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

D8.4 Report on Demonstration Results Evaluation – Use Case 2

February 2020

Imprint

Contractual Date of Delivery to the EC: **28 February 2019**
Actual Date of Delivery to the EC: 26 February 2019

Author(s): **Yousra Sidqi, Sébastien Dervey, David Tauxe, Marc-Henri Udressy, Pierre Ferrez, Dominique Gabioud, Pierre Roduit (HES-SO), Grégoire Largey (ESR-OIKEN)**
Participant(s): **HES-SO, ESR-OIKEN**
Reviewer(s): **Bradley Eck (IBM)**

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

Work package: **WP8**
Confidentiality: Public
Version: **4**

Contact: **yousra.sidqi@hevs.ch, gregoire.largey@oiken.ch, pierre.roduit@hevs.ch**
Website: **www.GOFLEX-project.eu**

Legal disclaimer

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 program 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.

Copyright

Executive Summary

This document (D8.4) reports the activities of Tasks 8.6 of the GOFLEX project, namely the results of the pilot phase.

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

Five key aspects are presented in this report:

- Analysis of the deployment and maintenance of the installed infrastructure. This includes installation complexity, observed problems, field maintenance, etc.
- Interaction with the clients. This includes aspects like recruitment, contracts, information, communication and the problems linked to these aspects.
- Analysis of the technical performance of the GOFLEX solution.
- Analysis of the business models tested during the pilot phase
- Cost benefit analysis with concrete evidence on the achieved results.

Document History

Version	Date	Status	Author	Comment
0.1	31.01.2020	Draft	Multiple	Initial Draft
0.2	12.02.2020	DSO+Prosumer experience + CBA	Multiple	
0.3	19.02.2020	KPIs	Multiple	
0.4	26.02.2020	Final version	Multiple	Corrections based on comments received from reviewer

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Abbreviation	Definition
BRP	Balancing responsible party
CDEMS	Charging Discharging Energy Management System
CEMS	Charging Energy Management System
DC	Direct Control
DOMS	Distribution Observability Management System
EMS	Energy Management System
HEMS	Home Energy Management System
FEMS	Factory Energy Management System
FMAR	Flexibility Market
PM	Power Meter
SP	Service Platform

1 Introduction

1.1 Purpose

This document consists in a final reporting of the results of the Swiss demonstration site of the GOFLEX project. It provides the reader with the description of the Swiss Pilot deployment phase, maintenance and monitoring. It also reports the project's Key Performance Indicators (KPIs) as well as a detailed Cost Benefit Analysis (CBA).

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.

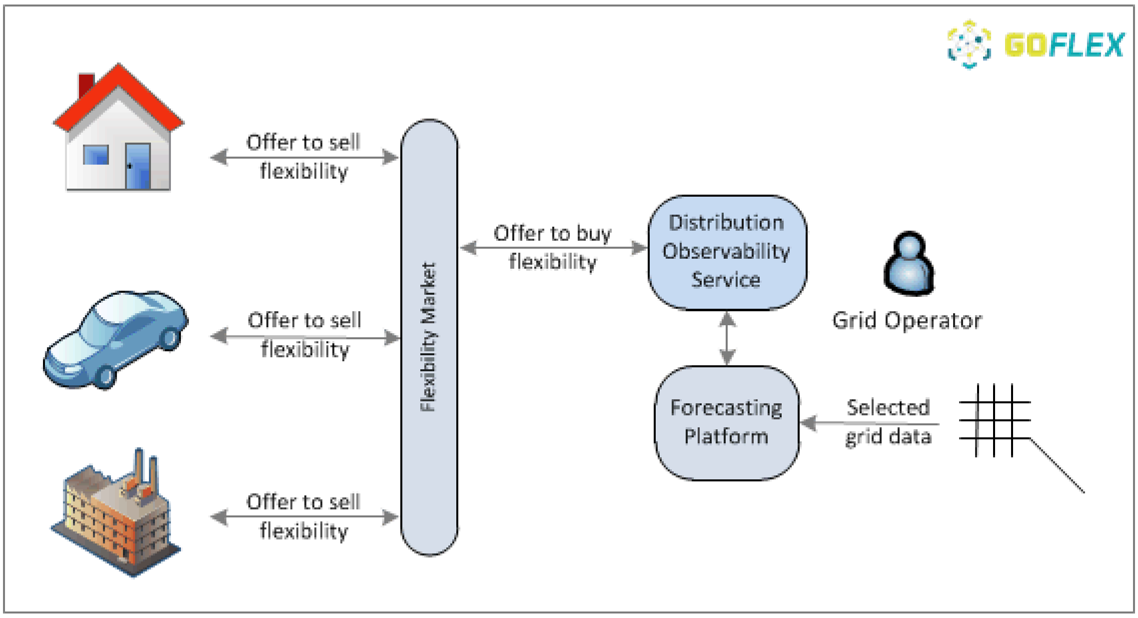

Figure 1: Illustration of GOFLEX Concept

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 aggregates FOAs' flexibilities and 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 optimizes 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.

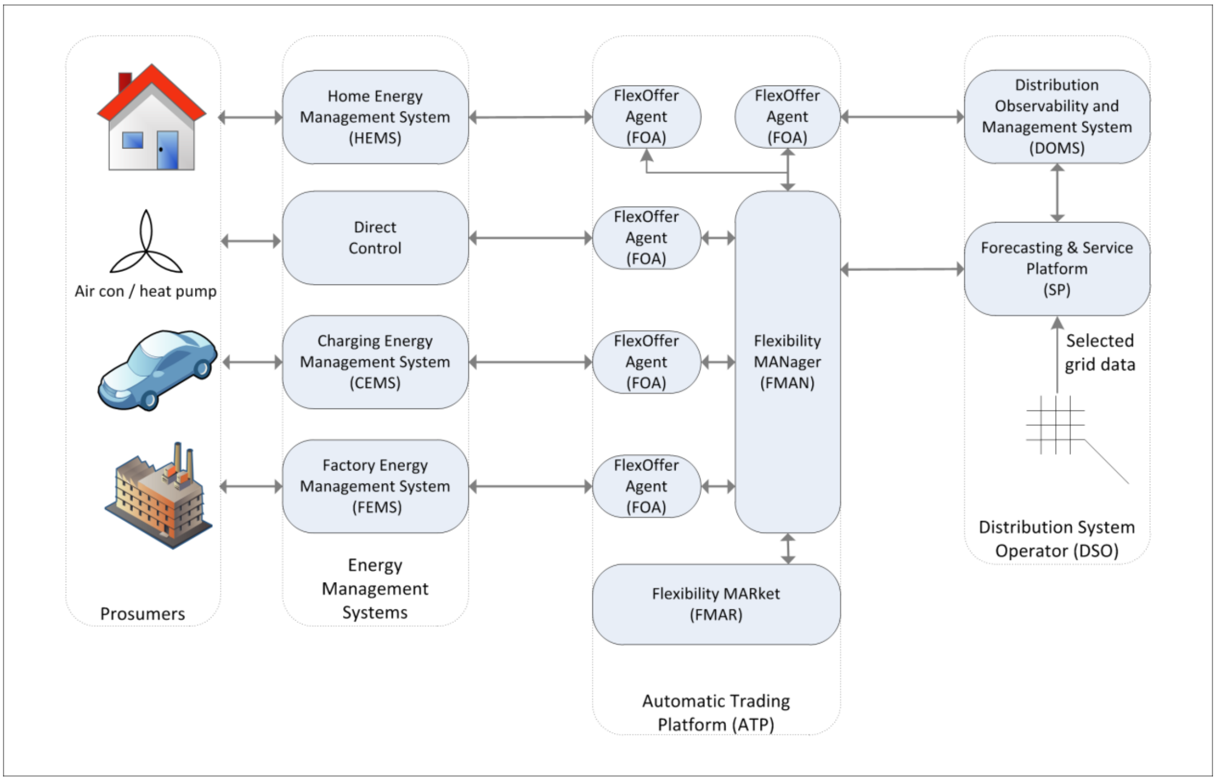

Figure 2: GOFLEX System Components

1.3 Business Summary for Use Case 2

In the past, ESR had many roles. It was at the same time a DSO (distribution system operator), an electricity supplier and a producer, mainly with hydro and solar production. Those roles were separated with the unbundling of the electricity suppliers, yet all three different roles are present at ESR group level.

The flexibility is important for each role and in the context of this GOFLEX project, a global vision was necessary. Considering legally separated entities, the roles and the respective interests of each party must not be mixed; it is important to understand this unbundling to keep the various reflections on track so that it can be implemented.

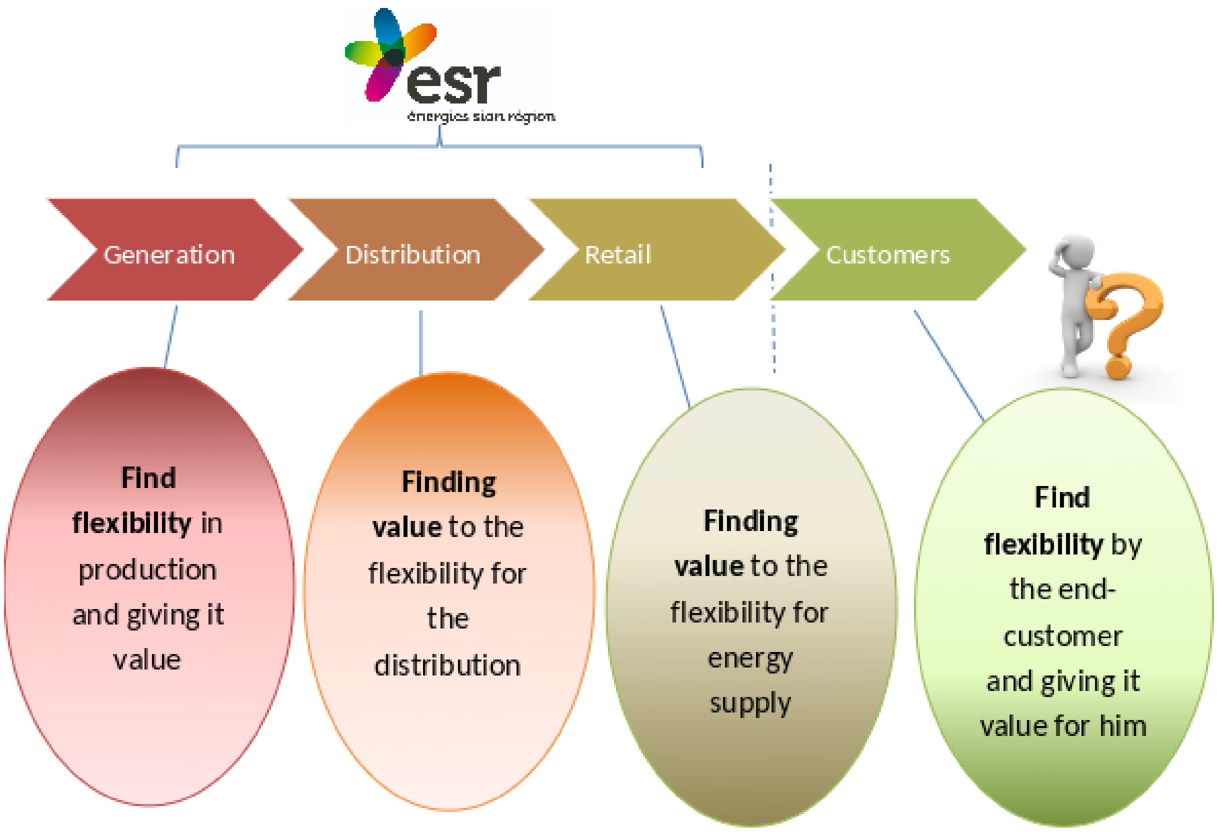

Figure 3: Market players at ESR's grid level

Connected to its distribution grid, ESR has: some traditional consumers, the newly come prosumers and production plants. The flexibility must be searched in all elements connected to the grid.

The elements with a large flexibility have generally already been exploited, for example hydroelectric production encompassing some storage. The flexibility left is disseminated between multiple small elements. Those must be aggregated to be usable.

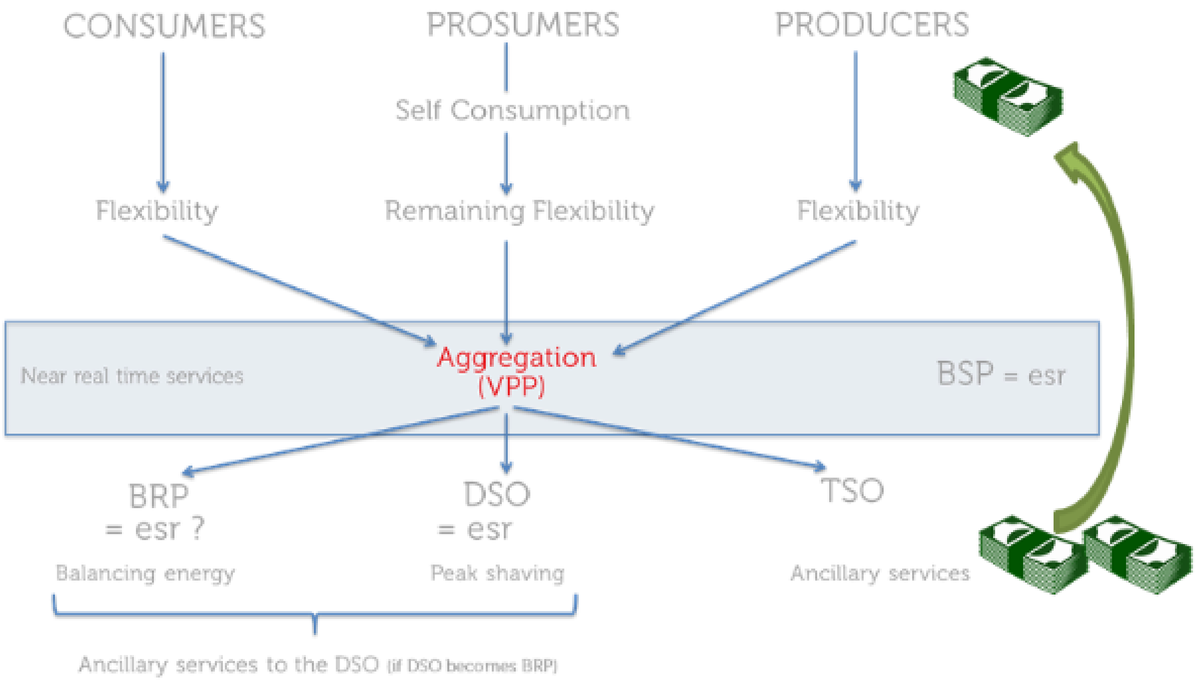

Figure 4: Flexibility is searched in loads a producer, aggregated and valued; a part of the value must be given back to the flexibility provider

On the other side, the flexibility must be valued; otherwise it is useless to deploy a flexibility harvesting infrastructure. A part of the value must be given back to the flexibility owner or some other kind of advantages.

In the context of ESR, the flexibility could be valued with:

1. Saved costs for BRP
2. For energy balancing
    - For levelling/shifting/shaving peak power at exchange point with TSO
    - For controlling the reactive power at exchange point with TSO
    - Reducing electricity cost: there is high price during the day and low price per kWh during the night.
3. Saved cost for DSO:
    - Investment deferral and reduction for new grid infrastructure (congestion management)
    - Efficiency improvement
4. New incomes for a service given to the customers:
    - Visualization of energy data
    - Automatic management of device

- Trading of flexibility

5. New incomes for a service given to the TSO:
    - Provision of ancillary services

    Beside of the direct incomes or cost saving in the short term, the control of flexibility at the customer level can have a strategic importance:

6. Service given to the customer: to keep ESR attractive in a context of a (future) liberalized market:
    - Visualization tool (web page, app…)
    - Special prices and flexible tariffs (today only night and day TOU pricing).
    - Energy management service for:
        - Individual solar installation and self-consumption
        - EV charging
7. Preparation of energy transition in the long term.
    - Energy management at distribution grid scale.

1.4 Related Documents

This document is related to similar deliverables of other demonstration sites of the project, namely D7.4 and D9.4. It is also directly linked to all deliverables of WP8, D8.1, D8.2 and D8.3.

1.5 Document Structure

This report consists of four different sections. The first one summarizes DSO's experience throughout deployment, maintenance and monitoring, followed by an extended section on prosumer's experience, which was analyzed via a survey. The third and fourth section describe respectively the performance cost benefit analysis of the GOFLEX solution.

2 DSO Experience

In this section, we will be describing the deployment of the GOFLEX solution for different prosumers and explain the maintenance and monitoring strategies, which were adopted until the end of the project.

2.1 Direct control households

1,100 customers were contacted in five separate phases according to the criteria defined in D8.3 (chapter 2.2.1.1). 273 people responded positively, which represents a ratio of 25%. (see Figure 5 and Figure 6)

Among the registered customers, we had 71 withdrawals, caused by several elements:

- Fear that the GOFLEX system will create problems on the heat pump (mainly for people who have already encountered problems with their installation before even knowing GOFLEX).
- In part of the network (around 30 registered customers), optical fiber has yet to be deployed: Its extension is planned for 2020. For these customers, it would have been possible to go through the TV cable, but this solution was not preferred due to the lack of field personnel.
- Some customers left Switzerland.
- Some customers were not reachable anymore.
- The installation of the GOFLEX system is too complicated, either because of the time it takes to complete the installation, or for technical reasons.
- The installation does not correspond to the chosen criteria for GOFLEX despite the customer selection filters (distributor's database not updated if the customer does not announce a modification in the installation):
    - Oil heating
    - A single heat pump for a group of several houses
- The clients saying, they no longer want to be part of the project when we contact them to carry out the installation (which sometimes happened when the optical fiber has already been deployed for the GOFLEX project).
- Impossible deployment of the fiber due to technical field deployment issues.

The number of installations carried out to date (29.01.2020) is 195. 7 installations could potentially be completed by the end of February, which will make us hit the target value of 200.

A variety of sensors was deployed as follows: Heat pumps PMs: 188, hot water PMs: 167, solar PMs : 26, boiler sensors : 195, ambient sensors : 185, smart meters : 195

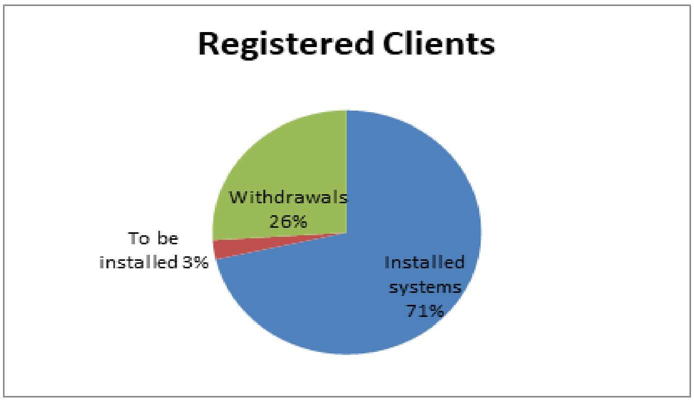

Figure 5: Overview of GOLFEX's registered clients in Switzerland

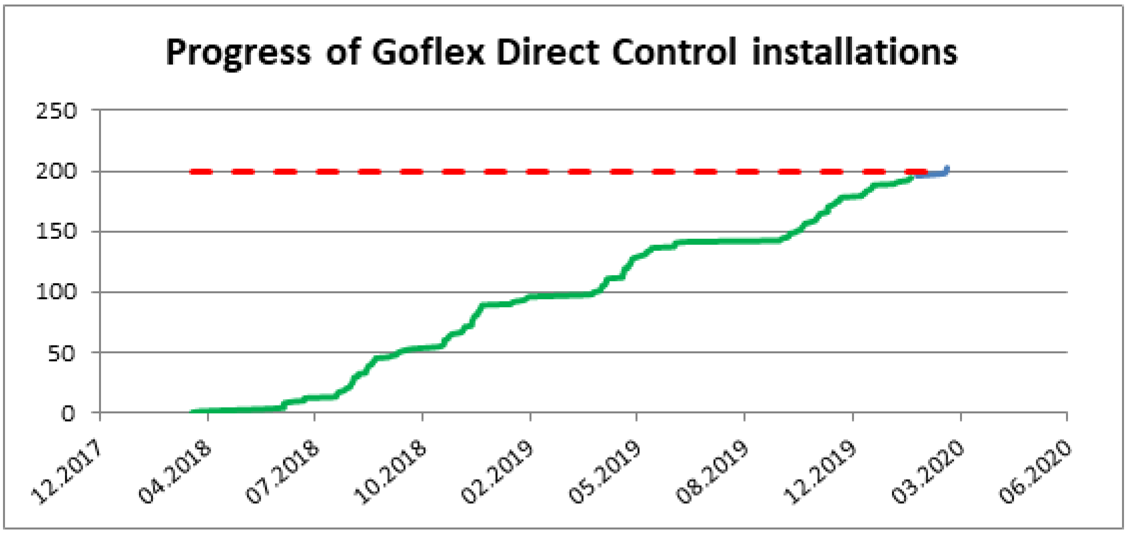

Figure 6: Evolution of the GOFLEX system installation in households

Various difficulties were encountered when installing the GOFLEX system. Figure 7 and Figure 8 show the main problems related to the installation of power meters (PM):

- Congestion
- It is necessary to connect each wire of the PM to each phase of the receiver whose consumption should be measured, there is therefore 2 possibilities :
  - Direct connection to the circuit breaker output: the advantage is that the PM will always have a voltage across its terminals. However, the main drawback is that this technique could be quite dangerous and requires great vigilance from the installer, as the PM wires are smaller in the terminal of the circuit breaker.
  - Connection to the terminals at the cable's start: this solution is less dangerous when connecting. however, when the load is disconnected, the PM is no longer connected.
- On a PM, there are 3 neutral wires to be connected. Ideally, a terminal should be placed inside the switchboard, provided there is room. It should also be noted

that the number of wires per terminal is limited, which increases the number of neutral terminals to be added and the required space to do so. One solution would be to use WAGO type screw clamps, but this option is not always accepted during ITTO checks (periodic checks according to the Low Voltage Installations Ordinance).

The main problems encountered during the installations of the whole system are as follows:

- Lack of space in the switchboard.
- The temporary connection of the hot water temperature sensor is not always appreciated by the customer, despite the efforts that were made to keep the installation clean.
- The house is too insulated, and the sensors do not communicate well or not at all.
- If a problem occurs after the installation of the GOFLEX system, even the slightest electrical problem linked to the heating system is caused by GOFLEX in the client's eyes, even if there is no correlation.
- The network remote control is not wired to the input box and / or the electrician has wired the controllable receivers directly in the main panel: in this case, the installation must be put back in order by an authorized electrical technician.
- The heat pump or the boiler's electrical contacts are defective: they remain in their up position and therefore do not allow the load to be switched off with the GOFLEX system.

Figure 7: Gateway insulation problem

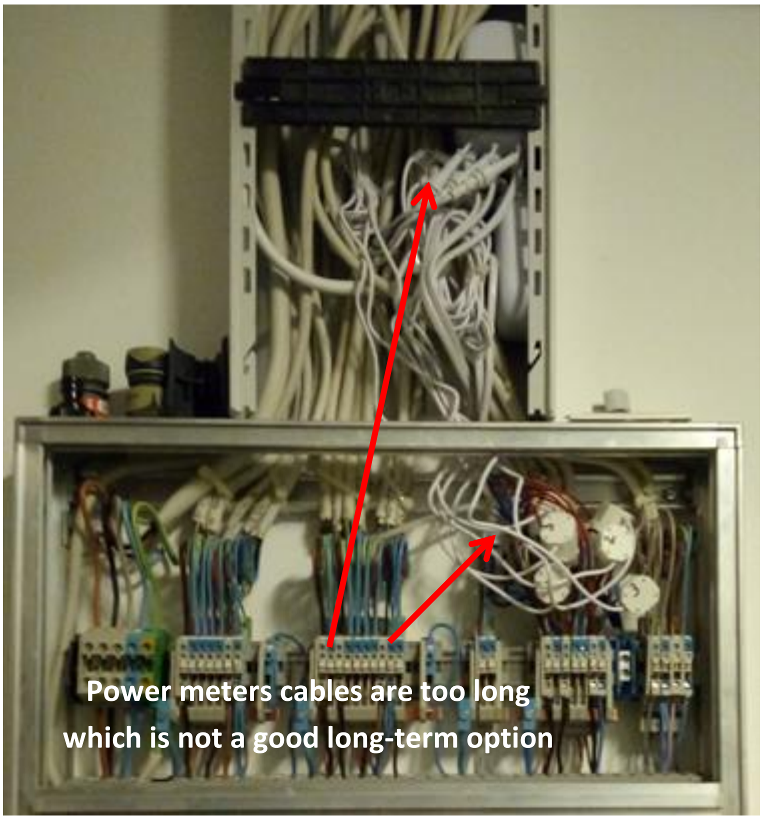

Figure 8: Space problem in a switchboard

2.2 FEMS

During the GOFLEX project, 50+ locations were analyzed, discussion with about 20 clients were made, 11 contracts were signed and only 9 of them could be installed and were up and running by the end of the project.

The main difficulties before the commissioning were:

1. Demonstrating an interest for the company and wanting them to participate, as no direct financial gain could be promised.
2. In two cases, FEMS installation had to be abandoned in reason of a third company. As nearly all FEMS (10 on 11) were planned to be installed in buildings or factories already automated, it was necessary to work with a third party: the company that made the automation. Even if the client was resolutely interested to participate, inacceptable prices for interfacing FEMS to existing automation system or continuous postponing were met that lead to dropping those two installations.

The main difficulties encountered during commissioning were:

1. Communication problems between FEMS and FMAR, filtering outgoing traffic for IT security reasons (FEMS 06, 07, 08, 09, 10) by administrators of the local network. IT configuration was not adequate.

2. No communication at all because the FEMS was not connected to the right IT network (FEMS 10).
3. Hardware problems, incompatible components implying measurement errors.
4. FEMS wiring errors (FEMS 10, 04)
5. Incorrect definition of the specifications and the way the devices were supposed to communicate due to difficulties of being able to agree between partners (INEA and local company which manages the machines).
6. The delivered FEMS could not be integrated into the system present on site. There was a need to adapt FEMS wiring on site (FEMS 11), which made the commissioning long and tedious.
7. Software, driver, or configuration problems.

Some difficulties were encountered after commissioning:

1. Malfunctioning of electric meters due to incorrect configuration (FEMS 03, 04, 07, 08, 09, 10).
2. Malfunctioning of electric meters due to wiring error (FEMS 10).
3. Malfunctioning of electric meters due to communication problems (FEMS 04) which was not solved even after changing the meter and checking the wiring.
4. Crashes of software updates.

A few technical issues were faced amid installation:

1. Communication losses with meters (FEMS 10, 02)
2. Connection problem with a meter (FEMS 04)
3. Computer failure resulting in communication loss between FEMS and FMAR (FEMS 10).
4. Communication loss during updates.

In order to tackle these issues, corrective actions were taken:

1. Modbus driver update to enhance communication with counters.
2. Replacement of an industrial PC with a new OS for a better robustness (FEMS 10).
3. Implementation of increased monitoring by setting alarms on receiving measured data while they would only go off if there was a communication loss.

The table below summarizes the visits, which were programmed for each FEMS, before, amid and after installation.

Table 1: FEMS installation process

	Numbers of visits before commissioning	Numbers of visits for commissioning	Number of visits for adjustment after commissioning	Number of visits due to troubleshooting after commissioning
FEMS 01	4	-	-	-
FEMS 02	2	1	0	1
FEMS 03	1	2	3	0
FEMS 04	2	1	1	1
FEMS 05	5	-	-	-
FEMS 06	3	1	0	0
FEMS 07	4	2	1	0
FEMS 08	1	2	1	0
FEMS 09	2	2	2	0
FEMS 10	4	3	4	2
FEMS 11	4	3	0	0

2.3 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.

Late delivery of the solutions (way after FAT) and continuous deployment and running problems up to autumn 2019 led to the installation of only 9 HEMS (encompassing 2 CDHEMS) during the period of the project. Their maintenance is performed in three vital and consecutive steps. Monitoring, remote intervention, on-site intervention.

- Monitoring:

The houses are sending all the data they are gathering to the HIQ website. The HES-SO gathers the information given by HIQ's API and monitor them. Then comes the checking of the availability and accuracy of data. The first check ensures that the house and all the equipment are still sending data and is still functioning correctly. The second check makes sure that the control signals sent to each house are not bringing the temperatures to an uncomfortably low point.

The monitoring must be autonomous. For now, we only have less than 10 systems, but if the number increases, the autonomous aspect will become central.

- Remote intervention:

Once a problem has been detected, the first step to solve it is a remote intervention. Connecting to the system and identifying the source of the problem.

  - Temperatures too low -> Correct the control signals and switch the heat pump back on if needed
  - Selected sensors are no longer sending data -> check the status of these sensors and try to reboot them remotely
  - Wireless sensors are no longer sending data -> check the status of the z-wave receiver
  - Whole house is no longer sending data -> reboot the house linker

- On-site intervention:

If the problem could not be solved remotely, an on-site intervention is needed. This is most of the time costly and a consuming procedure. Therefore, it has to be avoided whenever possible. However, in several instances, it is unavoidable.

  - Changing the battery of the temperature sensors
  - Rebooting a failed BEMS from the CDEMS
  - Changing a failed house linker

2.4 CEMS

Concerning CEMS, the first problem encountered was that no existing charging station was compatible with ETREL CEMS. In the area, nearly only charging station for GreenMotion are deployed and they are not OCPP compatible. As a result, the HES-SO decided to invest in the purchasing of charging stations for the project, outside of the project costs.

Five Etrel charging stations for electric vehicles have been installed in two CEMS on the domain served by ESR for a total of seven possible simultaneous connections. Two G6, one G5 and one INCH Pro 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 9 illustrates the two G6 installed in the car parks of HES-SO (top), the G5 (middle left) installed in the car park of HES-SO, the G5 (middle right) installed in the parking lot of a private individual and the new INCH Pro installed in the car park of HES-SO (bottom). These five charging stations all use Ethernet for communication to and from Etrel's dashboard. The four HES-SO charging stations use public IP addresses and are connected in a demilitarized zone (DMZ) for security purposes. The fifth 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 10, 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 9: The two G6 (top), the two G5 (middle) and the INCH Pro (bottom) charging stations installed in Sion.

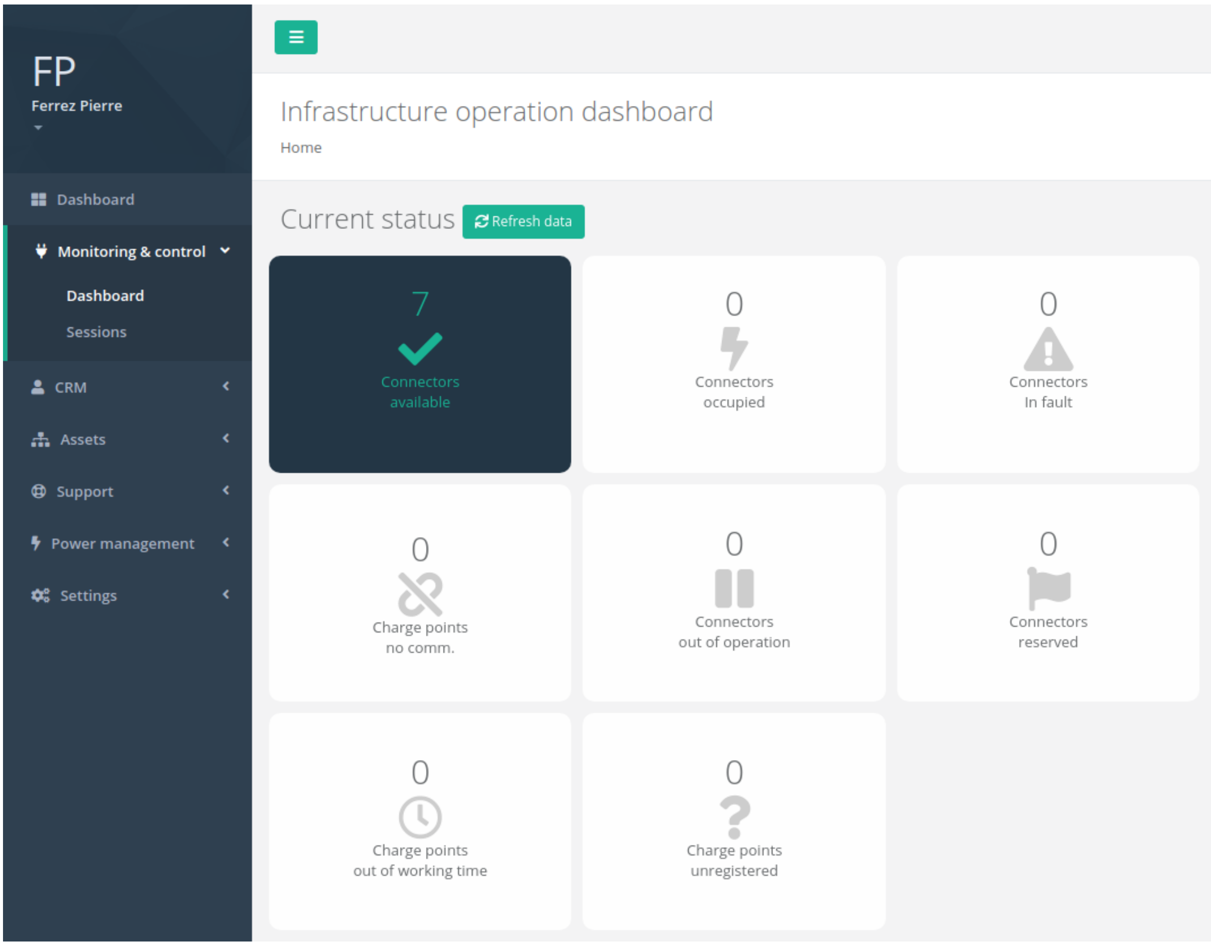

Figure 10: Etrel's dashboard used for monitoring and control of the charging stations as well as for the users' management.

2.5 FMAR, DOMS and SP

FMAR is the central marketplace for energy flexibilities. It receives flexibility bids in the form of Flex Offers. The core function is to provide techno-economical optimization on several levels and produce the result, which is also in the form of Flex Offer. The result (schedule) is sent to relevant prosumers for activation. FMAR also provides a methodology for execution validation and monitoring in real time. The final version of FMAR was made available for the Swiss demo site, prosumers are added when the components are deployed.

DOMS is responsible for short-term forecasting on the distribution grid. Using the metering data from the grid, DOMS is able to calculate the required energy flexibility that would resolve the potential problem in the future. Based on this forecast, DOMS automatically issues a Flex Offer to FMAR – purchase part of the trade. After execution on FMAR, DOMS is notified about the bought energy flexibility. Further-more, DOMS provides a calculation engine for energy transfer costs, which are taken into account in FMAR trading (implicit transfer capacity trading). Access to forecasts and retrieved KPIs by DOMS was made available to the Swiss demo site.

SP is providing several services to other GOFLEX systems. All the communication between FOA, FMAR and DOMS is handled through the APIs. Furthermore, SP also provides a datastore for timeseries and other data. The metering data is ingested by SP using the MQTT upload clients. After ingestion, data are made available to authorized systems. SP also provides several APIs for ECAST integration, which is used to optimize the prediction process.

3 Prosumer Experience

3.1 User Survey Design:

To get an overview of how prosumer experience GOFLEX technology, we conducted a survey study at Swiss demo-site. This method was utilized as it is an appropriate research method for getting user experience responses from a large number of people within a well-established target group. A survey is an instrumental device that can capture how individuals interact with certain technology, what kind of problems they may be experiencing, and the kinds of actions they may be taking.

In the following section, DC households as described for the swiss case are referred to as no-EMS.

Survey Purpose:

The overall purpose of the survey study was to develop an instrumental research device with the aim to gain deeper understandings of how GOFLEX technology is used in private households, and if GOFLEX technology is used as it was designed to be used. More specifically, the survey was devised to measure how GOFLEX technology is experienced by residential prosumers/consumers, the ease of which they interact and live along with GOFLEX technology, and the kinds of expectations they ascribe to GOFLEX technology.

Survey Design:

To help gain such insight we designed a user survey with four specific parts:

1. A part to report on the demographics of the respondents
2. A part to measure respondents overall understanding and experience of GOFLEX technology (user experience, main purposes and benefits, and future concerns and motivation)
3. A part to measures respondents experiences of GOFLEX technology related to the specific demo-site use case (e.g. heating)
4. A part to report on things respondents like or do not like and what their future needs may be.

We designed the survey with both closed- and open-ended questions. The open-ended questions are used to get a better understanding of participants experiences and their needs. They can also provide more context behind participants actions. The result from open-ended questions is typically a qualitative dataset. Closed-ended questions let respondents choose from a distinct set of pre-defined responses. The result from closed-ended questions is a quantitative dataset.

Most of the close-ended questions in the survey were designed to be measured on a 5-point Likert scale (from 1=strongly disagree to 5=strongly agree) with an additional “don’t know” response option. We also included an “other (specify)” option for each of these. When participants respond to a Likert item, respondents specify their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements. Thus, the range captures the intensity of their feelings for a given question. We chose to measure based on the 5-point Likert scale as it is the most recognised approach to scaling responses in survey research.

Survey Participants and Data Collection:

At the Swiss demo-site, the no-EMS system (AAU/INEA technology) households were asked to participate in the survey. In these households, GOFLEX technology automates flexibility with domestic heat pumps and/or boilers devices. These households do not have any direct control of GOFLEX technology nor flexibility settings. The only way they can interact directly with their GOFLEX component is through the GOFLEX/OIKEN website.

The survey was sent out via mailing list compiled by OIKEN and distributed to 185 households. The survey was hosted on SurveyMonkey, an online Survey collection tool. The data collection period lasted a week and took place at the end of January 2020. The participating households had at this time experienced GOFLEX technology running for an average of 6 months. All collected data was anonymised.

3.2 User Survey Results and Discussion:

When we report responses measured on the 5-point Likert scale, we sort overall questions based on the weighted average. The weighted average (WA) represents the average of questionnaire responses over the set of individual item questions. Thus, a high weighted average (WA [<3-5]) means that on average respondents agreed to strongly agreed with the item question, while a low weighted average (WA [1->3]) means respondent disagreed to strongly disagreed with the item question. An average WA (WA ~3) means respondents neither agreed nor disagreed

Characteristics of survey respondents:

A total of 90 individual persons chose to participate in the Swiss survey. From the collected data, we can clearly see that most participating households were residential houses owned by the participants (97,78 %). We can also observe that that respondents came from housing occupied with more than one person, indicating that the most respondents (96,67%) came from multiple-family homes. Mostly male respondents 84,27% participated from these households, while 15,74% respondents were women. The majority of the respondents (64,04%) were in the age range of 35-54. Only one young person between the age of 18-24 participated, while 29,21% of respondents were above 55 years of age. (Figure 11)

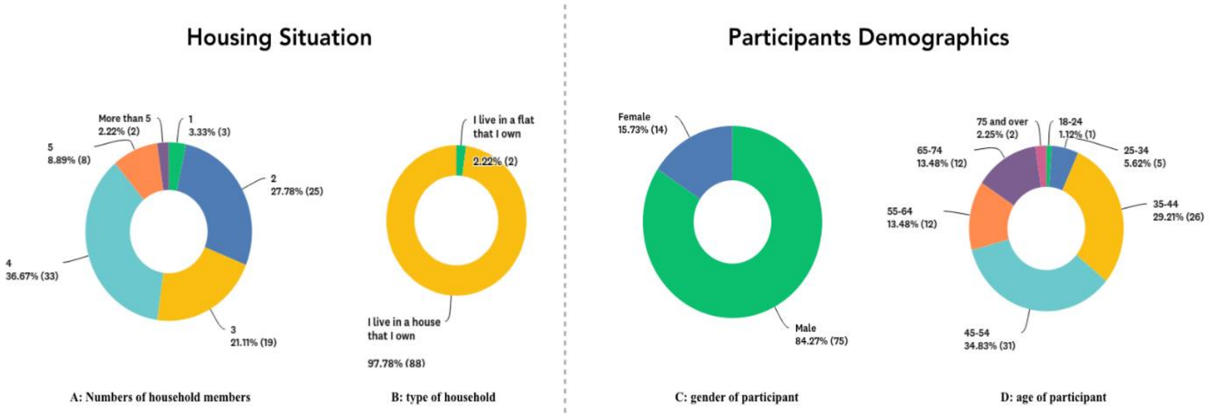

Figure 11: Main characteristics of participants and their housing situation

The respondents were also asked what motivated them to participate in the GOFLEX project (Figure 12). The respondents reported that the main motivational factor for participating in the GOFLEX project was wanting to try out new technology (WA: 4.34), closely followed by doing something good for the environment (WA: 4.26). Saving money was the third highest ranked motivational factor (WA: 4.09), while doing something good for the local community was the least ranked factor (WA: 3.86).

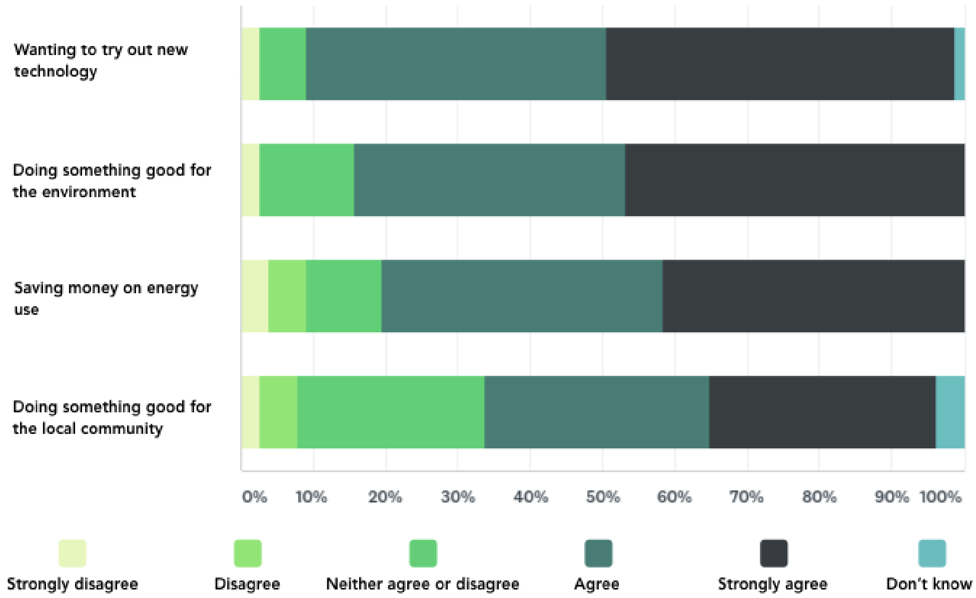

Figure 12:Motivational factors for participating in the GOFLEX project

User experience of GOFLEX interactive components and GOFLEX control of heater and boilers:

To measure the user experience of the GOFLEX interactive component at the Swiss demosite – the GOFLEX/OIKEN website - we asked questions about how and why the participants interact with this (Figure 13). From the survey responds, we can observe that a quarter of the respondents (25,97%) interact with the GOFLEX/OIKEN website a couple of times a month, while a sixth interact with the site weekly. We can also observe that over half (54,54%) rarely use or never use website. When respondents use the GOFLEX/OIKEN website (Figure 16), most respondents seek information about when their heat pump/boiler consumes energy, closely followed by what amount of energy the entire household consumes. Over 53 % of the survey respondents agreed or strongly agreed they seek temperature information either about the indoor temperature or the hot water temperature. Of the respondents producing own energy, 30,27% agreed or strongly agreed that they look at information about their own production. Lastly, 25% of the respondents agreed or strongly agreed at seeking green action advice when visiting the website.

This survey response indicates that energy related information about consumption and the effect of device control (changing temperatures and consumption of controlled devices) are perceived as valuable information. The survey responds also indicate this kind of information is not sought after on a regular basis from a majority of the respondents.

Here an extract on the main qualitative answers

- Interface not displaying correctly on mobile phone or tablet
- Sometimes slow
- General layout could be improved
- Aggregation on a weekly data basis
- Advice to reduce consumption
- Advice for PV installation sizing
- Alarm when some consumptions levels are reached
- Comparison with other users

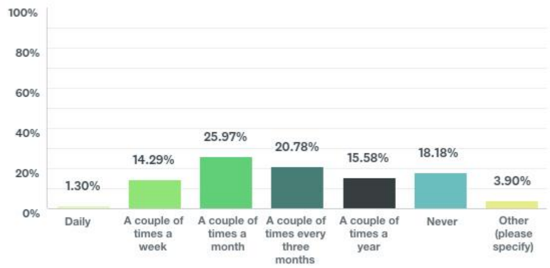

Figure 13:Number of times visiting the GOFLEX website

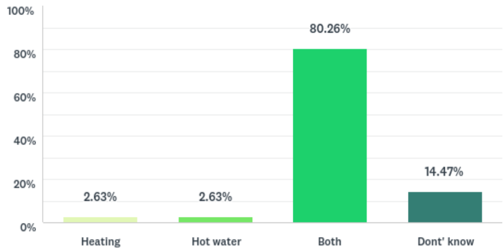

Figure 14:Respondents perception of what GOFLEX technology controls in their home

To get an indication of the overall user experience of interacting with GOFLEX technology, we asked questions related to measure the usability (how simple and easy the system is to use), and desirability (how much people perceive they look in control of things) of GOFLEX technology. All of questions had a weighted average above 3,6 (Figure 15). This indicates that the respondents perceived the interaction with GOFLEX technology to be average to good.

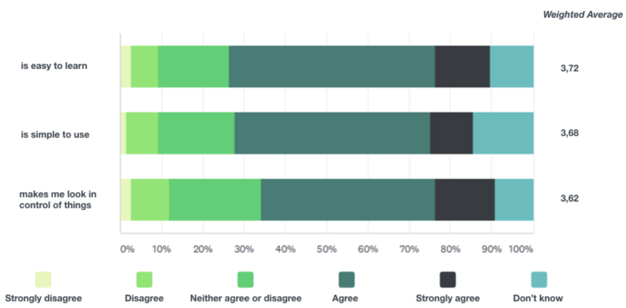

Figure 15:Energy related information respondents seek on the GOFLEX website

We also asked participants what energy related activity they perceived GOFLEX technology to control in their household (Figure 14). The survey response clearly indicates a majority (80,25%) of the respondents perceived GOFLEX technology to control both the heating and hot water in their home. Furthermore, almost 15% of the respondents did not know what

GOFLEX controls in their home. This is rather significant, as it indicates that a sixth of respondents did not have a proper understanding of the purpose of the GOFLEX demonstration.

The participants were also asked if they had experienced any improvement in their perception of comfort after being part of the GOFLEX demonstration related to both heating and the hot water production (Figure 17). 50% of the respondents neither agreed nor disagreed that GOFLEX technology improves the comfort of the hot water. Similarly, 13,51% of the respondents agreed (none strongly agreed) that the comfort of the hot water had been improved through GOFLEX technology, while 10,82% disagreed or strongly disagreed with this. When asked about how often they experience a loss of comfort 6,56% responded daily, none experienced this weekly, while 4,69 experienced it monthly. Most respondents (65.63%) expressed they did not experience a loss of comfort.

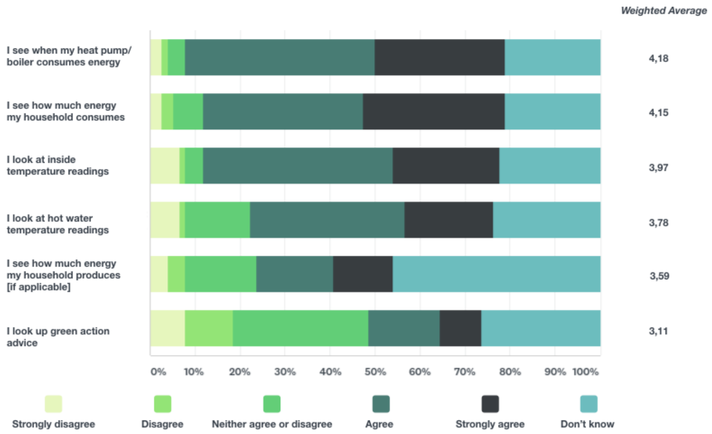

Figure 16:Energy related information respondents seek on the GOFLEX website

Likewise, 54,17% responded the same when asked about the comfort of the indoor temperature. However, 15,28% of the respondents agreed or strongly agreed that the comfort of the indoor temperature had been improved through GOFLEX technology, while 12,5 % disagreed or strongly disagreed with this. When asked about how often they experience a loss of comfort only one responded daily, while 6,56% responded a couple of times a week. Most respondents (62.30%) did not experience a loss of comfort.

That these results indicate only few of respondents experience a loss of comfort after GOFLEX technology has been installed in their homes, is not really surprising. The constraints on the flex control were set in order not to generate a loss of comfort and thus bother consumer. We have had some trouble with customers due to some installation issues. After it was cleared, esr received only a few complaints. In some cases, we observed that in case of an outage, GOFLEX was often blamed even if outage was due to other reasons.

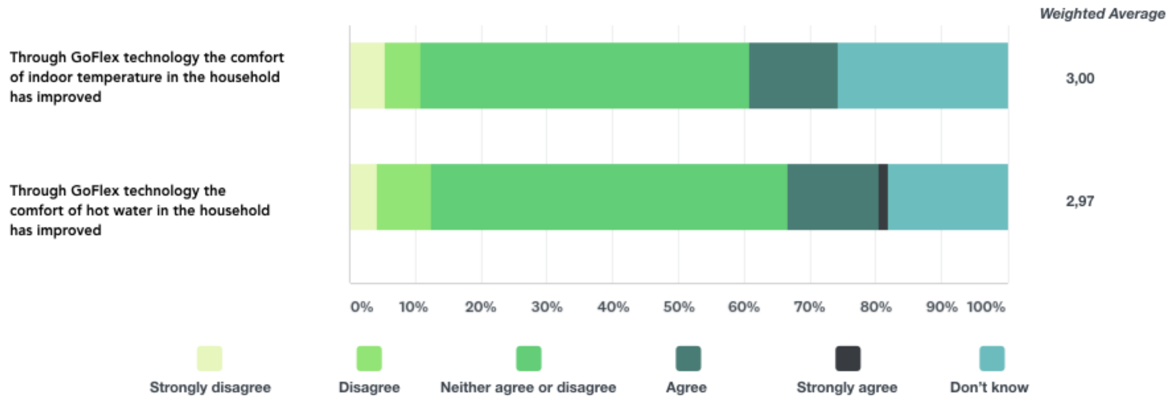

Figure 17:Perceived change of comfort due to GOFLEX technology

Qualitative questions were asked about the positive and the negative aspects of the GOFLEX project. About 30% did not respond to these questions.

- Positive aspects (55 answers)
    - Increased visibility on consumption and on heat pump behaviour (identification of outage)
    - Ease of use, sensitization
    - Improved temperature monitoring and management
    - Improved understanding on self-consumption for customers with PV production
    - Possibility to generate stats and export to excel
- Negative aspects (51 answers)
    - No clear vision on how the system controls and influence the consumption
    - Cannot control house and water temperature
    - Problems with sensor reliability and data “disappearing*
    - Outage: water temperature drops down
    - Not enough information on the website (too complicated, too slow)

User Expectations of GOFLEX Technology

We created different questions to measure respondents’ perception of the purpose and design attributes of GOFLEX technology. To measure the respondents’ perception of the overall purpose GOFLEX technology, we asked the specific questions related to the purpose of GOFLEX technology (Figure 18). The respondents clearly perceived the main purpose of GOFLEX technology is to provide energy information. This could be an indication of participants are only able to directly interact with the GOFLEX technology through the GOFLEX/OIKEN website. However, it is also interesting to observe that 67,10% of respondents agreed or strongly agreed the purpose of GOFLEX technology is to help them use less energy, while 39,47% agreed or strongly agreed that the purpose of GOFLEX technology is help them use clean energy. At the same time 46,05% agreed or strongly agreed that the purpose of GOFLEX technology is to help them control home appliances. This indicates that it is not clear for all participants what the overall purpose of GOFLEX technology is for them (as one visions of the project is the penetration of distributed renewable energies – at the Swiss demosite this happens through automation).

> *"A team came to install the system but unfortunately we did not have details explanations on GOFLEX is supposed to work..."*
>
> *"Lack of details on this technology, ultimately we do not really know what it is for ..."*

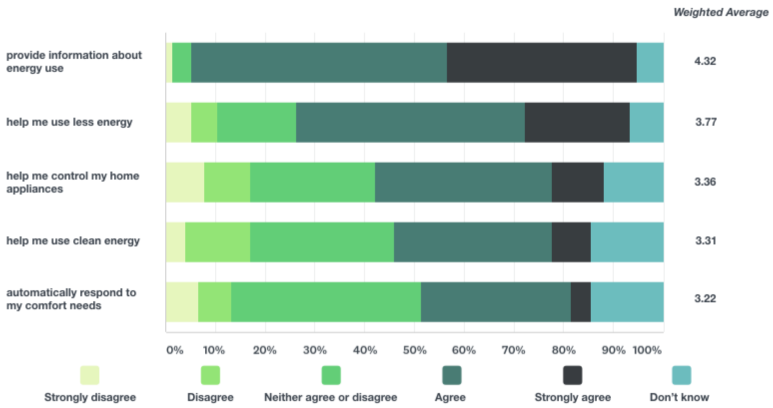

Figure 18:Perceived purpose of GOFLEX technology

To measure the respondents' perception of what GOFLEX technology is designed to do, we asked the specific questions related to the design and control of GOFLEX technology (Figure 19). The respondents clearly perceived that GOFLEX technology is designed to provide more information about each individual household consumption. 86,66% agreed or strongly agreed with this, which could be related to that they also weighted this to be the main purpose of GOFLEX technology (Figure 18). As no-EMS users, at the Swiss demo-site have direct control over GOFLEX technology, it is interesting to observe that 72,00% of respondents agreed or strongly agreed the GOFLEX technology is designed to help them manage their energy use, while 65,33% agreed or strongly agreed that GOFLEX technology is designed to manage this for them. However, despite these users having no directly control of GOFLEX technology, 56,00% still agreed or strongly agreed that GOFLEX technology is designed to provide them with greater control over household activities. At the same time 73,33% of respondents agreed or strongly agreed that GOFLEX technology is designed to always be on and active, while only 28,00% of the respondents agreed or strongly agreed that GOFLEX technology is designed operate only when activated.

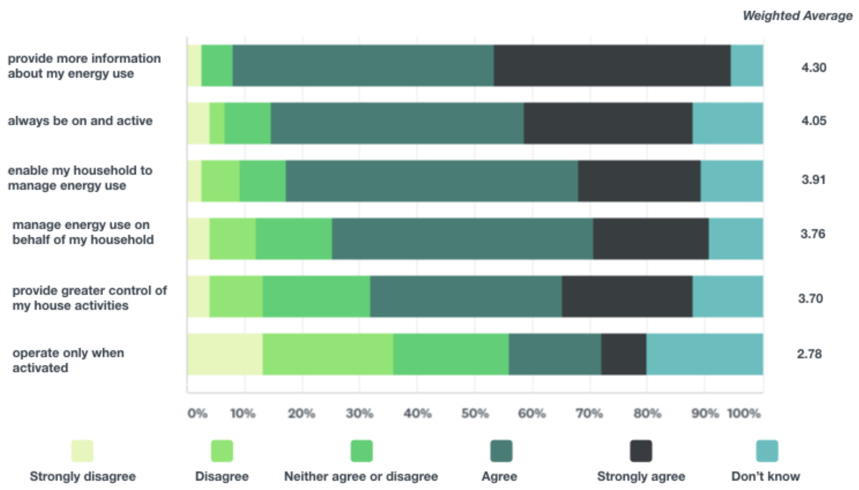

Figure 19:Perception of the design and control of GOFLEX technology

Future Use, Risks and Improvements of GOFLEX Technology

We created different questions to measure respondents' perception what GOFLEX technology must do for them to continue to use GOFLEX technology and as well as general future risks and information improvements of GOFLEX technology.

To measure the respondents' perception what GOFLEX technology must do, for them to continue to use GOFLEX technology, we asked specific questions related to the use and features of GOFLEX technology (Figure 20). Survey respondents clearly thought that GOFLEX technology must be reliable to use. A total of 94,67% of the respondents agreed or strongly agreed with this. A further 89,34% thought that GOFLEX technology must manage their energy use effortless and convenient. Interestingly, the least weighted average of the features was automating energy usage (65,33% still agreed or strongly agreed this is an important feature). Why this was rated the lowest may be because this is already what GOFLEX technology is designed to do at the Swiss demosite.

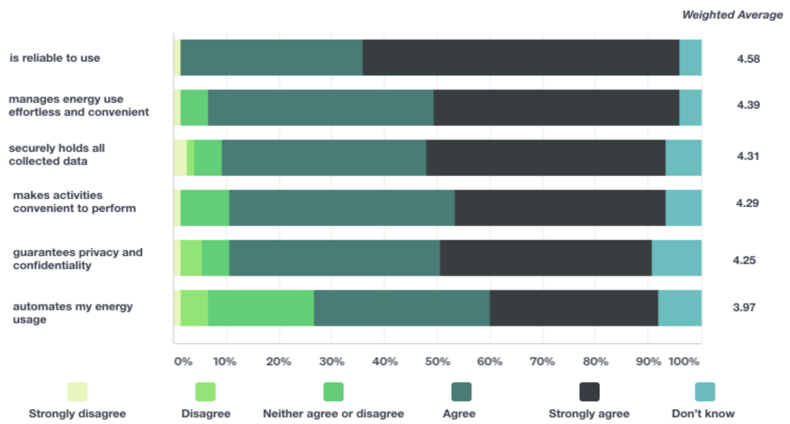

Figure 20:Perception of the importance of GOFLEX technology features for future use

To measure the respondents’ perception of the kinds of risks they associate with continued use of GOFLEX technology, we asked them six specific questions related to this (Figure 21). With this, there were no overall agreement for the six response options with response means not exceeding the midpoint of the response scale. This might be an indication of that respondents already associate GOFLEX technology either as being rather trustworthy or not knowing what the GOFLEX project/technology is all about. Nonetheless, the average of 3 risk factors were weighted equally near the midpoint of the response scale. Namely, a risk of an increased dependency on technology, a risk of an increased dependency on electricity companies, and a risk that will result in a loss of control. This suggests that these risk factors should be considered in future development as almost a third of respondents (25,34%, 24,00%, and 26,67%) still agreed or strongly agreed on these factors being a risk in the future.

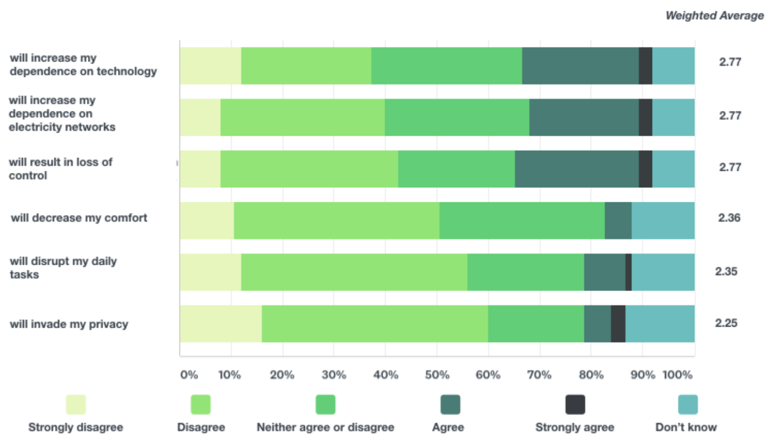

Figure 21:Perception of risks associated with continued use of GOFLEX technology

To measure what information respondents perceived to be of importance for the continued use of GOFLEX technology, we asked them 10 specific questions of this (Figure 22). Despite users having access to the GOFLEX/OIKEN energy information website, 30,00% of the respondents still disagreed or strongly disagreed with having the information they needed, with only 12,00% agreeing and strongly agreeing of that they needed no more information. Being able to compare household energy usage over time had the highest weighted average of importance of the information features with 89,33% of the respondents agreeing and strongly agreeing with this. 88,00% of the of the respondents agreed and strongly agreed with the importance of getting information about how GOFLEX technology controls home devices, while 89,33% agreed and strongly agreed the importance of getting information about how GOFLEX technology influences their energy use. This highlights the importance of properly informing users about what GOFLEX technology is controlling devices in their homes and how GOFLEX control influence the energy usage of the household in future development. The weighted average for getting information about what the household use energy on (89,34%

agreed and strongly agreed with this) was slightly higher than information about money saving as 77,33% of respondents agreeing and strongly agreeing with this. Interestingly, information about renewable energy usage (green energy usage and CO2 footprint) had a lower weighted average than saving money and GOFLEX control despite respondents ranking “doing something good for the environment” higher as a motivational factor for participating in the GOFLEX project. Being able to compare energy usage in the neighbourhood and getting information about the neighbourhood’s renewable energy consumption had the lowest weighted average, as 52,00% and 38,67% agreeing or strongly agreeing with these two information items being of importance.

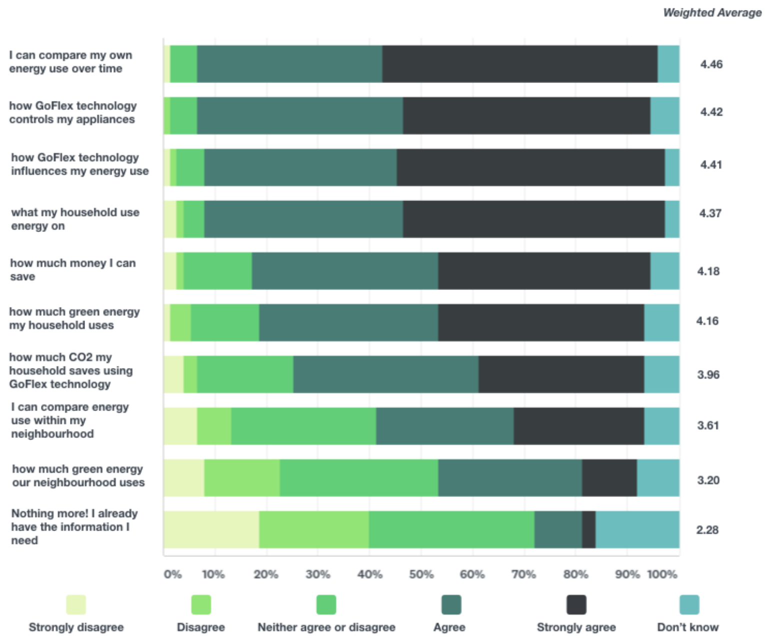

Figure 22:Perception of important information for continued use of GOFLEX technology

On top of these answers, we received a few propositions about how GOFLEX could improve in the future, here are the main ones:

- More information on the website would be welcome
- Would like to optimize consumption and save energy either through advices or automatic decision (PV, battery, …)”
- Would like more sensor to be able to monitor specific device
- Being able to compare with another user’s consumption
- Develop a mobile App to access the data
- Being able to sell excess energy to the neighbourhood

4 Technical Performance

The GOFLEX project defines several Key Performance Indicators used for measuring the impact of the project. We segmented the KPIs into 2 groups:

- Technically trackable KPIs: this KPIs are monitored by the solutions themselves. This means that the tracking is implemented as part of the code of the solution. Each solution provider has implemented this functionality into the system.
- Non-trackable KPIs: this group contains the indicators, which are either calculated once (e.g. count of the deployed systems) or are measuring non-technical values (e.g. benefits). This KPIs are not part of the integrated system – they are not implemented in code.

In this section, we address the relevant KPIs to the swiss demonstration site.

4.1 Scale of Installation

Table 2: Scale of installation

Quantity	Target Value	Achieved Value
Number of Home Energy Management Systems	20	9
Number of Factory Energy Management Systems	10	9
Number of Direct Controlled households	200+	197
Number of Electric Vehicle Charging Stations	10	10
Number of deployed servers and virtual machines for DOMS and DC	n/a	10
Number of deployed sensors in DC	n/a	956

4.2 Detailed Performance Evaluation

The following section details the computation and retrieving of all the relevant KPIs to the swiss demonstration site.

4.2.1 Lessen the burden of power grids through self-consumption

Over the period Dec 1st, 2019 through to Jan 29th 2019 DOMS service requested, on average, about 0.8 MWh/h of positive flexibility (increase energy production or decrease energy demand) and 4 MWh/h of negative flexibility (increase energy demand or decrease energy production), respectively corresponding to about 0.8% and 4.7% of the peak energy demand of ESR, nearly 101 MWh/h.

$$KPI2 = ABS\left(1 - \frac{Grid\ Loading}{Gross\ Demand - Delivered\ Flexibility}\right)$$

4.2.2 Distribution grid stability through responsiveness of flexibility services

Over the period Dec 1st, 2019 through to Jan 29th 2019 DOMS service issued 5633 flexoffers (this is about one every 15 minutes), amounting to a total of about 4453 MWh of positive flexibility requests (increase energy production or decrease energy demand) and 26592 MWh of negative flexibility requests (increase energy demand or decrease energy production). Over the same period there was a corresponding portfolio of about 55 MWh of offered positive flexibility and 25 MWh of offered negative flexibility from the prosumers, amounting to 1.24% and 0.09% of the flexibility requested by DOMS.

4.2.3 Grid state observability: near-real time (5min) and forecast (forecast 30min up to 24-48 hrs)

The Distribution Observability and Management Service (DOMS) developed in WP4 provides for estimates of the configured state variables over a rolling forecasting horizon of 0 to 24 hours, with a 15-minute interval. DOMS predictions are based on the energy forecasts made available from the IBM Coud Service Platform (WP5) and are updated continuously as new forecasts become available, typically every hour.

In the case of the Switzerland instance, DOMS configuration included the following 2 state variables:

- ESR energy imbalance, defined as the difference between the actual ESR Load and the ESR day-ahead prediction (based on which energy is purchased on the day-ahead market)
- TG8000 load, defined as the physical active power load at the interconnection (TG8000) with the transmission system operator (TSO) Swissgrid.

The following additional 49 support variables are included in DOMS grid model for Switzerland:

- The amount energy supply provisioned on the day-ahead market.
- 3 energy consumption sources, including the BRP demand, the external customers pool and the liberalized customers pool
- 45 distributed solar generation points

Two different metrics were proposed to evaluate the Grid state observability capabilities provided by DOMS:

$$OBSERVABILITY.1 = \frac{Number\ of\ \text{observed}\ state\ variables}{Number\ of\ state\ variables}$$

$$OBSERVABILITY.2 = 1 - \frac{Number\ of\ \text{"metered"}\ variables}{no.\ of\ all\ available\ variables}$$

The KPI “Observability.1” captures the number of observed grid state variables with respect to all possible states of interest (full observability).
An alternative KPI “Observability.2” was introduced to capture the improvement in observability provided by DOMS with respect to raw observations available purely from current system telemetry (e.g. SCADA, metering infrastructure).

Observability.1
Sept 2019: 81.31%
Oct 2019: 86.97%
Nov 2019: 100.00%
Dec 2019: 100.00%
Jan 2020: 66.57% ** (*Outage caused missing week in Jan 2-8, 2020)*
Total Observability.1 KPI = 89.66%

Observability.2 (Improvement over available metering/scada data)
Sept 2019: 38.30%
Oct 2019: 38.90%
Nov 2019: 35.85%
Dec 2019: 35.85%
Jan 2019: 36.18%
Total Observability.2 KPI = 37.01%

4.2.4 Likelihood of Prediction of congestion (voltage/power-flow limit violation)

Along with the prediction estimates of the configured state variables, DOMS software predicts the likelihood that any of the state variables is in an undesired operational range, with respect to the user-defined tolerance levels.

The performance of DOMS congestion predictions is evaluated using typical classification metrics of Precision, Accuracy and Recall, is defined as:

$$ACCURACY = TP + TN$$

$$PRECISION = \frac{TP}{TP + FP}$$

$$RECALL = \frac{TP}{TP + FN}$$

based on true-positive (TP), true-negative (TN), false-positive (FP) and false-negative (FN) rates of the predictions of undesired state variable operational ranges.

The following monthly values, from September through to December 2019, were observed during trial operation for the two configured state variables:

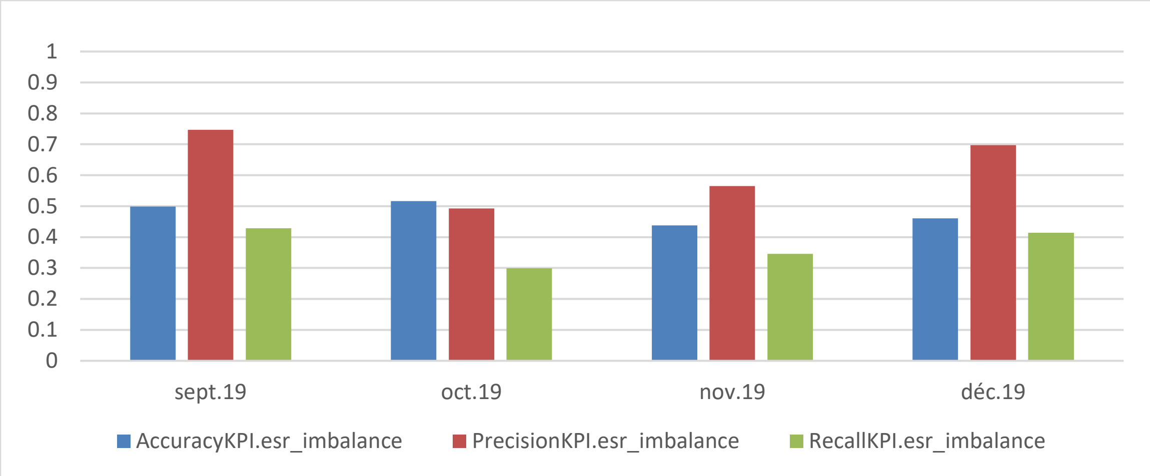

Figure 23:Likelihood Prediction of ESR Energy Imbalance

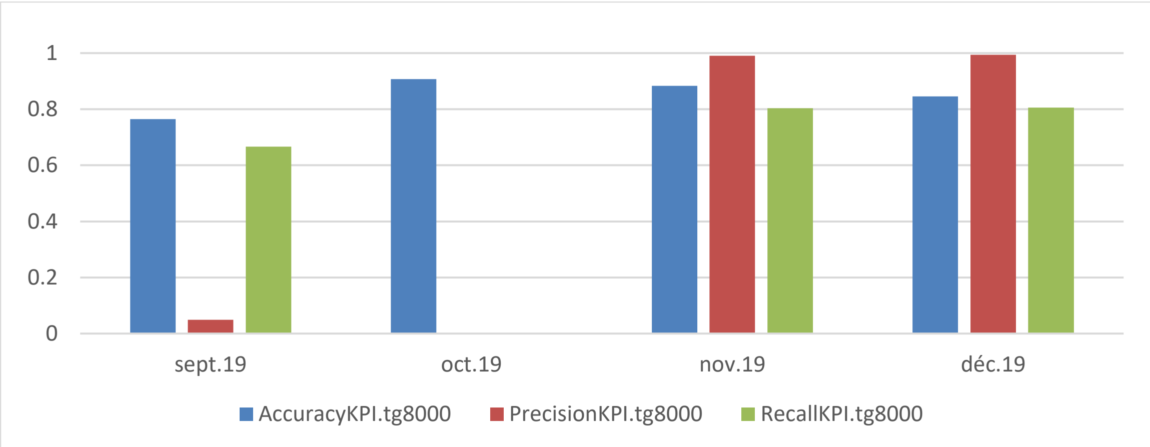

Figure 24: Likelihood Prediction of Physical Load Congestion

The month of January 2020 was excluded from the evaluation of this KPI, because of issues with the ESR metering data, which do not reflect the assumptions behind DOMS grid model after the merger and expansion of ESR with anotherDSO .

We use Accuracy to summarize the performance of DOMS congestion predictions, since it combines both true positives and true negatives, breaking down the value by active power and voltage congestions:

Accuracy.esr_imbalance (ESR imbalance) = 47.84%
Accuracy.tg8000 (physical load congestion) = 84.99%

Total Accuracy = 66.42%

Precision.esr_imbalance (ESR imbalance) = 62.54%
Precision.tg8000 (physical load congestion) = 99.28%
Total Precision = 80.91%

4.2.5 HEMS performance analysis

Figure 25 summarizes KPIs for HEMS and gives an insight into prosumers self-consumption. These values are computed weekly from 20.10.2019 to 09.02.2020.
The self-consumption index is computed using HEMS' direct consumption over the total consumption. It averages here at around 5%, which is lower than the target.
The prosumer involvement index is computed using the contracted flex offers over the total of the flex offers.
The consumption adaptability level is computed using the contracted energy over the overall consumption.

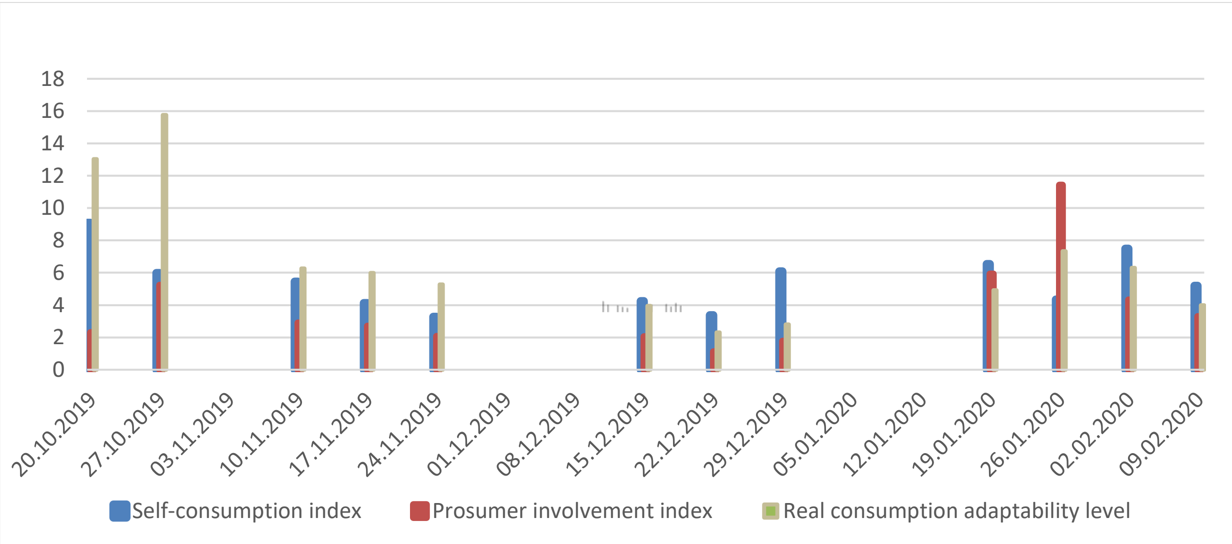

Figure 25: HEMS KPIs

4.2.6 DC performance analysis

In this section, we quantify the available flexibility for households over the last year of using the GOFLEX system.

The flexibility of heating and hot water systems is very interesting because of the possibility to store energy in the form of heat. Hot water is stored in a tank and preheated for later use. Figure 26 shows the share of electricity consumption for heating and hot water in households in 2019 and which depends heavily on the existing systems. The power consumption for heating and hot water represents a big share of the total consumption in cold months. During the night, the power consumption increases, because it is the time when most people are home and most likely to need heat in their homes.

In Switzerland there are strong seasonal temperature fluctuations which is the reason why consumption habits in summer are very different from those in winter. Heating systems remain switched off from May to October. The hot water consumption remains relatively constant throughout the year.

The seasonal temperature fluctuations are therefore high and affect the heating behavior of the population. The daily temperatures range from an average low of - -4°C in January to 27°C in July which means that there is a heating season where heating systems are used to keep the room temperature around 22°C as shown in Figure 28.

In central Valais, the heating season is usually shorter than the average in Switzerland. Figure 28 shows that the heating season starts as soon as the average daily temperature drops below 20 ° C. The energy demand for boilers remains relatively constant throughout the year. During the summer holidays in August, one could notice that there is hardly any consumed electricity. This corresponds most likely to the time of the year when people are on vacation.

Figure 27 gives a clear overview of the nature of power consumption in Valais's households where the power consumption is up to five times higher in some winter periods than it is during the rest of the year. It is also worth noticing that during these very cold months, two consumption peaks happen during early morning and evening, which correspond to regular peak times in European countries.

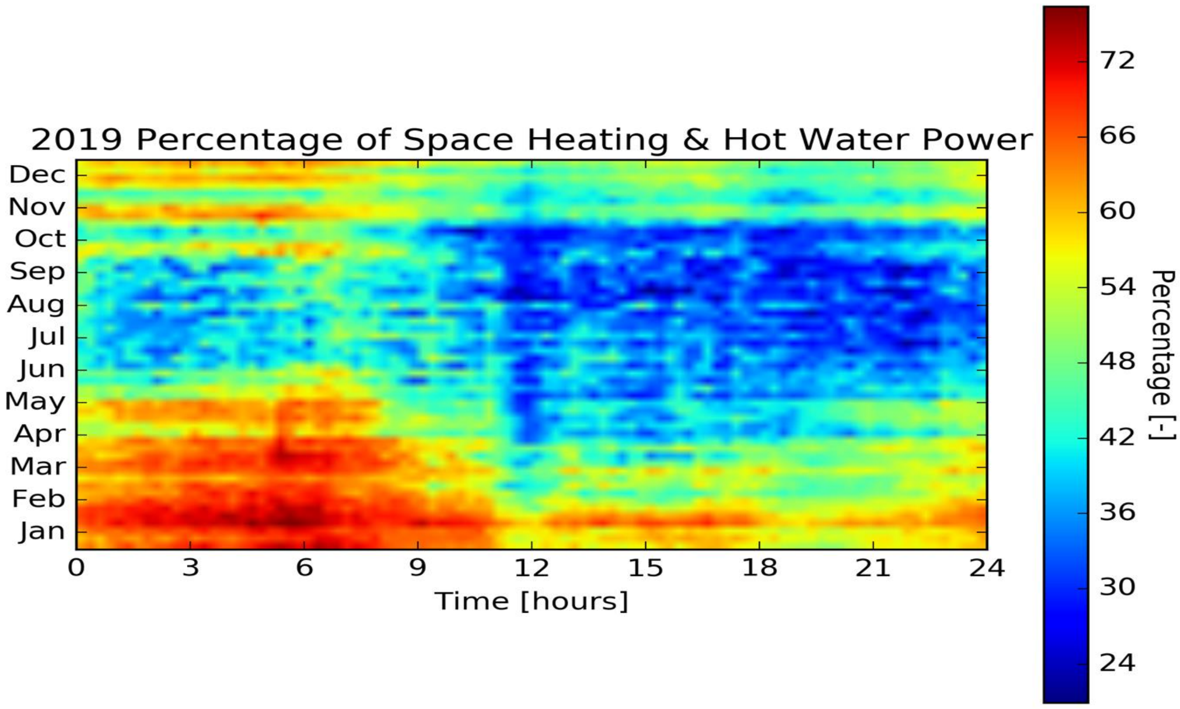

Figure 26: Percentage of space heating and hot water power in 2019

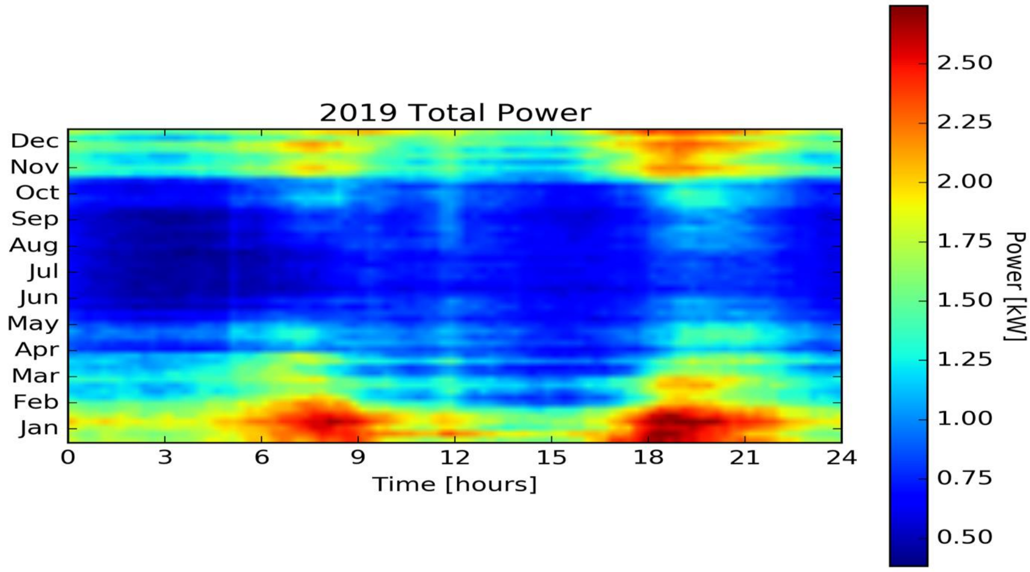

Figure 27: DC total power in 2019

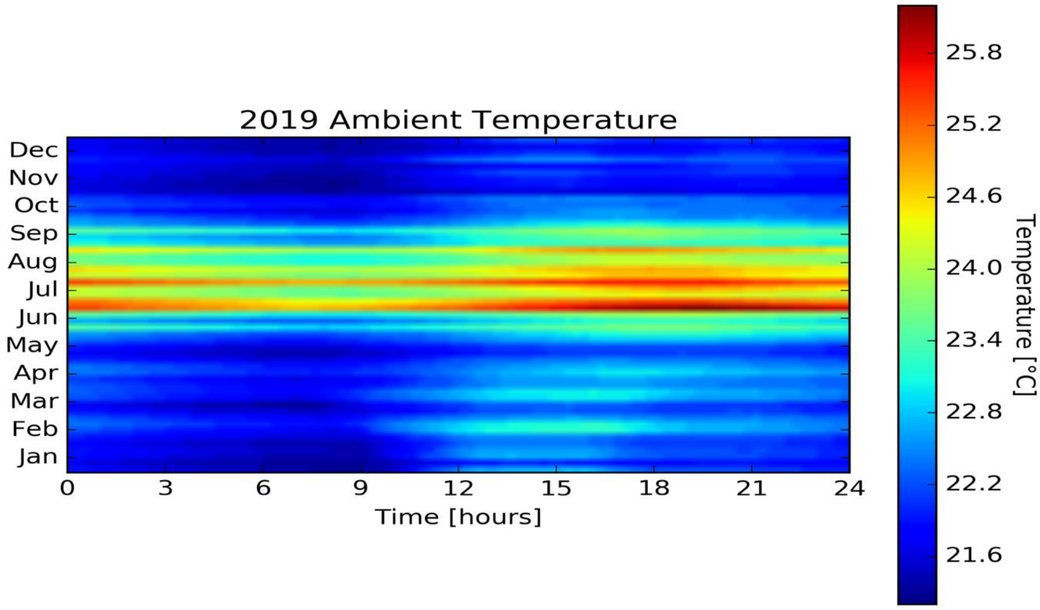

Figure 28: Ambient temperature in households in 2019

4.2.7 CEMS Performance analysis

The operation of CEMSs was characterized by a very low number of flexibility offers generated by the CEMS. Only 1% of charging sessions were initiated by smart phone, which is the precondition for acquisition of EV users' inputs (departure time and EV type) and calculation of flexibility parameters. This is especially valid for the private charging station where no flexibility offers were generated and consequently the associated KPIs ("Variation of electric vehicle charging load at private station, depending on parking time" and "Reduction in electric vehicle charging time and peak load at private station") could not be calculated.

From point of view of prosumers (EV users) the use of EV charging within the GOFLEX system seems quite complicated. Therefore, the users were using RFID cards which doesn't enable acquisition of data about user's charging requirements (time available for charging) and EV charger's technical characteristics (EV type, linked to maximum possible charging power).

The target values of KPI Variation of electric vehicle charging load at public stations (10% for increase of scheduled load - DOWN; 30% for reduction of scheduled load - UP) were achieved due to the nature of EV charging and associated flexibility margins (the entire range of flexibility is available during the complete duration of charging session). A risk for underperformance could occur in the case of clustered charging stations (several chargers supplied via the same supply cable): in this case the power available for charging (rated power of power supply) might not be sufficient to charge all EVs with full power and the achievement of KPI DOWN (increase of scheduled load) could be endangered. In Use Case 2 such limitation doesn't exist due to strong prosumers' network (high grid connection power and strong internal – behind the meter – network); as a result, the KPI target values were achieved for both directions of possible energy variation.

At present state of development, using mobile phone represents a workaround for acquisition of mentioned data and is highly inconvenient for users. To enable a wider incorporation of EV charging into demand response schemes, a more user-friendly method of acquisition of input data should be implemented. The solution lies in a direct communication between the EV and the charger. The relevant standard for such a data exchange already exists (ISO 15118) but is not yet widely implemented in EVs.

4.2.8 Increase of installed capacity of renewable energy sources

Figure 29 shows the penetration rate of PV from 2008 to 2019. We notice that there was a high penetration of PV in the grid over the last ten years. During the period of GOFLEX, new installations were done at a lower but still high rate with a mean value around 20%.

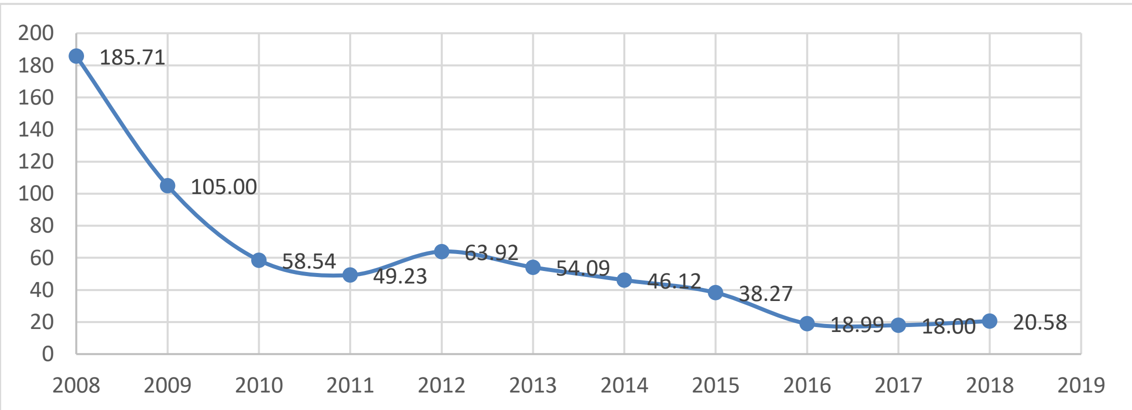

Figure 29: Rate of new PV installation in ESR'S grid

4.3 Summary Performance Evaluation

We evaluated performance as described above. The results are summarized in the following table.

Table 3: Performance metrics for GOFLEX Demonstration in Switzerland

Quantity	Target Value	Achieved Value
Safe increase of installed capacity of renewable energy sources	>15 %	**20%**
Adaptability of energy load with respect to peak demand	>15%	**0-5%**
Estimated profit(revenue?) from supplying/activating aggregating demand response	>€35,000/MW/year + €200/MWh	**€60'000/MW/year or 12.8€/MWh ***
Avoided costs for congestions	€1M / MW	**€30k/MW/year****
Reduction in peak demand	>15%	**0-5%**
Increase in self-consumed energy	>10%	**5.5%**
Coverage of grid state variables of interest with distribution observability and management system	>80%	**89.66%**
Likelihood of correct prediction of congestion	>90%	**84.99%**
Accuracy of forecasts at BRP level	<5%	**2.25%**
Service platform query response time	< 1 minute	**0.92 seconds**
Service platform availability of observations	< 5 minutes	**0.15 seconds**
Service platform availability of next forecast update	< 30 minutes	**26 seconds**
Variation of electric vehicle charging load at public stations	+10 / -30 %	**>10 and <30%**

* This KPI evaluates the profit that can come from balancing energy (see chapter 5.3). The figure represents the opportunity to save money by avoiding balancing energy. The balancing energy mean price for ESR over the last years is 12.8€/MWh. 5MW of flex will allow to decrease the balancing energy volume by 82% from 26.7 GWh to 3.8GWh. 22.9 GWh at 12.8 €/MWh represents roughly 300'000 € per year with 5MW. It's equivalent to 60'000€/MW/year.

** For this KPI we will focus only on congestion from the peak shaving point of view as the ESR grid is today far from a general and local congestion (see chapter 5.2). The mentioned figure will be achieved with a theoretical battery of 5MW/5MWh. However, for the time being, the flex gathered through the GOFLEX trial is not enough to reach the characteristics of the mentioned battery. More installations and a higher reliability would be needed.

Focusing only on peak shaving is explaining why the KPI is smaller. Avoided cost for improving and building new electrical lines could be important and increase this KPI. However, we are not estimating this value as ESR will not face congestion in a near future and because it will be too much theoretical to make calculations as we cannot yet figure out how many line meters we could save with flex.

5 Cost Benefit Analysis

The business case described previously is analyzed in this chapter and the various associated KPI are calculated or clarified. 4 sources of potential benefits are identified:

- Network
    - Congestion avoidance / decrease investment
    - Peak Shaving
- Energy
    - Balance Energy reduction
    - Tertiary reserve

The following chapters will go into details, as a good understanding of the state of the grid and of the properties of flexibility are needed to analyze the potential benefits.

5.1 Congestion Avoidance

Objective: ensure a safe increase of installed capacity of renewable energy sources

The increase of renewable production is important on the ESR grid. In ten years, the number of recorded grid-connected PV plants has gone from almost nothing to close to a thousand operating installations.

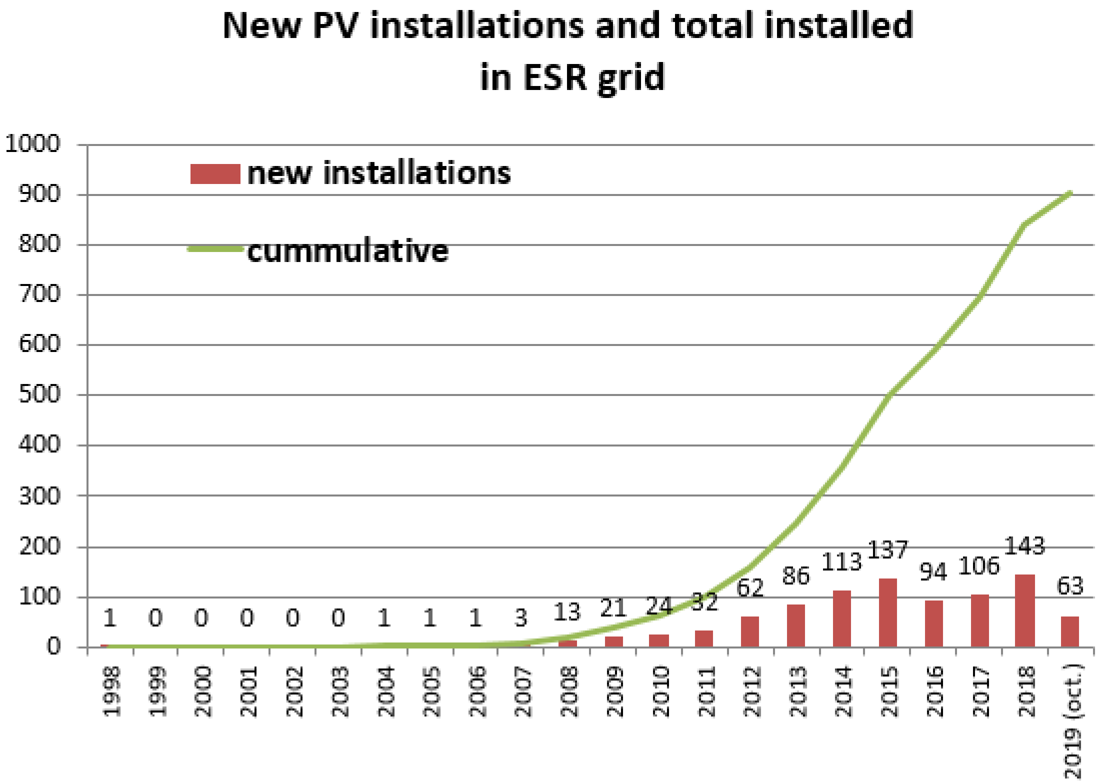

Figure 30: New PV installations in ESR grid

The total installed power is over 20MWp in October 2019. This looks small compared to the global PV installation, but it is already relevant compared to the size of a DSO like ESR.

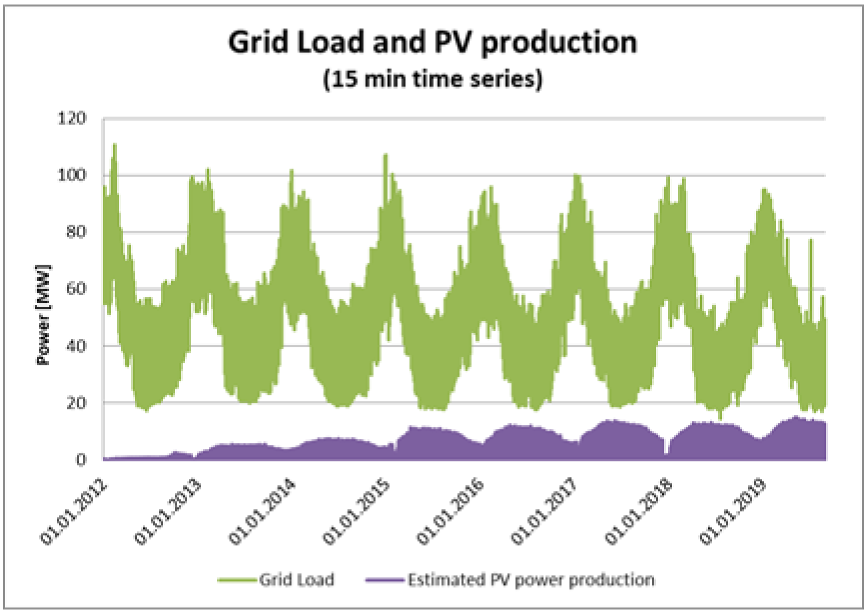

Figure 31: Grid load and PV production

During the summer, on a Sunday (low load) the PV production can be as high as 50% of the grid load.

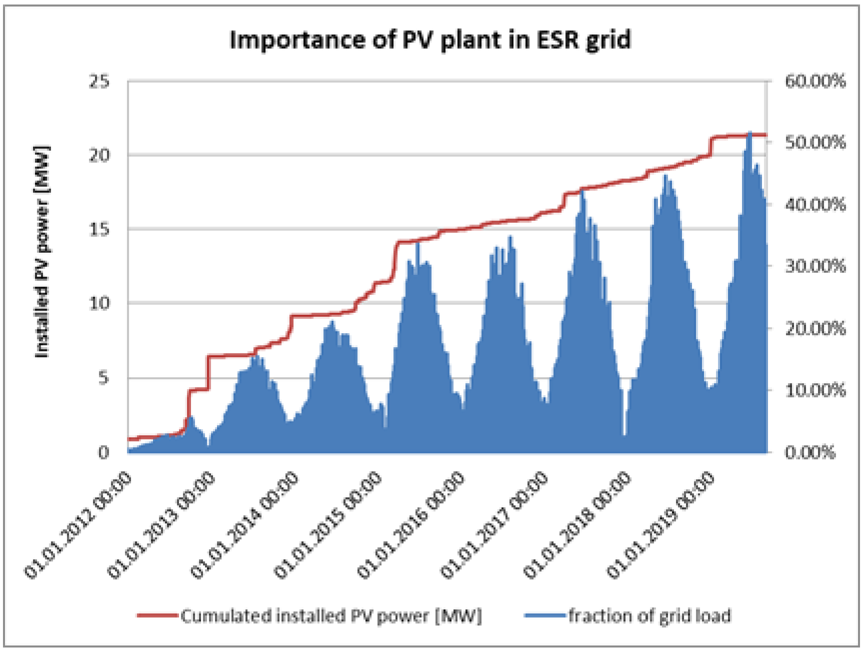

Figure 32: Importance of PV plant in ESR grid

The ESR grid is far from a general congestion as the grid is designed for the winter load with a peak of more than 100MW. The Valais region has many ski resorts and is then much more crowded in winter with a higher electricity consumption (high number of electric heating either direct or via heat pump).

With a similar increase rate of PV solar installation as of today (20 MWp/7 years), we could reach 100 MWp in 28 years, which means in 2047. Even with an increase in PV solar installation rate, we are still far from a general congestion. What will happen first are localized congestion on specific feeders.

5.1.1 General congestion

In ESR catchment area, the type of distributed renewable source expected to grow in the future is the solar PV. With that kind of production, the goal is to reduce peak production in summer at midday.

The flexibility requirement to address the peak power problem is estimated here in power and energy. This is computed on real data of the year 2018 considering that a given peak power must be shaved, for example at 40% of installed power on the figures below:

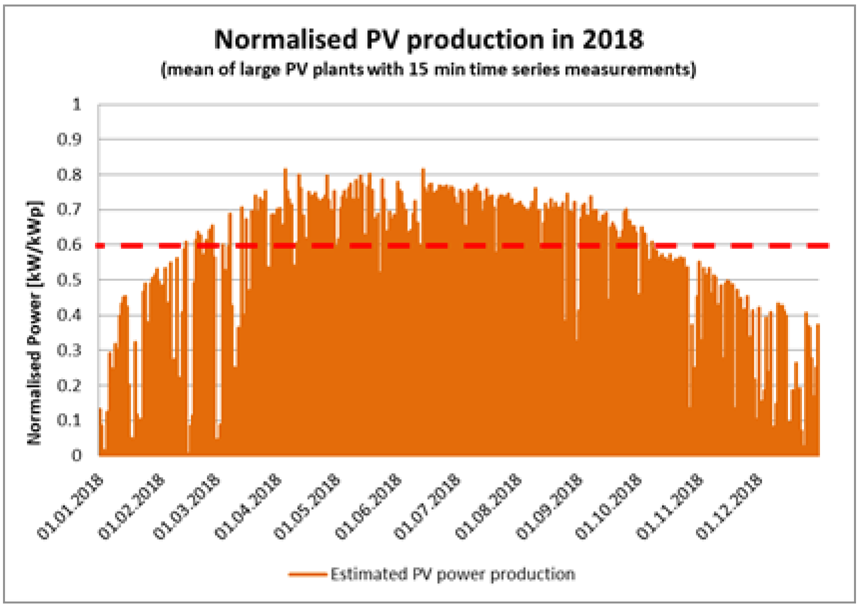

Figure 33: Normalized PV production in 2018

For one kWp of PV installed, the peak production is around 0.8kW. The ration of 0.8kW/kWp corresponds to the difference between STC (Standard Test Conditions) and NOTC (Normal Operating Temperature Conditions) for PV. That means that if there is 20MWp of installed solar, the expected production peak on a nice sunny day is of 16MW.

Absorption with flexible loads of the PV production of 40% of installed power would require the equivalent of 20% of the realized power during summer.

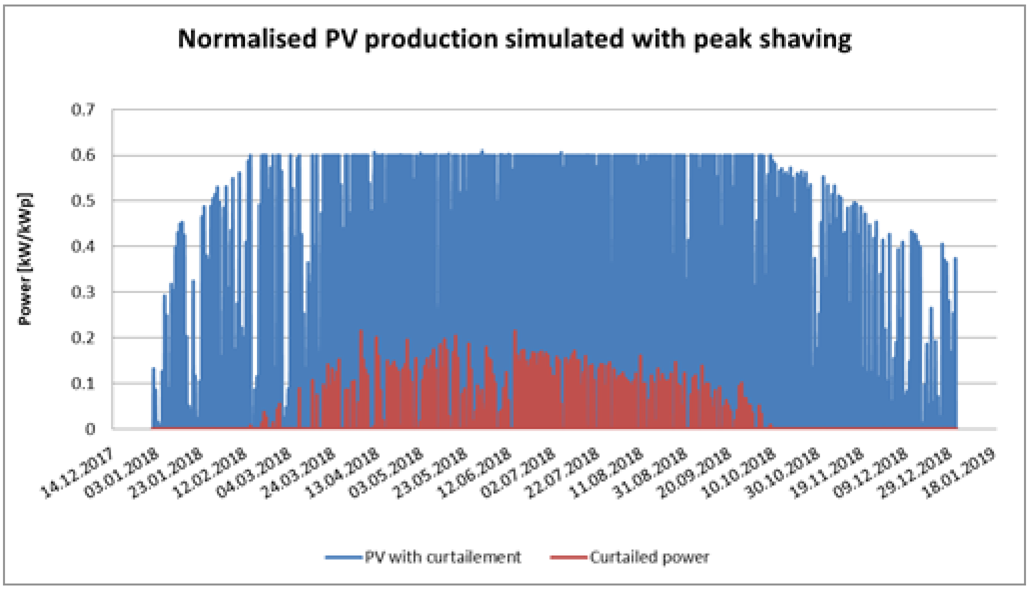

Figure 34: Normalized PV production simulated with peak shaving

The energy of each curtailed peak is then computed (integral of curtailed peak power for each day). The following graphic illustrate the necessary energy for flexibility and how many hours it needs to be shifted.

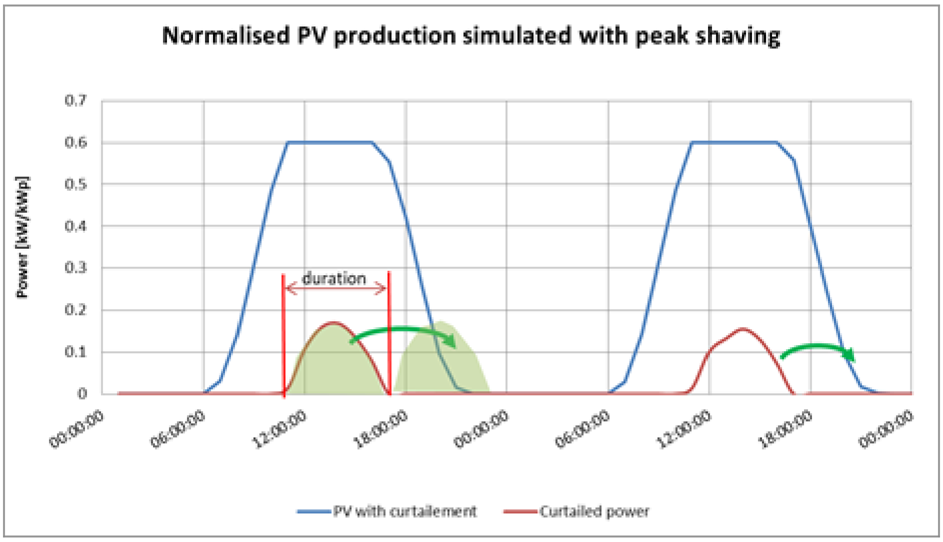

Figure 35: Normalized PV production simulated with peak shaving

The integral is applied to all days of year 2018:

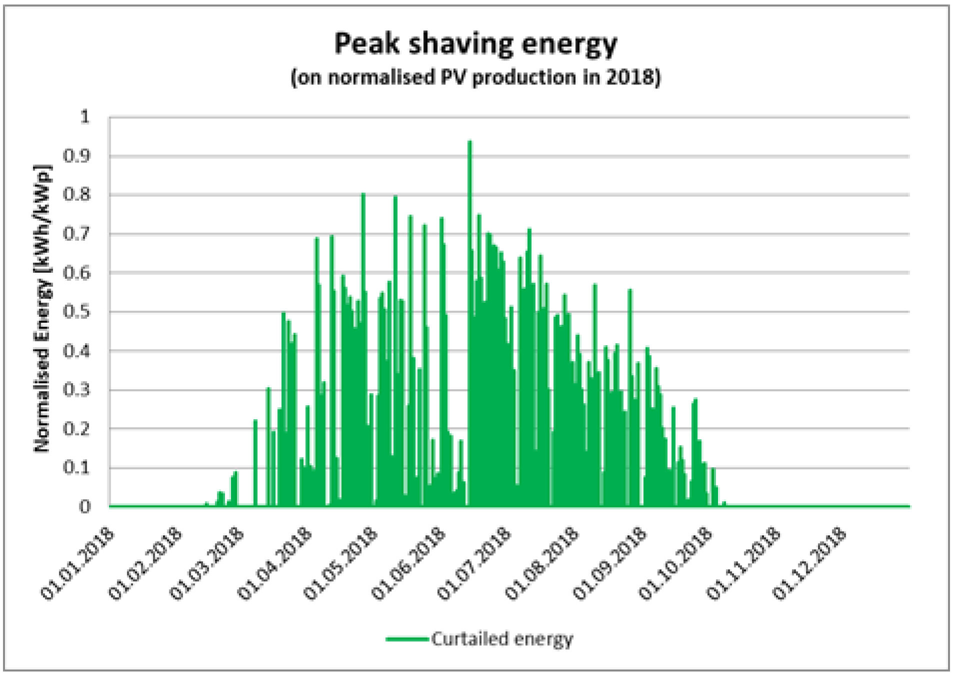

Figure 36: Peak shaving energy

A curtailed energy of 0.8kWh/kWp means that for 20MW of solar curtailed at 12MW (40% curtailment and peak limited to 60% of installed power), the necessary energy is of 0.8x20=16MWh. The power needed is of 4MW.

The necessary energy required for the flexibility is summarized in the chart below:

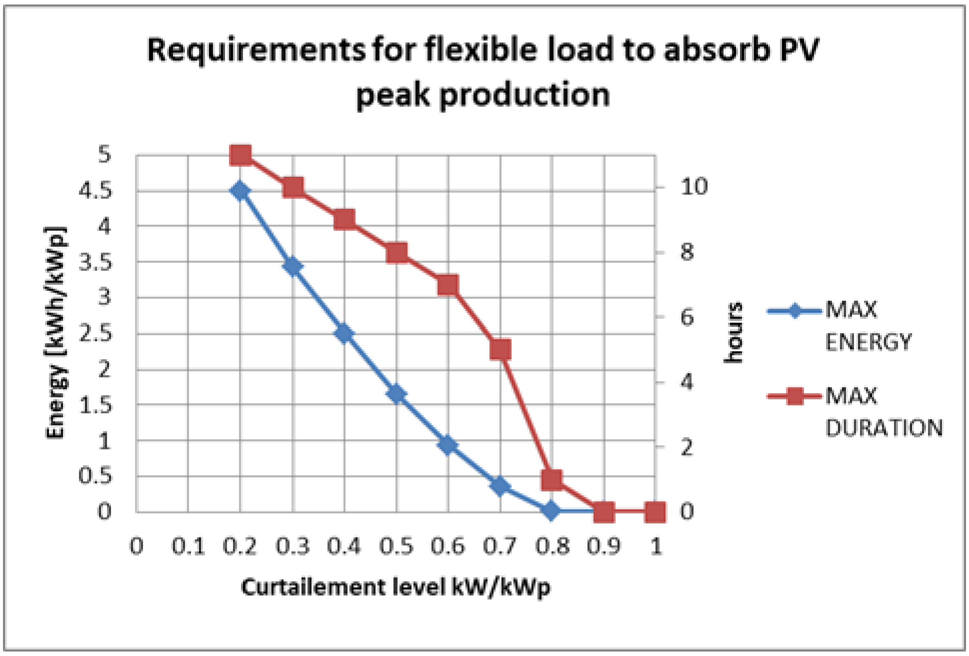

Figure 37: Requirements for flexible load to absorb PV peak production

A 50% curtailment would require 1.6kWh/kWp of energy and an 8-hour shift. Per example:

In 20 years, it is possible to expect 100MWp of installed PV. To absorb the peaks above 50MW (50%) would require about 30MW of power, 160MWh of energy and the capacity to shift it of 8h to cover the worst-case peak production of the year.

The values here can be used as rule of thumb to assess flexibility required in a grid to absorb solar peak power and avoid congestions.

PV Inverter control as a flexibility

The other way of seeing flexibility for this case is to consider a real curtailment: with remote control of PV inverters that are asked to reduce the power production on demand.

The graphics above shows the energy required for the worst day of the year (best production day).

On that day, the energy lost/not produced is also given by the same chart. Per example 100MWp of solar curtailed at 60MW of production requires 1kWh/kWh that means 100MWh of curtailment. If this energy is paid to the producer at a market price of 50€/MWh, it would cost 5000€ to avoid congestion with that method on that day.

For all the year, the graphic below gives the total energy to curtail in a year and the equivalent price with 50€/MWh:

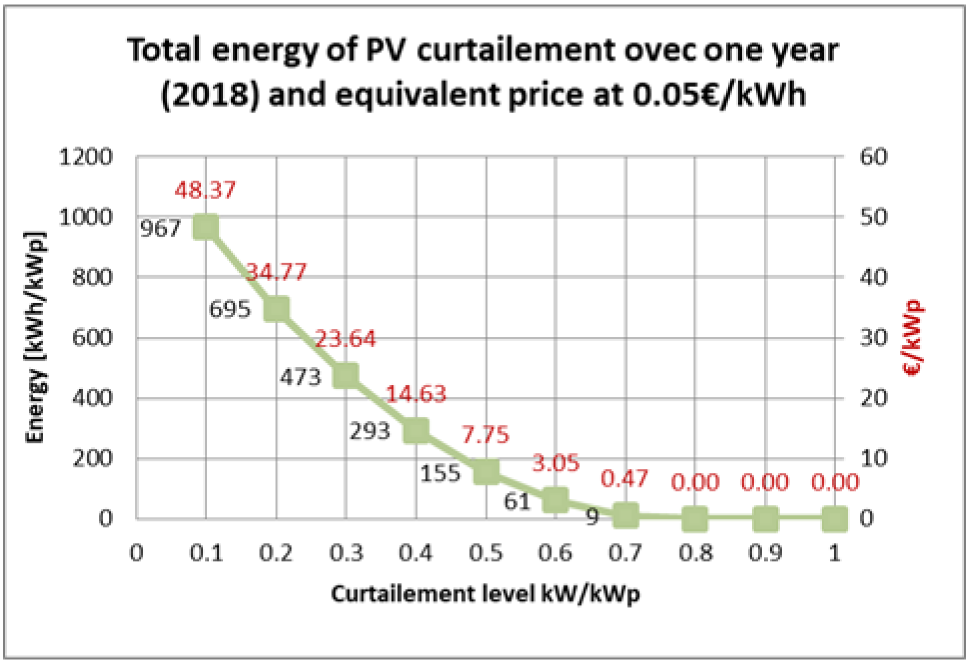

Figure 38: Total energy of PV curtailement over 2018

A curtailment at 50MW of 100MWp of solar induces an unproduced energy of 15,5 GWh/year and a value to be paid to the producer of 775'000€.

5.1.2 Local congestion

Before a general congestion, the increase of PV can already give local congestion today in sub network. The peak power will require reinforcement or smart grid solutions such as production curtailment or flexible loads to adapt consumption.

For example, below is a measurement of a line in a district where there is a small hydro and a large PV plant on a farm (negative power= excess production). A voltage increase up to a high level is observed, yet not out of the norms. EN50160 that tolerates +10%, which is 253V.

This was one of the first large PV plant on a farm in an end of line in a remote area. The impact of the PV production was not assessed properly, as this was new subject. Today the learning phase is over and this kind of cases do not happen anymore.

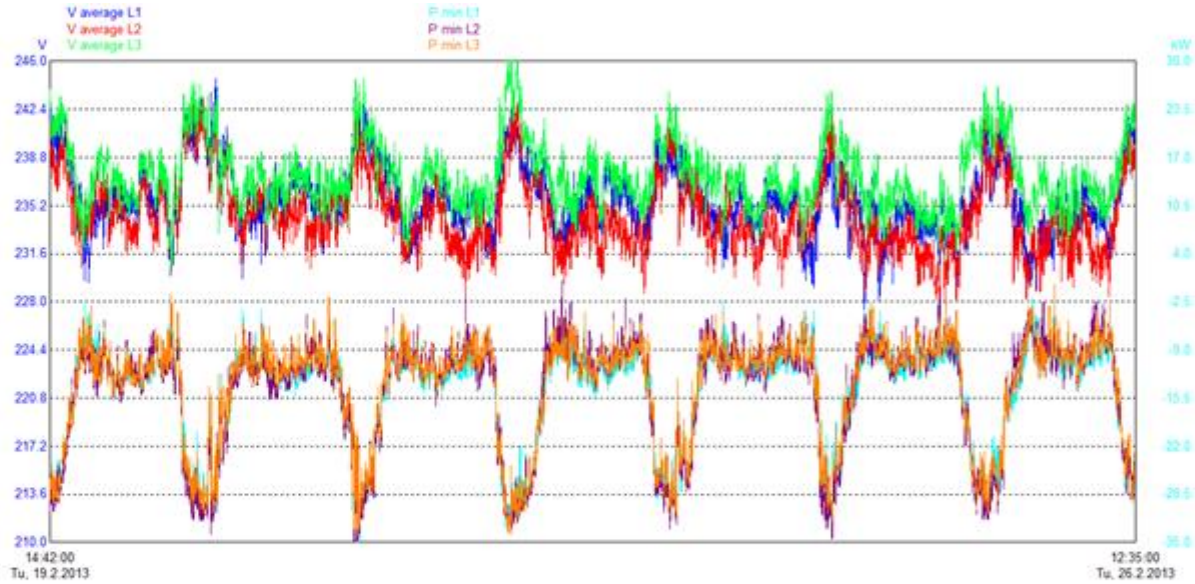

Figure 39: Real time measurements over a line with hydro and PV penetration

This case was solved with a rerouting of the lines in the feeder.

Addressing the peak power production congestion with flexibility could be a solution but it should be localized in the same feeder line, with adequate power/energy and the availability must be guaranteed. In the short term, the use of flexibility to fight local congestion is not accepted as there is no confidence in this kind of method and no proven track records, even on pilot installations.

5.2 Peak shaving

Peak demand has a general impact on the grid and on the sizing of elements: lines and transformers. However, it has also a direct impact on costs as the connection to the TSO (Swissgrid) is paid based on the peak power of the year.

The official prices: https://www.swissgrid.ch/en/home/customers/topics/tariffs.html

The price went up to 41’000CHF/MW in 2016 and 2017 and went down in the last years to 31’100 CHF/MW for 2019.

	2020[1]	2019[2]	2018[3]	2017[4]	2016[5]	2015[6]	2014[7]	2013[8]	2012[9]	2011[10]	2010[11]
Grid usage											
Working tariff [cents/kWh]	0.18	0.19	0.23	0.25	0.25	0.22	0.19	0.16	0.15	0.17	0.18
Power tariff [CHF/MW]	28,800	31,100	38,200	41,000	41,000	36,100	30,900	24,600	23,500	25,600	26,180
Fixed basic tariff per weighted exit point [CHF/AP p.a.]	269,400	288,000	365,300	387,700	387,700	336,300	285,500	235,400	225,000	248,800	254,620

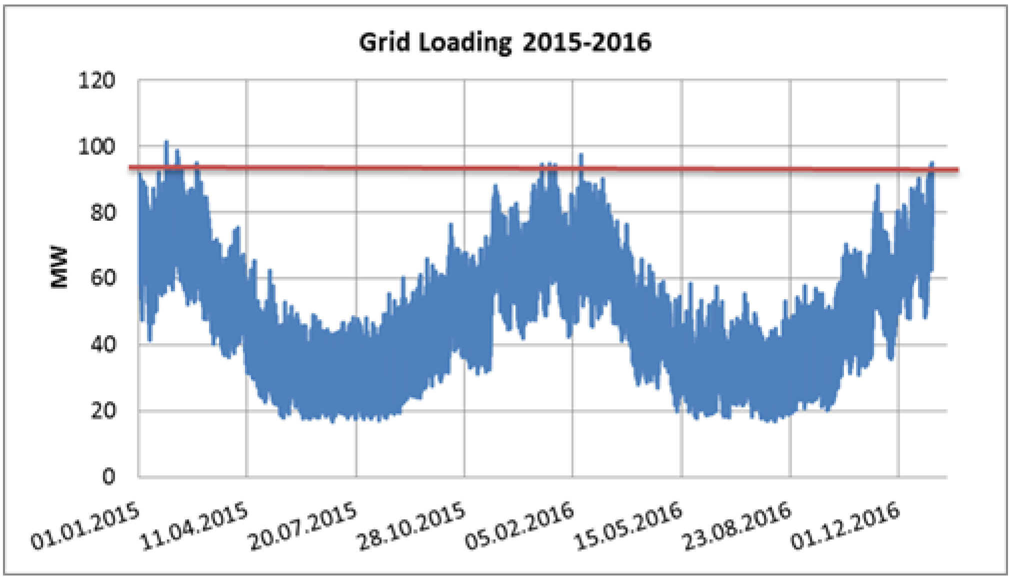

Figure 40: Grid loading over 2015-2016

The peak power happens very few times during the year. Therefore, there is a good potential of improvement. For this business case, the service requires a full availability and reliability. If one peaks having is missed, the business case is lost for the year.

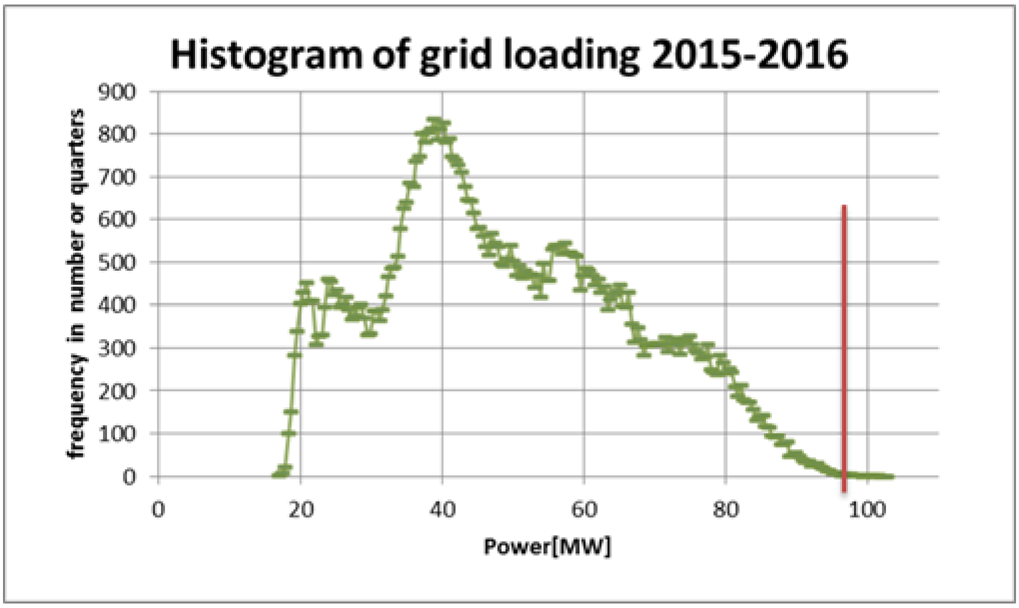

Figure 41: Histogram of grid loading over 15-16

The properties if the flexibility required is given here below with the simulation of 2 years of grid load.

The peak shaving is simulated, and the required power and energy is computed.

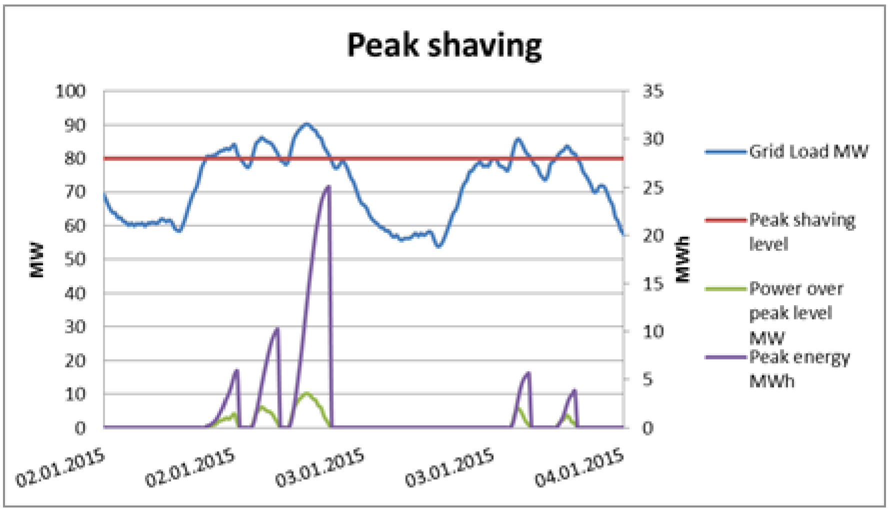

Figure 42: Peak shaving

From that simulation, we can see that a reduction of the peak down to 90MW requires only 4MW as the maximal peak is short, but with a lower level, the energy becomes important.

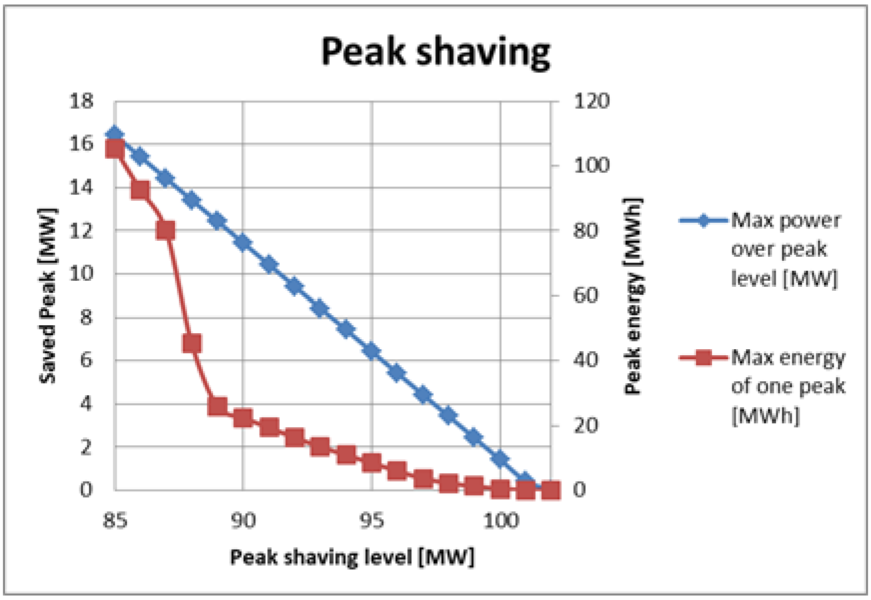

Figure 43: Peak shaving

A peak load over 101 MW happens only two times in two years, but peaks more than 96 MW happens 10 times.

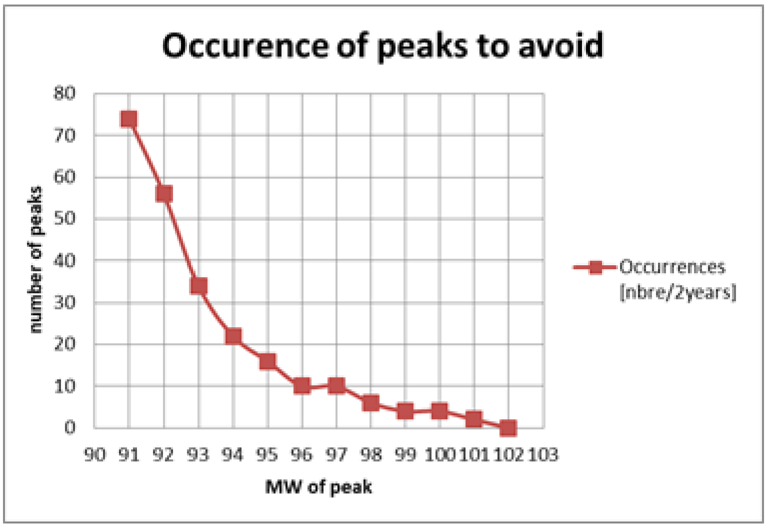

Figure 44: Occurrence of peaks to avoid

From the above simulation, the saved cost with a given power for flexibility is computed. To be able to perform the peak shaving, the flexible load must have a given energy to absorb the full peak.

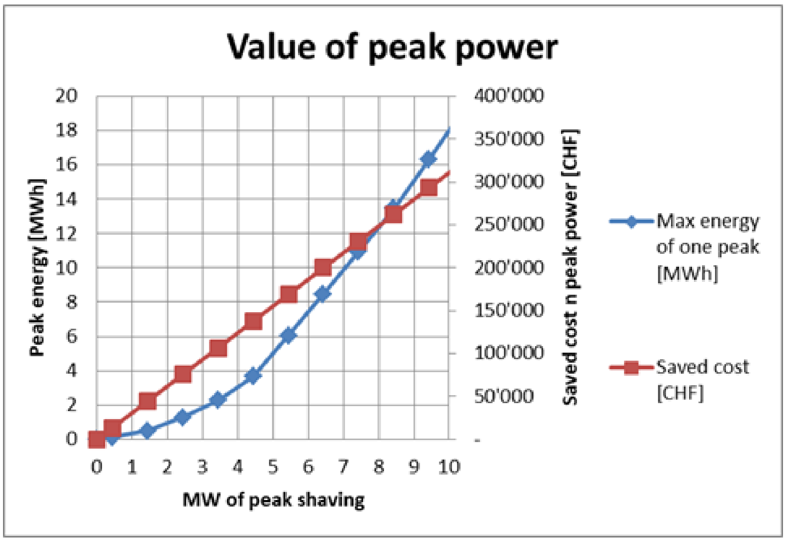

Figure 45: Value of peak power

For example, a battery of 5MW 5MWh could be used 10 times per year for that peak saving purpose and could save about 150kCHF per year. This is substantial and can be a very good complement to other business cases. However, for the time being, the flex gathered through the GOFLEX trial is not enough to reach the characteristics of the mentioned battery. More installations and a higher reliability would be needed.

5.3 Balance energy reduction

Estimated revenue from supplying/activating aggregating demand response for BRP

The potential revenue of flexibility for a BRP is in the avoided balance energy cost (buying at a higher price and selling at a lower price the difference between the grid forecast announced the day before and the real grid load)

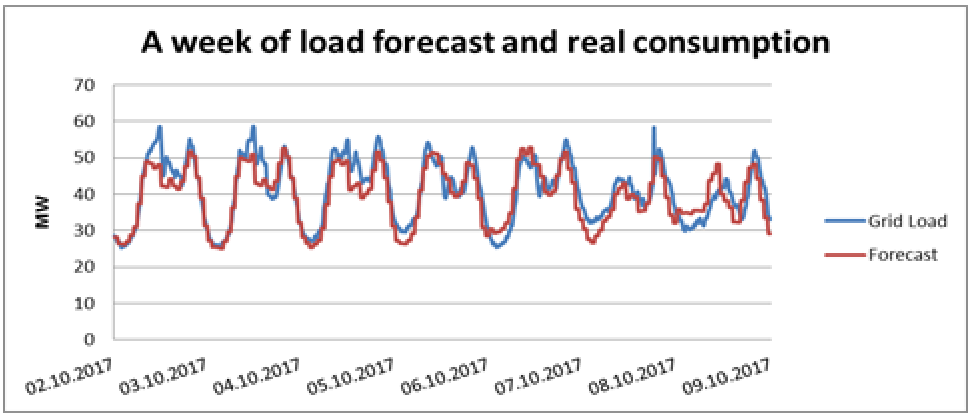

Figure 46: A week of load forecast and real consumption

The TSO publishes the prices for balance energy (for swiss TSO here[1]) The cost of balance energy is a function of spot price, secondary and tertiary power reserve prices. It is more of less 30% over the mean spot price.

[1]https://www.swissgrid.ch/en/home/customers/balance-groups.html

Balance group	short (deficit)	BGM pays $(A + P_1) * \alpha_1$
	long (surplus)	BGM receives $(B - P_2) * \alpha_2$

$A = \max. (P_{spot}; P_{sek+}; P_{ter+})$ $B = \min. (P_{spot}; P_{sek-}; P_{ter-})$

With alpha factors as following	α_1	1.1
	α_2	0.9
With base price as following	P_1	1 ct/kWh
	P_2	0.5 ct/kWh

Figure 47: Prices for balancing energy

Over the last years, the mean price of balance energy was:

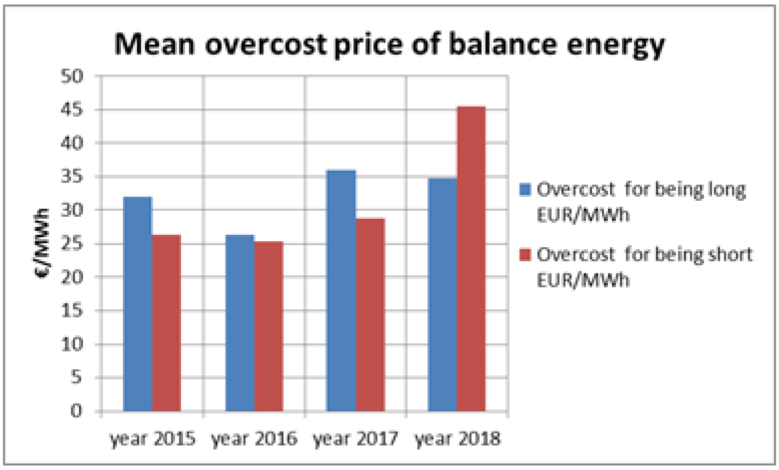

Figure 48: Mean over cost price of balance energy

Simulating the past years with the known forecast errors and the balance energy price, it is possible to assess the total potential of the correction of balance energy with flexibility.

	forecast error long [MWh]	forecast error short [MWh]	ESR would receive for long with swissgrid price [EUR]	ESR would pay for short with swissgrid price [EUR]	penality/overcost for being long compared ot exact predictions	penality for being short compared ot exact predictions	total penality [EUR]	Estimated 40% penality because of prediction error [EUR]	Overcost for being long EUR/MWh	Overcost for being short EUR/MWh	Sub BRP 40% Overcost for being long EUR/MWh	Sub BRP 40% Overcost for being short EUR/MWh
year 2015	9'360	15'334	91'996	1'059'015	300'163	403'201	703'364	281'345	32.1	26.3	12.8	10.5
year 2016	6'892	19'886	90'948	1'272'300	181'030	504'005	685'035	274'014	26.3	25.3	10.5	10.1
year 2017	9'413	19'865	148'854	1'479'753	339'115	571'284	910'399	364'160	36.0	28.8	14.4	11.5
year 2018	9'191	14'064	132'840	1'400'949	319'507	640'830	960'337	384'135	34.8	45.6	13.9	18.2

Figure 49: Overview of penalties paid by ESR from 2015 to 2018

ESR doesn't have its own balance group, but is a sub-balance group in a balance group. Its forecast error can be compensated within the group and with PSA (post scheduling adjustment). That makes a gain of about 40% on the final bill. If ESR would be alone in its balance group, the bill would be with a mean at 31.9€/MWh over the last four years.

As a first estimation, the mean value of BRP cost is at **12.8€/MWh**. So all the avoided cost with flexibility can be computed from that KPI for the ESR case.

5.3.1 Potential with a given power

Analyzing the historical data (of 2016 here below), the distribution of required balance energy can be computed.

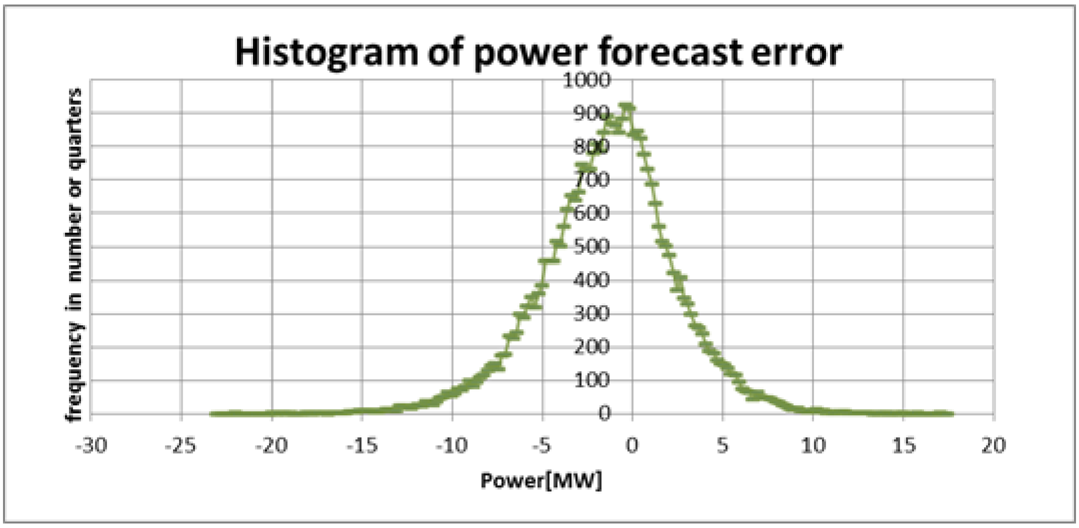

Figure 50: Histogram of power forecast error

The MAPE of the prediction was of 6.20%.

During that year, 28881 quarters have a prediction error between -5 and 5MW (82%). That means an ideal 5MW flexibility could reduce to 0MW 82% of the errors of the year (total 35040 quarters). The MAPE is reduced to 0.89%.

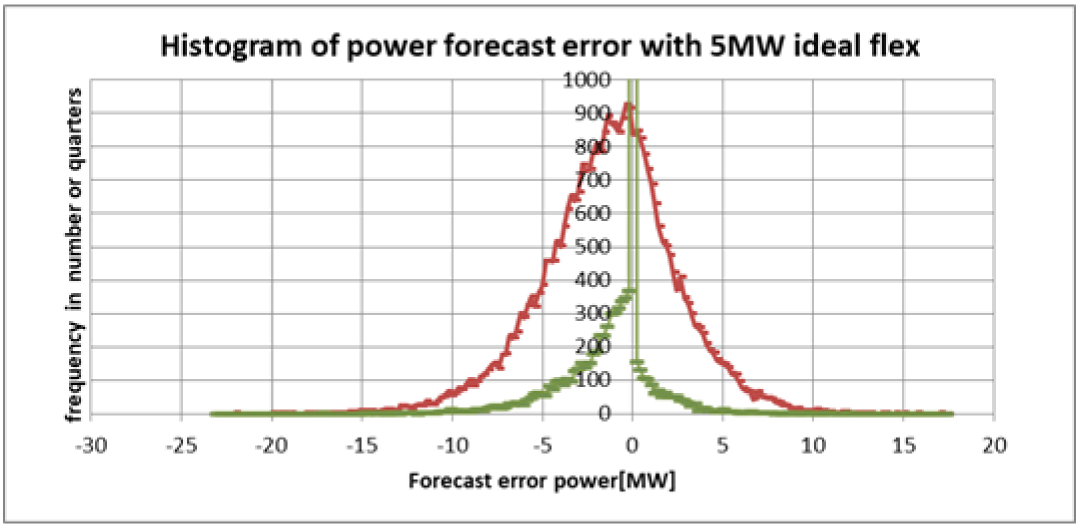

Figure 51: Histogram of power forecast error with 5 MW ideal flex

In term of saved balanced energy this must be weighted, as a quarter with 1MW of error does not cost the same has a quarter with 12MW of error.

There is a total of 26’778 MWh balance energy and, with corrections, there is 3’849 MWh of error left. The difference is 22’929 MWh corresponding to 293’491€ of balance energy cost saved at mean cost of 12.8€/MWh.

5.3.2 Potential with a given power and limited energy

The calculation above is with an ideal flexibility. Considering a limited capacity of flexibility in terms of energy, the residual error looks very differently. With 5MW and 5MWh of flexibility, a constant 3MW of error over 3 hours cannot be fully suppressed.

To assess the gain in this case, a simulation is performed, as we had an ideal battery with a limited power and a limited energy.

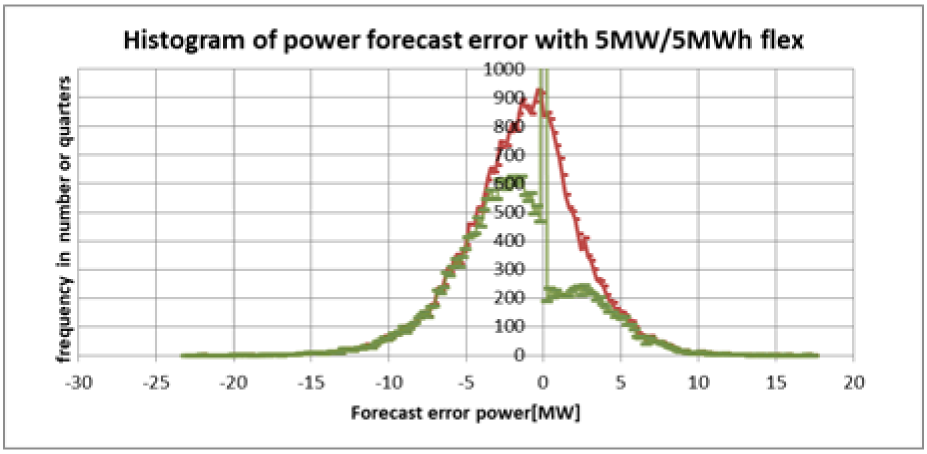

Figure 52: Histogram of power forecast error with 5 MW/5MWh

With 5MW and 5MWh the MAPE is reduced to 5.31%. The total error is reduced of 3'863 MWh, corresponding to savings of 19'778 €. The difference is great with the previous case and this is explained with the “battery” being very often full or empty.

The analysis of left imbalance in function of power and energy is given with the chart below

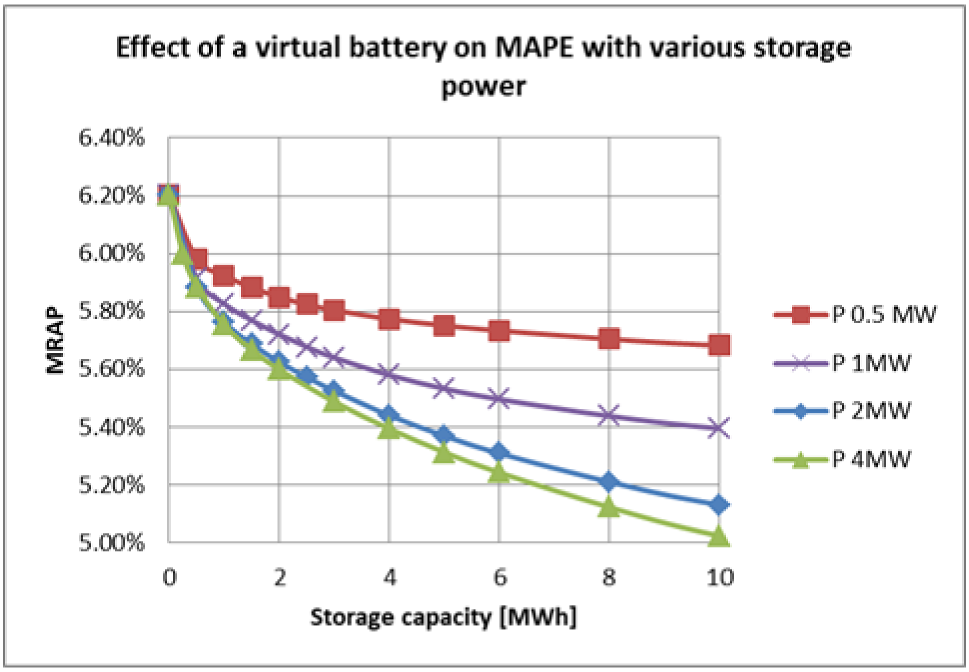

Figure 53: Effect of a virtual battery on MAPE with various storage power

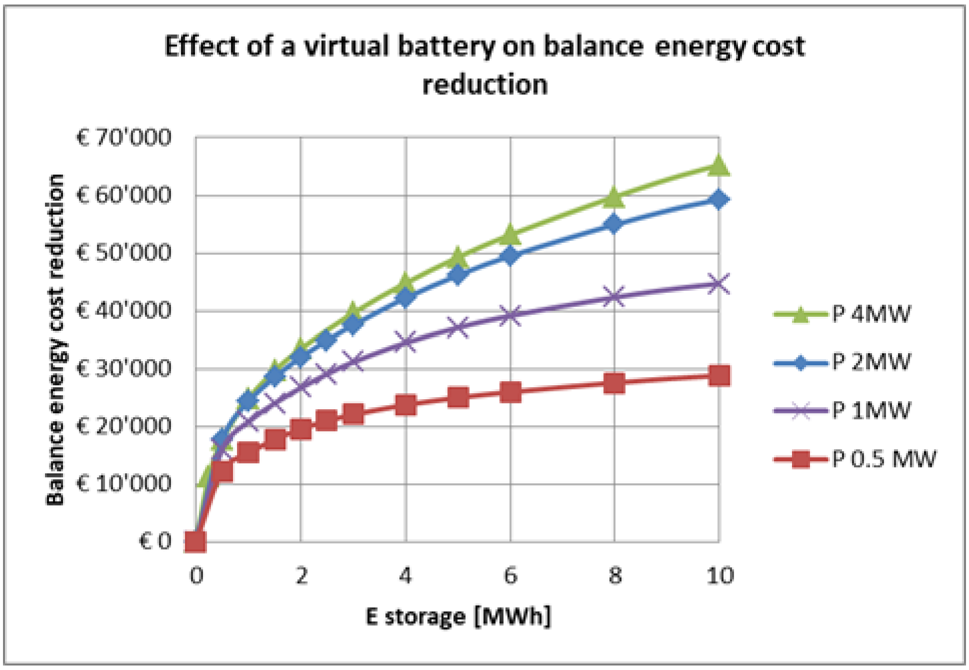

Figure 54: Effect of a virtual battery on balance energy cost reduction

A third dimension should be integrated within this analysis to have the full picture of the effect of flexibility. It is the time shift capacity. Per example a water heater in function can be stopped, but it cannot be halted for a long time else the end-user will have cold water. The duration of the error is analyzed counting the duration of an error. An error duration is the time spend with the same sign of forecast error.

There are 4980 errors in 2016. 74% of errors are less than 60 minutes (3852 errors)

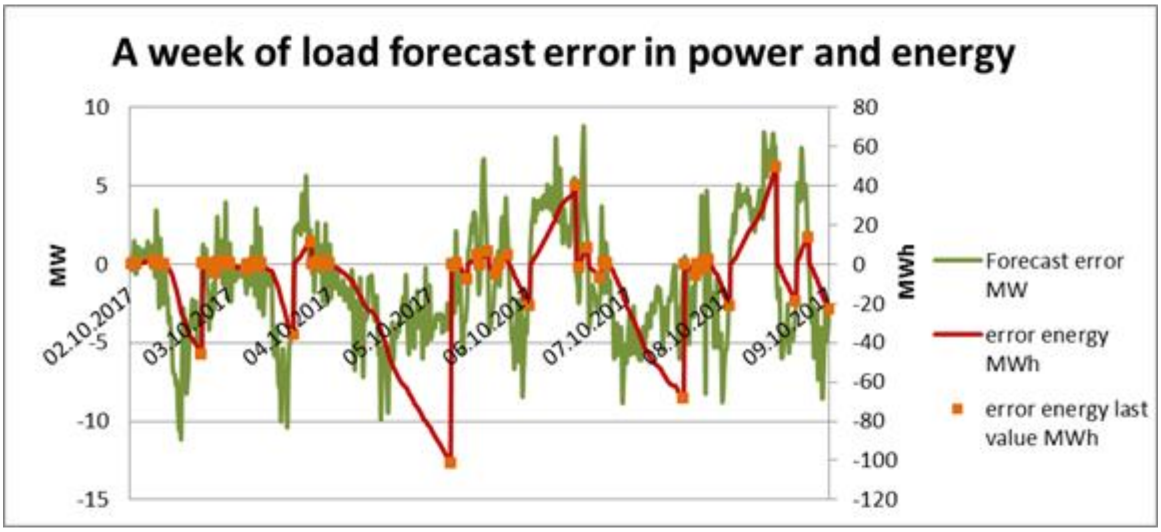

Figure 55: A week of load forecast error in power and energy

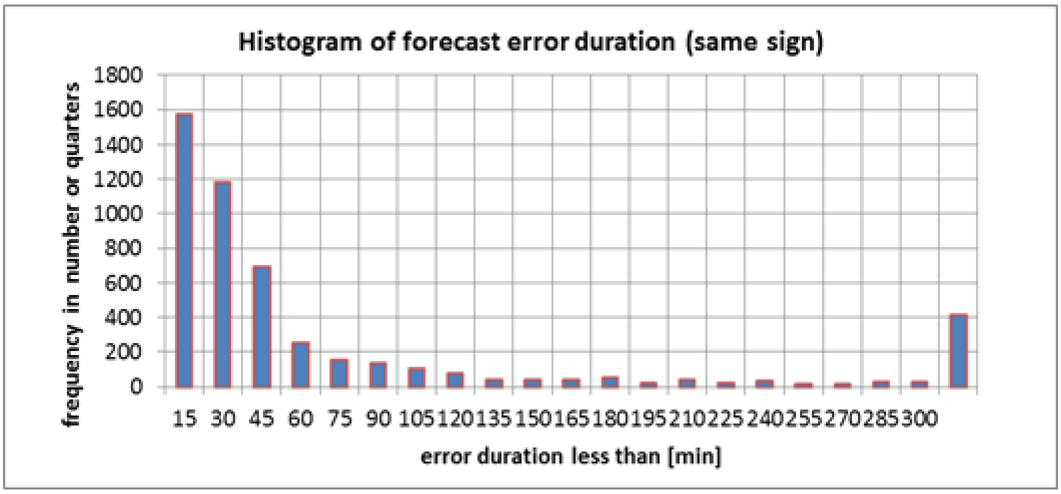

Figure 56: Histogram of forecast error duration

Errors less than 2MWh represent 7.8% of imbalance energy. Errors less than 5MWh represent 13.0%.

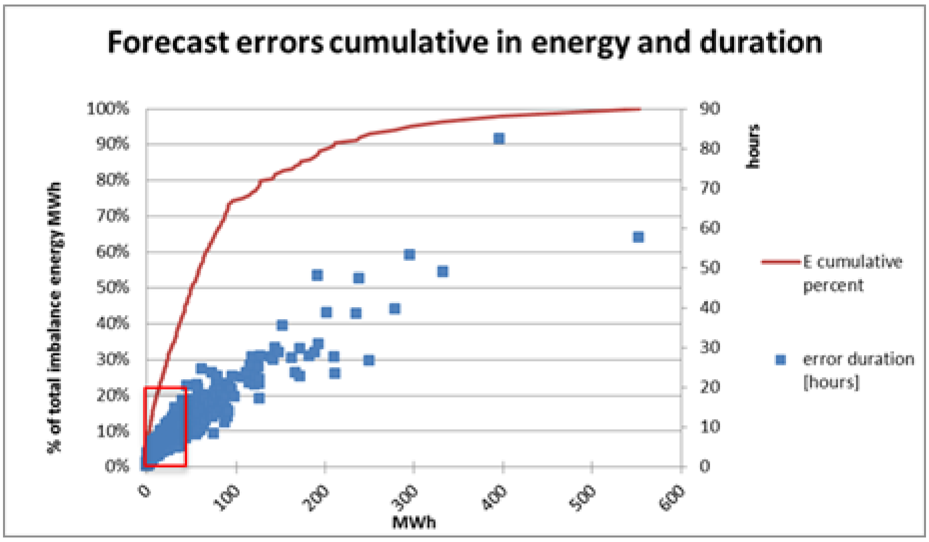

Figure 57: Forecast errors cumulative in energy and duration

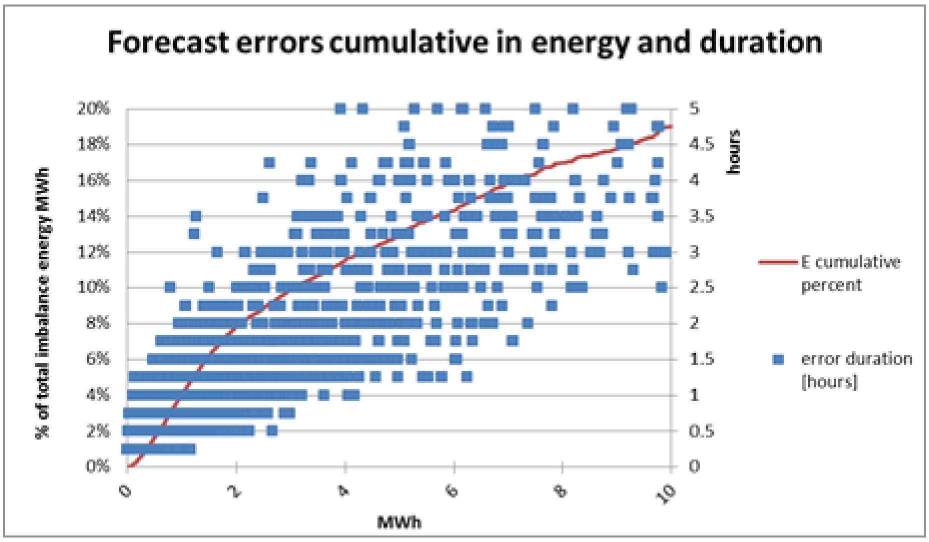

Figure 58: Forecast errors cumulative in energy and duration

Even if the error is small in term of power, per example forecast is just 1MW under the real power but during 1 full day of 24h. This would be very hard to suppress with flexibility.

From this analysis, it is possible to conclude that today, to have a real impact on cost, the GOFLEX project should be coupled with other method, such as market access, because there are very long errors and they represent a substantial part of the corrective energy.

5.3.3 Conclusions/summary on BRP business case

- Mean imbalance price is 12.8 €/MWh for ESR.
- Properties of flexibility needs to compensate balance energy are described.
- +/-5MW of DSM power is sufficient for the majority of cases (82%).

- There are a lot of short term errors (74% less than 1 hour)
- BUT: short term energy errors represent little imbalance energy at the end of the year (on the bill)
- Need to shift loads of 4hours to decrease bill by 40%.
- To explore: coupling with intraday/PSA taking into account the DSM capacity: reduce errors to 2 hours

5.4 Flex offer to tertiary market

The last business case is based on the opportunity to sell flex to tertiary market managed by Swissgrid in Switzerland. This case is currently under investigation. The prequalification in order to be eligible in this market is really complex. The flex offer must be at least at 5MW :

- This requires a high number of DC or factory
- Quality and reliability must be really high
- The provider must be capable of providing the entire amount of tertiary control power offered upon request from Swissgrid. Requests are for full bids i.e. it is not possible to request parts of bids

We will still need to investigate this subject but for the time being and with the actual quality of Flex Offer from the GOFLEX trial, we do not see tertiary market as the first and easiest revenue source to address.

5.5 Cost Analysis

In the previous chapters, we analyzed the potential revenue streams. In order to be complete, we also need to assess the cost associated with installation and acquisition cost. In this chapter we will focus only on the installation cost for a specific customer (metering, IOT, telecom). We are not taking into account the IT infrastructure cost (server, license ...)

Average cost per customer (statistics from GOFLEX installation)

- Communication: 500CHF (optical fiber)
- Electrical installation: 400 CHF (fibro-modem and meter)
- IOT (HES-SO): 600 CHF (material) + 250 CHF (manpower)
- TOTAL: 1750 CHF / customer

Optical fiber represents an important cost. In the long term we can assume that this cost will not only be supported by the Flex. We can therefore adjust the cost per customer at 1400 CHF.

Without taking real foreseen revenues into account, we can try to determine for a high-level estimation what would be the required revenues per kWh to cover the cost

- Potential flex per customer: 2kW during 1h, 300 times per year for 10 years

  $\rightarrow$ 6000 kWh
- 1400 CHF / 6000 kWh = 0.23 CHF/kWh

Thus, the minimal revue per kWh should be 0.23 CHF. This number is really high. We clearly need to industrialize the installation process to decrease the cost and to look for other services that could be propose to customer in order to increase the revenues.

6 Conclusions

In this report, we conducted a detailed reporting of the results of the Swiss demonstration site of the GOFLEX project. We described the Swiss Pilot deployment phase, maintenance and monitoring. It is important to mention that although all the challenges that were faced in installing and maintaining the solution, there was very little to almost no complaints from clients, meaning that it did not at any time alter their comfort.

The prosumers experience was analyzed throughout a survey which was conducted over DC clients. It allowed a better understanding of their interactions with the system.

This document also reported the project's Key Performance Indicators (KPIs), which showed to what extent the initial targets were achieved.

A detailed Cost Benefit Analysis (CBA) was conducted to show the impact of the system on ESR's savings over the course of the project compared to before.

Throughout this final report, we came to the conclusion that the GOFLEX solution is not yet ready to be rollout in production. Some elements that need to be improved in order to do so are:

- Solution quality and stability
- DC installations: sensor and stability issues
- Flex offer reliability
- Offered flexibility quantity is currently not big enough compared to the flexibility resources that ESR is having with the hydropower dam.
- Costs of installation for DC and other solutions is still high compared to actual potential revenues
- In terms of product definition, rewarding end customer for the flex they are offering is not obvious. We are currently looking at possibility to offer other services on top of flexibility

However, we are still convinced that flexibility and the concept aggregator role are key elements for the evolution of the role of the DSO. ESR will therefore continue to move forward on this topic and capitalize on all the achieved results and harvested field experience during the GOFLEX project.

In the next couple of years, we will particularly focus on two projects combining bottom-up and top-down approach.

- domOS: a horizon 2020 project that aims at developing tools and solutions towards smart buildings and smart districts.
- GBFlex: a marketplace for flex management at BRP level (Swiss Project sponsored by OFEN - Swiss Federal Office of energy - together with a hydropower producer.

All the experience and the development made in the GOFLEX project will be very valuable in the future for our company and to enable an increased deployment of PV in Switzerland, without having to increase drastically in storage capacity and grid reinforcement.