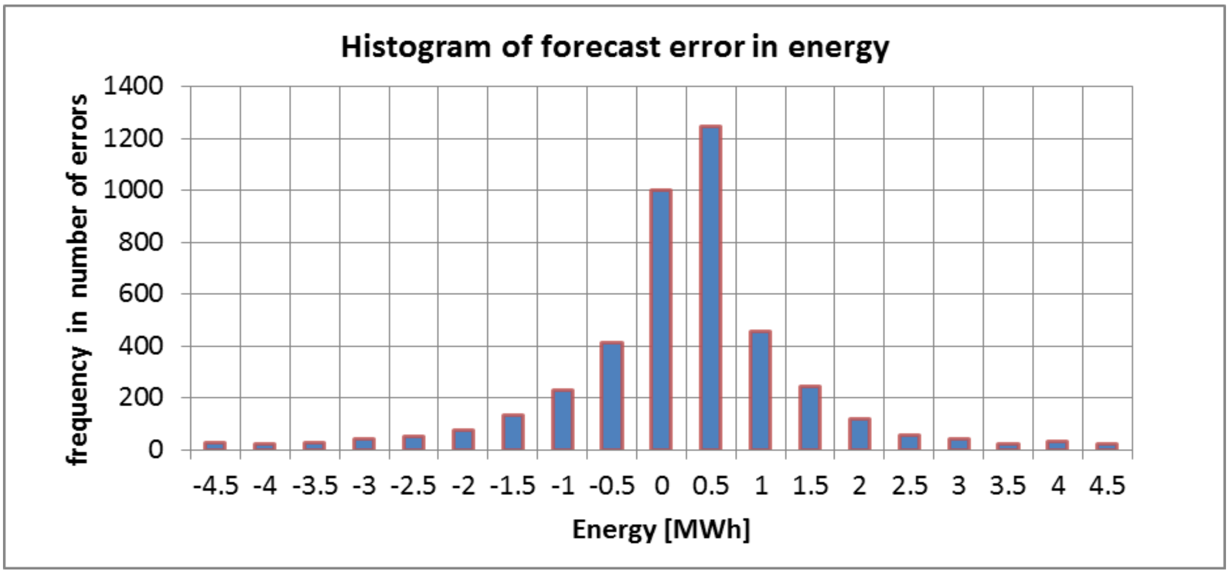

Figure 52 - Energy of a forecast error

There are 3852 errors (74%) lasting less than 60 minutes

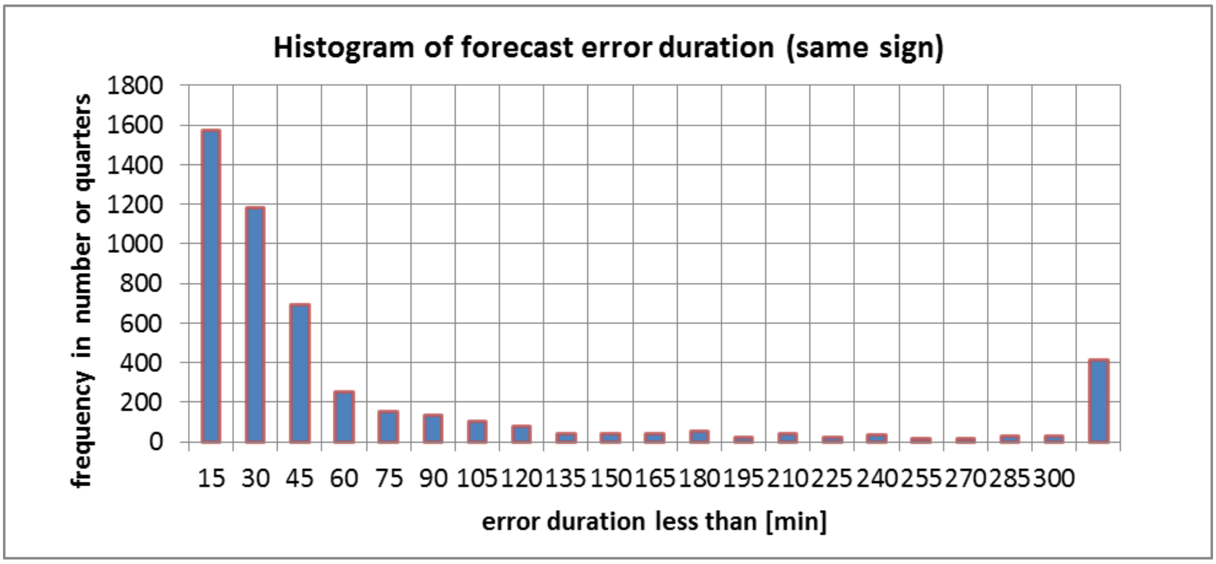

Figure 53 - Distribution of the error durations

Most of the errors are small in power, quite short in duration and with low energy. There are many small errors, but long duration errors represent a substantial amount of total imbalance energy.

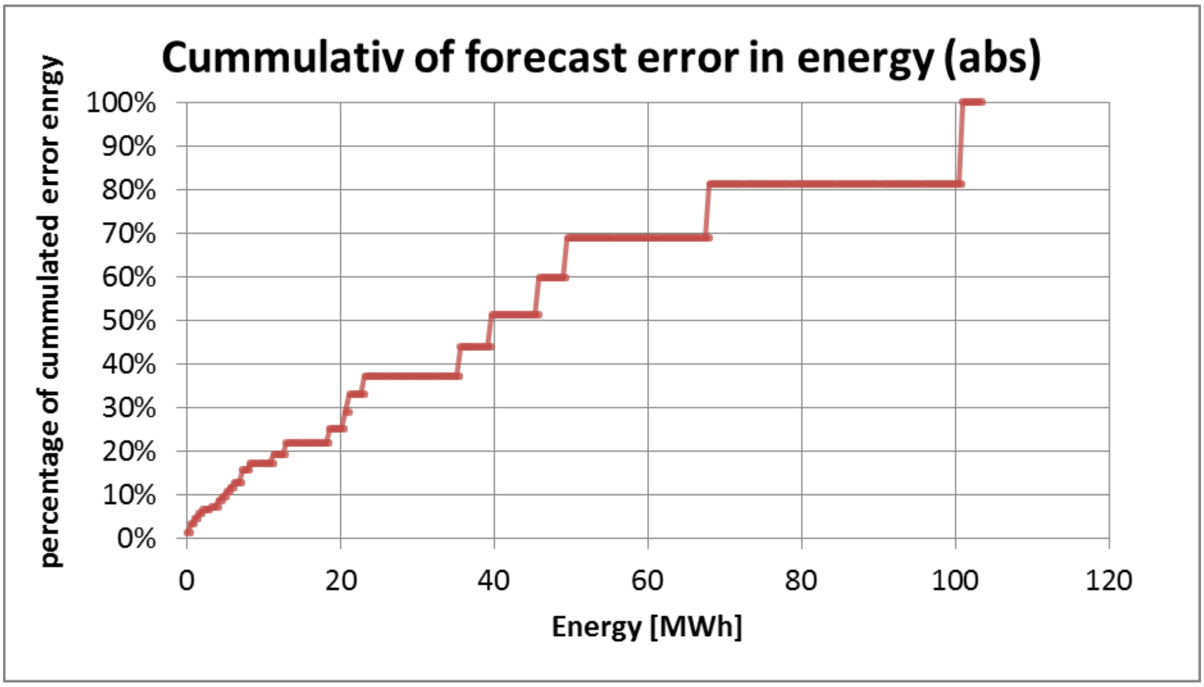

Figure 54 - All the small errors represent a small fraction of the total energy.

Errors smaller than 2MWh represent 7.8% of the imbalance energy and errors less than 5MWh represent 13.0%.

5MWh DSM means we need between 1 to 5 hours shifting possibility.

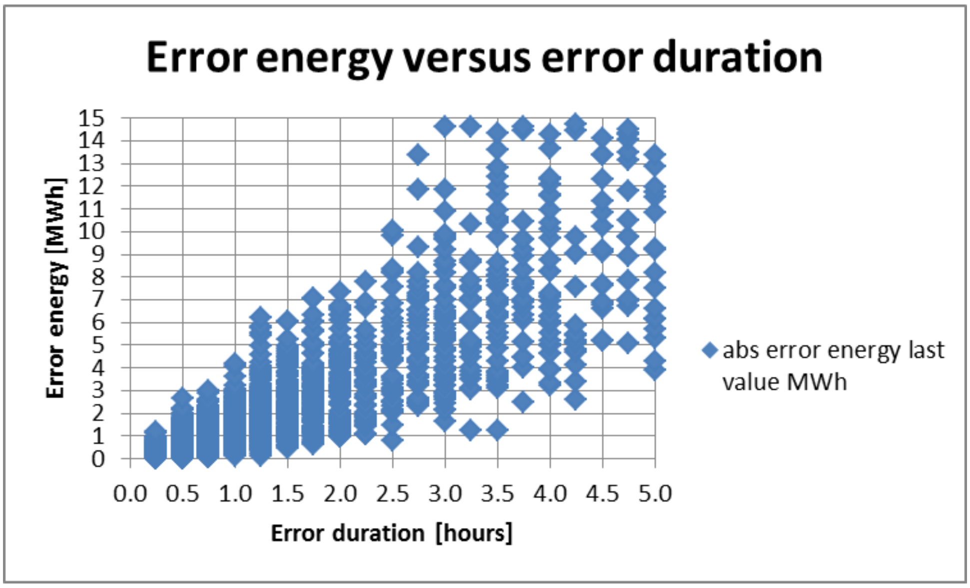

Figure 55 - Energy versus duration of recorded forecast error

Those values set roughly the need in flexibility to compensate the balance energy with the GOFLEX system.

3.3.2 DOMS specifications

What DOMS must do:

- Use the transmitted load forecast
- Construct the best possible load estimation with available data (TG8000 live measurement) and some predictions of unavailable load live data:
  - The liberalized customers (make a prediction)
  - The production not in ESR balance group such as large PV (Swissgrid GB ER) and hydro plants using either live data when available or schedules with day after data
- Compare the day ahead forecast and the actual load estimation to construct the balance error at this moment.
- Build an intraday forecast of the load to estimate the error in the short-term future.
- Calculate the errors in the future.
- Try to minimize the penalty caused by the error over a given horizon with load displacement. This requires the imbalance energy price to be optimized economically as well as a simulation of load displacement.

A few security policies should be implemented:

- The validity of the TG8000 data should be checked. The data need to be coherent, holes in the data might occur
- The control of flexibility should automatically stop when out of tolerances
- The flexibility should not be used if we are in the possible error between TG8000 and 65kV measurement: +/-1MW dead zone

3.3.3 DOMS setup at ESR

The software used in ESR for Energy Data Management (EDM) is Robotron[9]. The necessary time series were prepared and sent to IBM with a MQTT client.

Data are collected on meters and sensors all over the grid. Time series with a resolution of 15 minutes steps are generally available from the electricity meters. All energy exchanges are accounted on the 15 minutes basis.

For the grid load, we have a live data with a 5 minutes sampling time. This allows us to assess if during the present quarter hour, there is a prediction error and how much must be corrected with the flexibility. The live measurement comes from a system called TG8000, which is separated from the official metering used for energy accounting. Official data are only available the day after. It was verified that the difference between 65kV and TG8000 is small and so TG8000 can be used for a good live estimation.

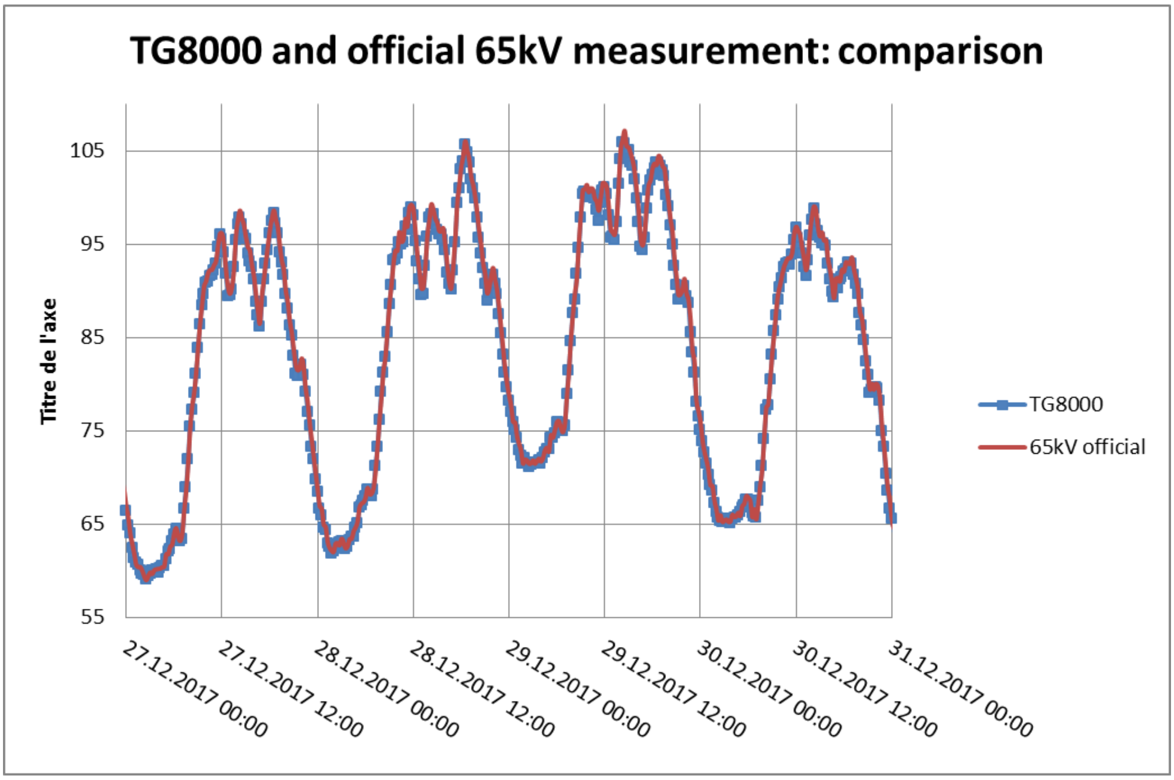

Figure 56 - Comparison between the live measurement (TG8000)

[9] https://www.robotron.de/

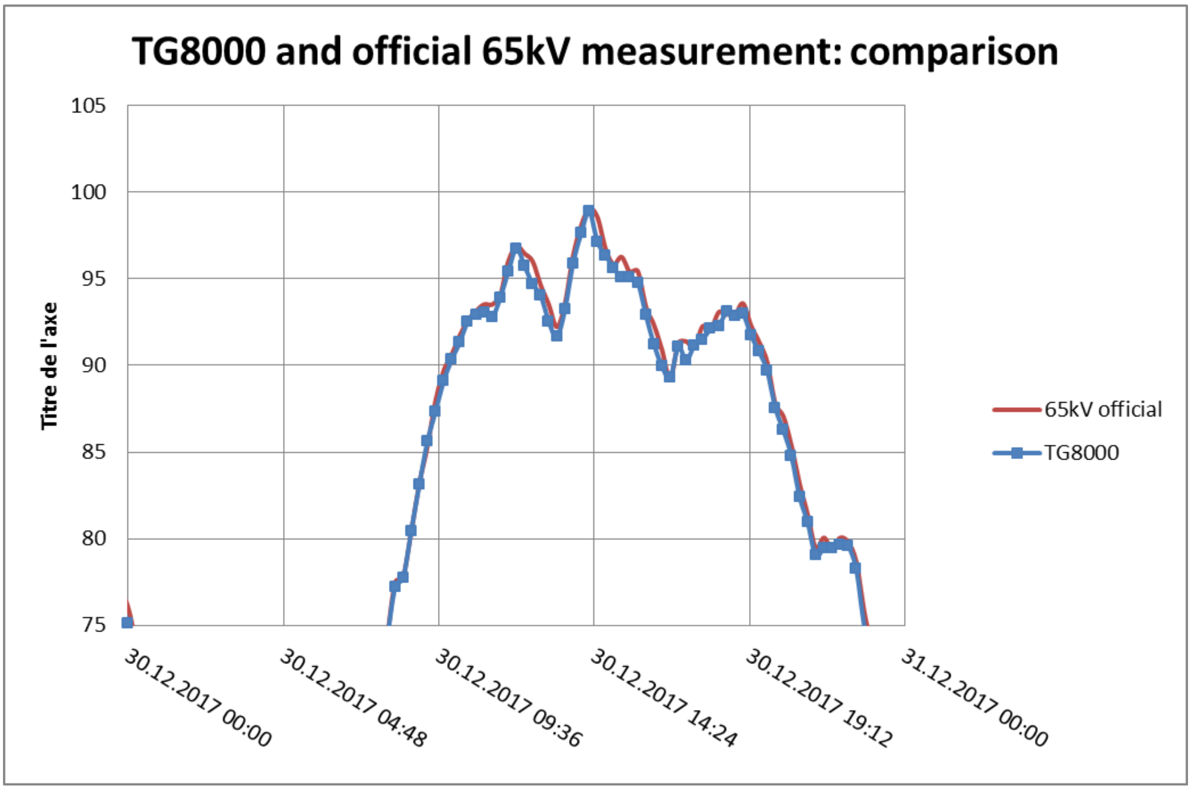

Figure 57 - Zoom on measurement from official meter and unofficial meter providing the live measurements

3.4 Cloud Service Platform (SP)

This solution is offered as a SaaS. As a result, it was not installed.

4 Conclusions

This report describes the produced efforts, met difficulties, and proposed technical solutions that were implemented in order to be able to interact with real end-clients.

The recruitment and installation period were very challenging since a lot of people and partners were involved. However, representative prosumers of CEMS, FEMS, HEMS, CDHEMS and delegated control (direct control) were successfully recruited and installed. The different solutions were installed in the field and even if all participants are not yet installed, the pilot phase can start, as the whole chain is installed for each type of technical solution.

APPENDIX

APPENDIX 1: Example of letter sent to the customer

Sion, le 25 août 2018

Pour la rentrée, investissez-vous dans le tournant énergétique avec nous !

Monsieur,

Votre fournisseur d'énergie électrique, énergies sion région, et la Haute Ecole d'Ingénierie (HEI) de la HES-SO Valais-Wallis participent à un projet de recherche d'envergure européenne nommé GOFLEX. Celui-ci permettra une meilleure gestion du réseau électrique global en intégrant au mieux les nouvelles énergies renouvelables qui y sont produites. Cela sera fait en optimisant votre consommation et celle de vos voisins, tout en vous garantissant un confort maximum.

Nous cherchons 200 particuliers pour participer à ce projet important et novateur et vous pouvez en faire partie ! Vous avez l'occasion d'être ainsi un pionnier de l'intégration du renouvelable dans les réseaux électriques.

Vous bénéficierez dès lors d'un système de gestion, appelé Direct Control. Celui-ci sera utilisé pour couper des consommateurs électriques flexibles (boiler, pompe à chaleur,…) pendant des petites durées. Il vous permettra notamment de **visualiser la consommation énergétique des équipements et de votre logement** sur une interface web dédiée. Vous aurez ainsi accès à des outils d'analyse qui vous permettront alors une **meilleure compréhension de votre consommation, afin de réduire cette dernière er par conséquence votre facture d'énergie.**

Pour cela, nous devons simplement remplacer votre compteur électrique par un neuf et installer un boîtier additionnel de dernière génération, développé par les ingénieurs de la HES-SO**. Vous profiterez ainsi, gratuitement et en avant-première, de la meilleure technologie pour votre foyer.** Si le projet continue et que le système vous a convaincu, vous pourrez conserver ce dernier. **Pour cela, il vous suffit de nous renvoyer le formulaire ci-joint à l'aide de l'enveloppe préaffranchie jointe à ce courrier.**

Vous pourrez à tout moment demander la désactivation du système de pilotage de charge si vous souhaiteriez vous retirer du projet.

Envie d'en savoir plus ? Vous pouvez consulter notre site à l'adresse http://www.esr.ch/goflex ou contacter le chef de projet Pierre-Olivier Moix au 027 324 06 30.

L'Energie de Sion-Région SA (ESR)

Formulaire de participation

Merci de remplir ce formulaire et de nous le retourner dans les meilleurs délais par courrier à l'aide de l'enveloppe préaffranchie ci-jointe.

Nom : Prénom :

Adresse : NPA/ Ville :

Email : N° mobile :

N° client ESR : (*laisser vide si inconnu*)

Je possède les dispositifs suivants pour piloter la consommation :

- ☐ Une pompe à chaleur
- ☐ Un boiler eau-chaude électrique
- ☐ Un chauffage électrique à accumulation
- ☐ Un chauffage électrique direct (p.ex. nattes chauffante dans les dalles)
- ☐ Installation photovoltaïque
- ☐ Une voiture électrique
- ☐ Je ne sais pas
- ☐ Autres/remarques :

En signant ce formulaire de participation, vous autorisez la HEI et ESR à vous contacter, à vous rendre visite, sur rendez-vous, et à installer un module de pilotage si cela convient dans votre maison, tel que décrit dans ce document. De plus, vous déclarez avoir pris connaissance et accepté expressément les conditions de participation disponibles en tout temps sur le site internet goflex.esr.ch.

Vous autorisez également la HEI et l'ESR à collecter tout ou partie de vos données de consommation électrique, de consommation thermique ainsi que les températures de certaines pièces et certains procédés. Ces informations vous seront mises à disposition via une plateforme en ligne dédiée. Elles seront traitées avec confidentialité et pas partagée à des tiers.

Veuillez noter que vous êtes seul responsable de votre comportement énergétique. En cas de doute, nous vous prions de nous contacter immédiatement.

Vous pourrez désactiver à tout moment le système de pilotage de charge et retrouver ainsi le fonctionnement normal de vos installations si vous pensez qu'il vous dérange.

Lieu et Date Signature du client

APPENDIX 2: Consent form

Projet GOFLEX

Conditions de participation

1. La collecte, le traitement et l'utilisation des données sont soumis aux lois et règlements suisses sur la protection des données, notamment la Loi Fédérale sur la protection des données du 19 juin 1999 (LPD) et son ordonnance d'application.
2. Les données collectées peuvent être considérées comme des données personnelles ou, dans certains cas, comme des données sensibles selon l'Article 3, alinéas a et c de la LDP.
3. La HEI et ESR garantissent qu'ils remplissent toutes les conditions pour traiter les données collectées conformément à la LPD et à son ordonnance d'application.
4. Les données collectées seront stockées par ESR et gérées par la HEI et ESR. En parallèle, une partie de celles-ci pourront être transmises aux partenaires du projet GOFLEX à des fins de recherche, de développement de solutions d'optimisation, de calculs d'intérêts économiques et de gestion de la charge.
5. Dans tous les cas, ces données seront rendues anonymes avant d'être transmises aux partenaires. Le lien entre le nom du propriétaire des installations et les données sera uniquement connu par la HEI et ESR. Aucune communication publique mentionnant le nom des personnes participant ne sera faite sans l'accord explicite de celles-ci.
6. Les données collectées seront distribuées aux partenaires du projet GOFLEX sur la base d'un contrat de licence d'utilisateur final (CLUF) et uniquement aux utilisateurs finaux qui auront souscrit au CLUF. Les destinataires des données peuvent être affiliés à d'autres institutions de recherche ou à d'autres entités que la HEI et ESR.
7. Les personnes participant à la collecte de données ont un droit d'accès à leurs propres données. Leur consentement peut être retiré à tout moment auprès des personnes de contact. A la réception d'un retrait de consentement, la HEI et ESR feront tout leur possible pour effacer et détruire les données concernées dans un délai de 15 jours ouvrables. La HEI et ESR ne conserveront aucune copie des données concernées et stopperont leur distribution.
8. Après 15 jours ouvrables à compter de la signature du présent formulaire de participation, les données peuvent être distribuées à des tiers sur la base de ce formulaire de participation. La HEI et ESR n'auront plus de contrôle sur les données transmises. En cas de retrait du consentement conformément à ce qui précède, la HEI et ESR demanderont aux tiers qui détiennent une copie des données de les effacer. Cependant, la HEI et ESR n'offrent aucune garantie en ce qui concerne les données qui ne sont plus sous leur contrôle et ne peuvent être tenus responsables de l'effacement des données déjà transmises à des tiers sur la base du présent formulaire de participation.

En signant le formulaire de participation, le soussigné accepte expressément les conditions susmentionnées et déclare donner à la HEI et à ESR le droit de collecter, utiliser, traiter et distribuer les données personnelles sans limitations conformément aux dispositions susmentionnées.

APPENDIX 3: Interview of the first client

8.05.2018 https://www.esr.ch/fr/actualites/detail/goflex-interview-du-premier-client-2597

GOFLEX, interview du premier client

Pouvoir consommer les énergies renouvelables au moment où elles sont produites. Voilà en résumé l'ambitieux objectif du projet européen GOFLEX, auquel participent l'esr et la HES-SO Valais-Wallis. La région sédunoise est le plus grand des trois sites pilotes. Pour mener à bien le projet, 200 boîtiers de commande intelligents seront installés auprès de clients sur le réseau de l'esr. A Grimisuat, la villa de Jessen Page a été la première à être équipée de ce système innovant. Ce premier client partage son expérience.

Pourquoi avoir choisi de participer à ce projet ?

Le domaine des énergies m'intéresse fortement, en particulier celui des énergies renouvelables. En tant que professeur à la HES SO Valais-Wallis, j'ai eu connaissance de ce projet assez tôt. Quand on m'a demandé d'y participer en tant que client test, je n'ai pas hésité une seconde. C'est une chance de pouvoir contribuer, à mon échelle, à un projet d'une telle envergure.

Comment s'est déroulée l'installation du boîtier de commande chez vous?

Mon logement est équipé d'une pompe à chaleur «air-eau». Après une première visite sur place pour évaluer mon installation, un technicien de l'esr est venu installé ce fameux boîtier de contrôle sur mon tableau électrique, et m'a mis au courant de son fonctionnement. Désormais, c'est ce boîtier qui pilote ma pompe à chaleur.

Concrètement, comme ce boîtier fonctionne-t-il?

Plusieurs mesures sont prises en temps réel dans ma maison, par exemple la consommation électrique de mon installation de chauffage ou la température de mon boiler d'eau chaude. En fonction des données récoltées et de la production d'énergies renouvelables sur le réseau, l'esr choisit d'enclencher ou de déclencher mon appareil. Je ne m'occupe de rien.

Votre boîtier est en fonction depuis quelques semaines. Cela a-t-il eu des impacts sur votre quotidien?

Absolument aucun. Nous n'avons pas changé nos habitudes de consommation. Niveau confort, notre eau chaude est toujours à température idéale quand nous avons besoin de prendre une douche! Tout fonctionne parfaitement. Et si d'aventure je ne devais plus être satisfait, j'ai la possibilité de désactiver le système à tout moment.

Quels enseignements espérez-vous tirer de cette expérience?

J'attends impatiemment la mise à disposition de l'interface web développée pour ce projet, qui me permettra de visualiser ma consommation d'énergie. En fonction des résultats et des analyses, nous pourrons adapter nos comportements pour optimiser notre consommation énergétique.

Un conseil pour les personnes qui hésiteraient à participer ?

Foncez ! J'encourage vraiment toutes les personnes éligibles pour ce projet à y participer. Cela est entièrement gratuit, et ne demande aucune connaissance technique particulière. Nous mettons simplement à disposition notre installation. Et c'est une vraie chance de pouvoir participer concrètement à la transition énergétique.

APPENDIX 4: DirectControl attributes

4.1 Measures

4.1.1 Ambient room temperature sensor (Philio Pat-02b) (5 to 10 min)

Topics	Description	Unit
goflex-dc-###/nodes/ambientSensor-#/objects/temperature/attributes/datapoint	Measured ambient room temperature	[°C]

Note: The Z-Wave products' report intervals are sometimes irregular.

4.1.2 Boiler/PAC temperature sensor (Qubino ZMNHID) (10 to 30 min)

Topics	Description	Unit
goflex-dc-###/nodes/boilerSensor-#/objects/temperature/attributes/datapoint	Measured probe temperature	[°C]

4.1.3 Power meter (Home Energy Meter [HEM] ZW095) (15 sec)

Topics	Description	Unit
goflex-dc-###/nodes/powerMeter-#/objects/kWhClamp1/attributes/datapoint	Accumulated kWh on clamp 1	[kWh]
goflex-dc-###/nodes/powerMeter-#/objects/kWhClamp2/attributes/datapoint	Accumulated kWh on clamp 2	[kWh]
goflex-dc-###/nodes/powerMeter-#/objects/kWhClamp3/attributes/datapoint	Accumulated kWh on clamp 3	[kWh]
goflex-dc-###/nodes/powerMeter-#/objects/kWhTotal/attributes/datapoint	Accumulated kWh of whole HEM	[kWh]
goflex-dc-###/nodes/powerMeter-#/objects/wattsClamp1/attributes/datapoint	Instantaneous Watts on clamp 1	[W]
goflex-dc-###/nodes/powerMeter-#/objects/wattsClamp2/attributes/datapoint	Instantaneous Watts on clamp 2	[W]
goflex-dc-###/nodes/powerMeter-#/objects/wattsClamp3/attributes/datapoint	Instantaneous Watts on clamp 3	[W]
goflex-dc-###/nodes/powerMeter-#/objects/wattsTotal/attributes/datapoint	Instantaneous Watts of whole HEM	[W]

4.1.4 SmartMeter billing (1/day)

Topics	Description	Unit
goflex-dc-###/nodes/SmartMeterBilling/objects/obis_1_1_1_8_1_255_2/attributes/datapoint	Active energy tariff 1, import	[kWh]
goflex-dc-###/nodes/SmartMeterBilling/objects/obis_1_1_1_8_2_255_2/attributes/datapoint	Active energy tariff 2, import	[kWh]
goflex-dc-###/nodes/SmartMeterBilling/objects/obis_1_1_2_8_1_255_2/attributes/datapoint	Active energy tariff 1, export	[kWh]
goflex-dc-###/nodes/SmartMeterBilling/objects/obis_1_1_2_8_2_255_2/attributes/datapoint	Active energy tariff 2, export	[kWh]

4.1.5 SmartMeter energy (15 min)

Topics	Description	Unit
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_1_8_0_255_2/attributes/datapoint	Active energy import	[kWh]
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_2_8_0_255_2/attributes/datapoint	Active energy export	[kWh]
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_5_8_0_255_2/attributes/datapoint	Reactive energy +Ri (QI)	[kvarh]
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_6_8_0_255_2/attributes/datapoint	Reactive energy +Rc (QII)	[kvarh]
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_7_8_0_255_2/attributes/datapoint	Reactive energy -Ri (QIII)	[kvarh]
goflex-dc-###/nodes/SmartMeterEnergy/objects/obis_1_1_8_8_0_255_2/attributes/datapoint	Reactive energy -Rc (QIV)	[kvarh]

4.1.6 SmartMeter technical (1/sec)

Topics	Description	Unit
goflex-dc-###/nodes/SmartMeterTechnical/objects/obis_1_0_1_7_0_255_2/attributes/datapoint	Active power import +P	[W]
goflex-dc-###/nodes/SmartMeterTechnical/objects/obis_1_0_2_7_0_255_2/attributes/datapoint	Active power export -P	[W]

4.1.7 Gateway (Once per modification)

Topics	Description	Unit
goflex-dc-###/nodes/gateway/objects/relay1State/attributes/datapoint	State of the relay 1	[boolean]
goflex-dc-###/nodes/gateway/objects/relay2State/attributes/datapoint	State of the relay 2	[boolean]
goflex-dc-###/nodes/gateway/objects/switchState/attributes/datapoint	State of the switch (auto : 1/ manual : 0)	[boolean]

4.2 Commands

4.2.1 Gateway

Topics	Description	Unit	Default value
goflex-dc-###/nodes/gateway/objects/relay1Control/attributes/parameter	Control of the relay 1	[boolean]	true
goflex-dc-###/nodes/gateway/objects/relay2Control/attributes/parameter	Control of the relay 2	[boolean]	true

4.2.1.1 How to use

```
topic :
@set/goflex-dc-###/nodes/gateway/objects/relay1Control/attributes/parameter
    message : {"timestamp":[timeStamp],"value":1}
    or      : {"timestamp":[timeStamp],"value":0}
```