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

Report on Demonstration Results Evaluation – Use Case 3

February 2020

Imprint

Contractual Date of Delivery to the EC: **28 February 2020**
Actual Date of Delivery to the EC: **28 February 2020**

Author(s): **Gerhard Meindl (SWW), Sebastian Auer (SWW)**
Participant(s): **Andreas Lucas (SWW)**
Markus Hausmann (SWW)
Reviewer(s): **yousra.sidqi@hevs.ch, gregoire.largey@oiken.ch**

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

Work package: **WP9**
Confidentiality: Public
Version: 2.0

Contact: **Gerhard Meindl – g.meindl@s-w-w.com**
Sebastian Auer – s.auer@s-w-w.com
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 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.

Copyright

Executive Summary

This document summarizes the achievements in the German demo case over the last 40 months.
It consists of

- a description of the technical approach and the original business assumptions
- the DSO experiences during installation, acquisition of customers and operation of the new solution
- the prosumer experiences during installation and operation of the new solution
- the technical performance and the ways of evaluation
- a cost benefit analysis of the business model based on the findings and the SWW business data of 2018
- the description of the next steps in the operational and R&D planning of SWW

Document History

Version	Date	Status	Author	Comment
1.1	24.01.20	draft	G.Meindl	first version
1.2	27.01.20	draft	A.Lucas	Input Cap. 2/3
1.3	26.01.20	draft	S.Auer	Input Cap. 2/3/4
1.4	27.01.20	draft	S.Auer	Input KPI´s
1.5	28.01.20	draft	S.Auer	documents consolidated
1.6	30.01.20	draft	S.Auer	Input KPI´s
1.7	10.02.20	draft	G.Meindl	Input review
1.8	23.02.20	draft	S.Auer	Input review
1.9	26.02.20	draft	G.Meindl	Input KPI´s/CEMS
2.0	27.02.20	draft	S.Auer	consolidation

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Abbre-viation	Definition
ATP	automatic trading platform
BRP	Brutto regional product
CA	Consortium Agreement
CDEMS	Charging/Discharging Energy Management System
CEMS	Charging Energy Management System
DOMS	Distribution Observability and Management System
DSO	Distribution system operator
EEG	Renewable energy law
EMS	Energy Management System
FEMS	Factory Energy Management System
FMAN	Flexibility Manager
FMAR	Flexibility Market
FOA	FlexOffer Agent
GA	Grant Agreement
HEMS	Home Energy Management System
KPI	Key performance indicator
MAPE	Mean absolute percentage
RCCB	Residual Current operated Circuit-Breaker
SP	Service Platform
SWW	Stadtwerke Wunsiedel GmbH
TAP	Technical Connection Conditions

1 Introduction

1.1 Purpose

This document gives an overlook on the experiences and findings in the GOFLEX project in the SWW demo case covered in work package 9 – Report on Demonstration Results Evaluation – Use Case 3 after 39 months (November 2016 – January 2020). It provides the reader with SWW´s general findings when aggregating flexibility, the different Business Models and the possible prizes together with the achieved Key Performance Indicators (KPIs) related to the SWW pilot, details about the Cost-Benefit Analysis approach for each category of prosumers and details about the variety of SWWs next steps.

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.

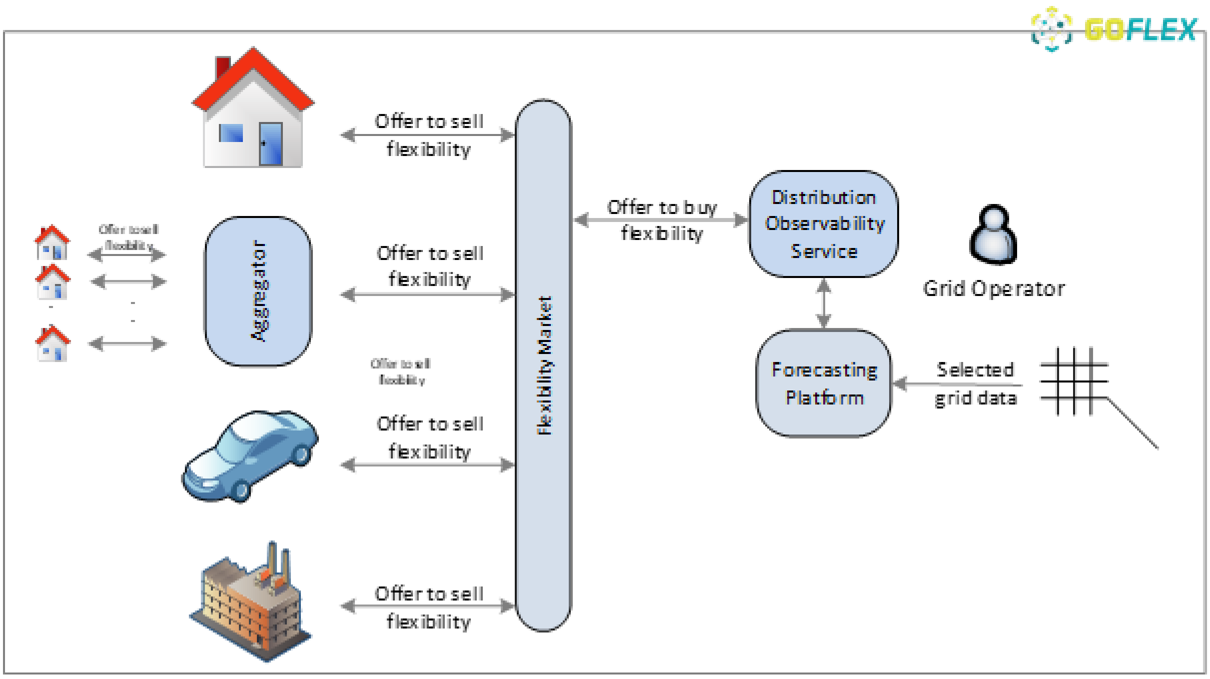


Figure 1: Illustration of GOFLEX Concept

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 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.

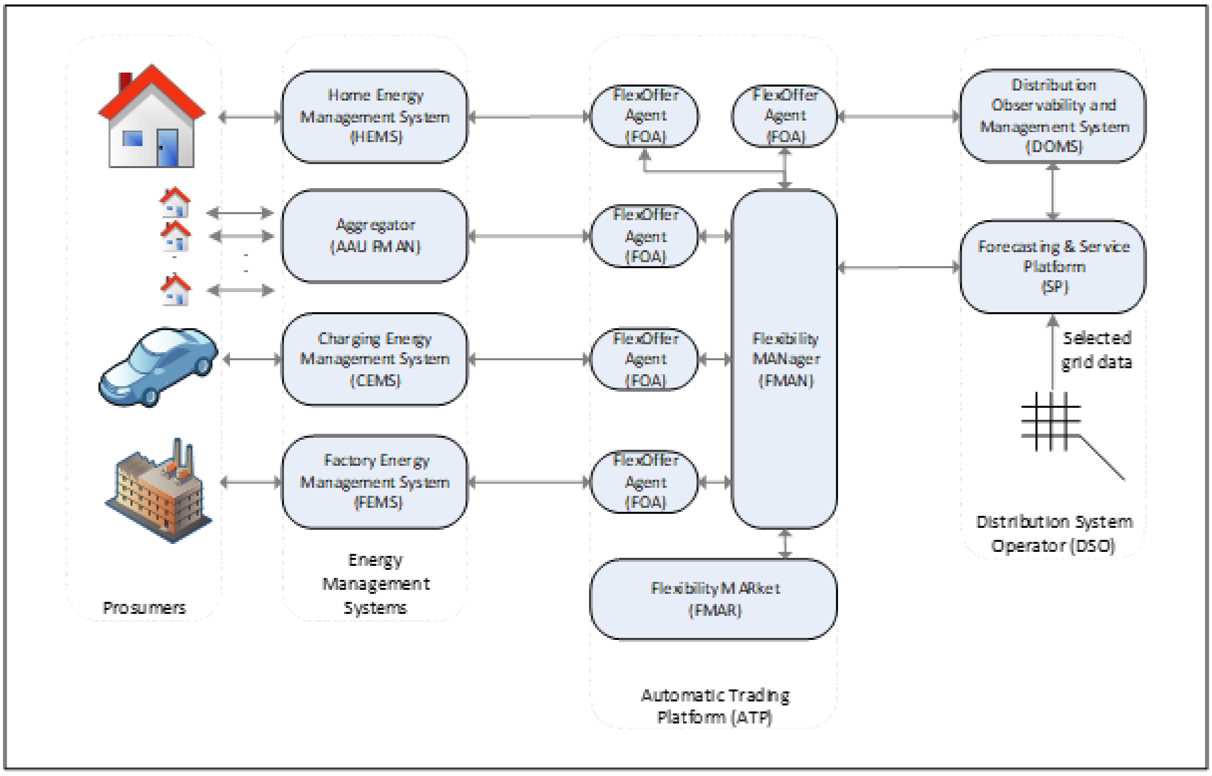


Figure 2: GOFLEX System Components

1.3 Related Documents

This document is related to similar deliverables of other WPs. It is also directly linked to all deliverables of WP9 (D9.1, D9.2, D9.3).

1.4 Business Summary for Use Case SWW

In the beginning of the project the actual status of SWW in terms of market roll, players to be integrated, responsibilities to be fulfilled and regulatory boundaries to be obeyed were summarized in graphical models. After this the possible steps for changing market rolls by taking over more responsibilities, e,g, full-BRP and aggregator of local flexibility potentials, were analysed and shown in D9.1. The following graphic shows the starting point of SWW.

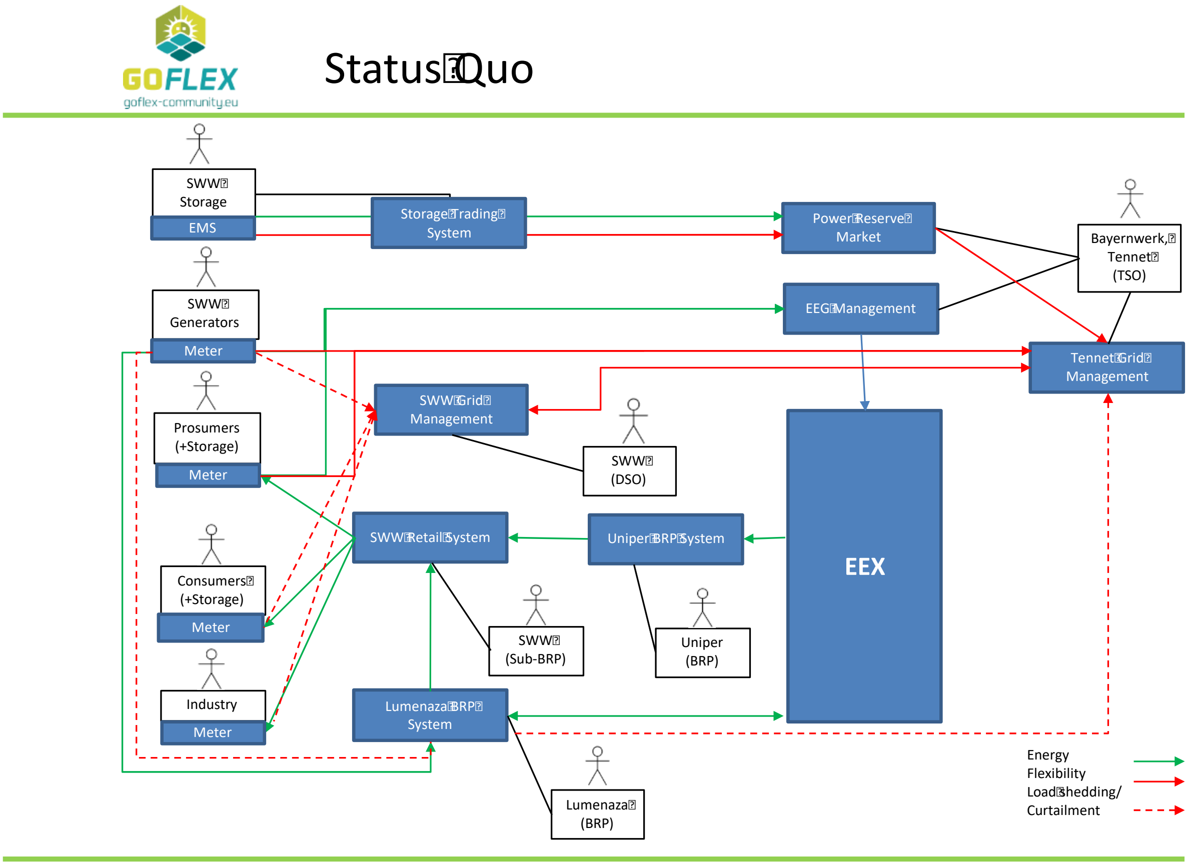


Figure 3: Status Quo

During the project period all necessary steps to reach step 1 (initial) were undertaken:

- Integration of (local) GOFLEX aggregator in SWW
- bundles all local (Non-EEG)-Prosumers involved in the project
- enters market through Storage trading. All other actors and business processes remain the same
- the DSO uses the GOFLEX Aggregation Management System to aggregate flexibility.

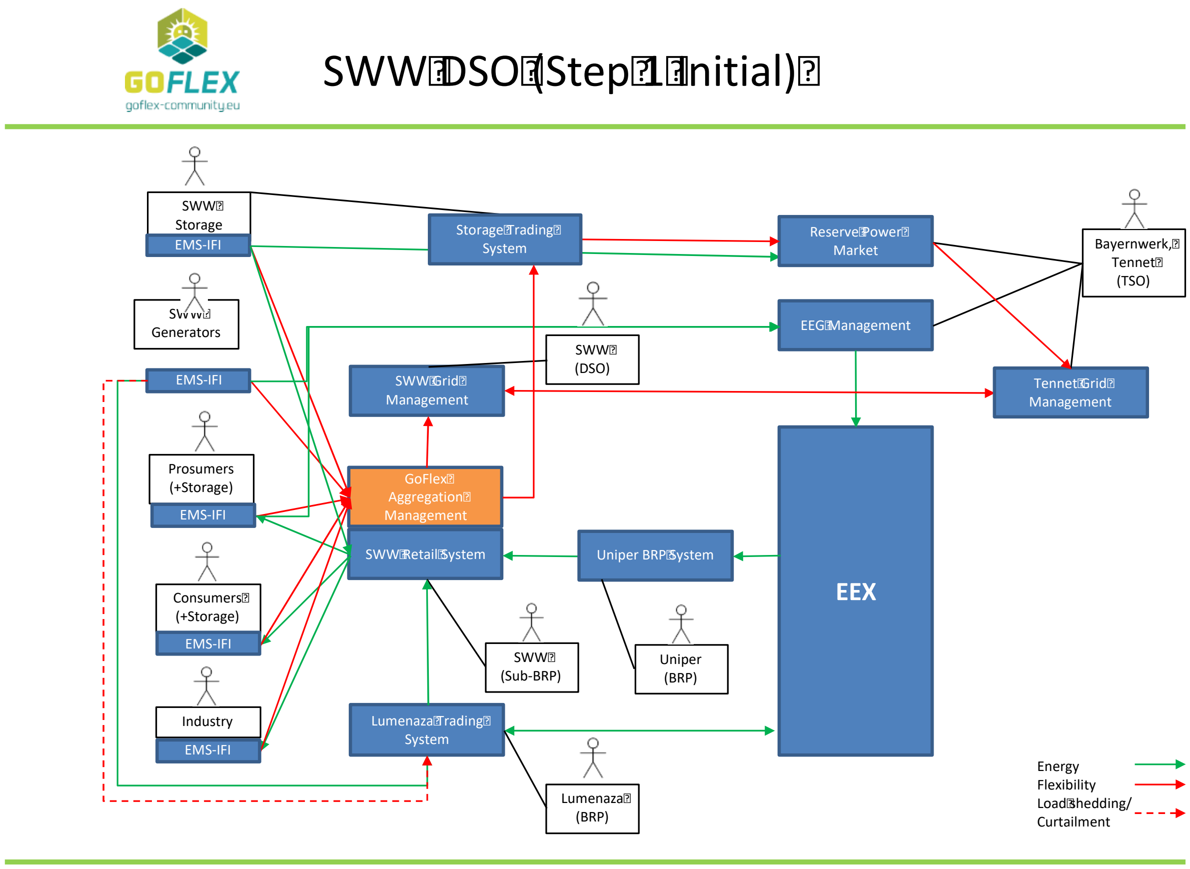


Figure 4: SWW DSO

1.5 Document Structure

This document presents the D9.4 deliverables of WP9: Report on Demonstration Results Evaluation – Use Case 3 [month 36]

Section 1 follows this introduction and presents the GOFLEX Systematic Framework Conditions. This includes a description of Use Case 3 and the related documents.

Section 2 describes the DSO experience during installation and operation of equipment and system as well as the experience when dealing with customers.

Section 3 presents the prosumers view during the installation and operation of equipment and system as well as their general comments on flexibility trading.

Section 4 presents the technical performance of the system in the use case 3 including scale of installation, detailed performance evaluation, trackable and non-trackable performance indicators and a summary.

Section 5 presents the Cost-Benefit Analysis approach for the different services to be implemented, starting with an overview of the initial assumptions and calculation, followed by the actual status as of today, the possible achievements out of the project for the different types of GOFLEX participants, a description of the period of extended observation and additional follow-up actions planed in SWW for the coming five years.

Finally, Section 6 with a short conclusion.

2 DSO Experience

This section deals with the experiences of SWW with the partners and their respective technologies while setting up the platform, the system and the components in the field.

2.1 Installation and Implementation of equipment and system

2.1.1 Home Energy Management Systems

Space requirement for components:

For most applications, additional distributors had to be installed to house the components. For some users, the distribution had to be rewired accordingly in order to free up sufficient space. In houses where the meter cabinets are distributed over several floors, a spatial separation between measurement and receiving devices must be overcome, as it was possible to use existing control lines.

Figure 5: existing electrical sub-distribution on floor

Figure 6: equipped central control box with Goflex components

Figure 7: Z-Counter - Control cable connected

For users with electrical systems older than 30 years, installation is technically not possible.

Figure 8: Old meter distribution

Lan Connection complex:

In most cases, it is not possible to connect to an Internet connection via a network cable because the meter distributions and sub-distributions are not always located near a router. Alternatively, we have created the Internet connection via W-Lan Repeater and Fritzbox or with D-Lan systems. Both systems cannot be operated completely without interruption.

After power failures in the power supply system, the components have different reboot times, so that the home linker does not log on to the network properly and must be reset again.

Figure 9: D-Lan with 2x Ethernet

Figure 10: W-Lan connection

2.1.2 Factory energy management systems

Selection of investments difficult:

Systems which were considered in the first step were not considered for installation on closer inspection, as various factors preclude their use. Also, there are applications of other companies, which exclude a pure GOFLEX benefit.

Figure 11: Other user of the system

Integration of the components sometimes difficult:

Integrating instrument transformers into different systems is often difficult due to limited space, but usually a simple solution to measure large currents reliably. For measurements with correspondingly high-quality meter equipment, meter pulses can also be tapped. Different measuring methods are mandatory.

Figure 12: Measuring device with fibre optic relay

Figure 13: Instrument transformers

Figure 14: Top hat rail counter

2.1.3 Direct Control NoHems (Inea)

Size uncomfortable => practical 3-point mounting

For the previous system (ripple control receiver), which is used in Germany, there is an empty space in the meter cabinet for 3-point mounting according to the Technical Connection Conditions (TAB).
The control cabinets used are unsuitable for this purpose, as they are very difficult to integrate into the customer's plant.

Figure 15: Plant before installation

Figure 16: Plant with NoHems

Complex installation for top hat rail meters:

The installation of DIN rail meters for direct measurement of electrical energy in existing systems is sometimes only possible with increased wiring effort. Often the right space had to be created for the installation.

2.1.4 Direct Control NoHEMS (AAU)

Installation and platform:

The installation and integration into the Casa App, as well as the login to the platform is after some practice a simple task.

Figure 17: Washing machine with smart plug

2.1.5 Charging Energy Management System

Registration of the charging stations in the software:
The login of the stations, which should be included in the same network, only worked after changing the Mac address of the devices, because this was identical for both devices.

The installation of the charging stations and the necessary power and communication cables could be carried out easily.

An additional RCCB installed in the building's distribution cabinet where from the charging stations are fed is not necessary because the stations are equipped with a suitable RCCB.

Figure 18: Charging infrastructure SWW

2.2 Operation of equipment and system

2.2.1 Home energy Management Systems

Determination of the components / reason for use/user group:

At the beginning of the project it was not clear from the documents for what purpose the components were to be used, which plants were to be integrated and how.
Descriptions to the components were not available or only in English.
In a workshop a circle of users was sought who were willing to have the components installed in their homes.

2.2.2 Factory energy Management Systems

Partial data connection only possible via GPRS:

Plants, which are far away from the normal infrastructure had to be supplied via GPRS connection, such are mainly water supply plants.
There is no need to lay cables for Lan cabel, card contracts for data transmission are inexpensive.

Additional system monitoring or evaluations:

It is also advantageous for the energy supplier or for the user of the plant to monitor the plant additionally. In this case, the possibilities of an alarm system in case of different events should be considered.

2.2.3 Direct Control NoHems (Inea)

Wlan, Lan, Router sometimes not available:

The majority of users are over 60 years of age and do not have an Internet connection and therefore no routers are available in these households.

2.2.4 Direct Control NoHEMS (AAU)

Compatibility with older tablets or mobile phones difficult:

Unfortunately, the app for Casa could not be installed on the outdated systems of the first few (older) volunteers. Mostly it was due to the lack of memory on the mobile phones or the old OS.

2.2.5 Charging Energy Management System

The majority of users did not use the Etrel "website" (mobile app) installed on their mobile phones to insert the necessary input data (departure time) before charging and thus enable the CEMS to calculate flexibility parameters an communicate flexibility offers to GOFLEX FMAN. The charging process was mostly initiated by Etrel Charging Card (RFID), but this was changed in the last period of demonstration.

Due to mentioned obstacle (necessity of using mobile app for identification instead of RFID card) and also other issues that affected a proper operation of the system the number of flexibility offers communicated to FMAR was quite low compared to all executed charging sessions, as well as the number of received flexibility activation requests received from FMAR. The low number of flexibility activation requests is due also to the fact that the EV charging is not a continuous process, with a permanently present load (as is the case with other xEMSs). At each prosumer (or charging station) the actual charging occurs only during few hours of the day; if during these short periods the grid operation is not endangered or the flexibility activation is not required due to any other reason, the EV charging flexibility remains “unexploited” (i.e. the flexibility activation is not triggered by FMAR).

2.3 Customers and Contracts

2.3.1 Factory Energy Management Systems

Compact design of the control cabinets is an advantage, as FEMS components are installed centrally and isolated from the plant. Industrial customers are usually used to the fact that equipment installations require a lot of space.

2.3.2 Direct Control NoHems (Inea)

Separate control and evaluation of devices or groups:

the data supplied is used for the evaluation of consumption behaviour, but also for error detection and even for troubleshooting.
Essential advantage is the individual control of the systems compared to the old (ripple control receiver) system.

3 Prosumer Experience

In section 3 all experience with consumers, prosumers and involved stakeholders are shown. Additionally, the outcomes and findings of the survey study will be published.

3.1 Installation of components and subsystems

3.1.1 Home Energy Management System

The relationship between generation and consumption is clearly visible in the HIQ software. The additional functions such as temperature displays are often used. A continuation of expandability and usability was addressed. Some users had to rewire the distribution system to free up space, which is a safety improvement for the systems. The private customer is often surprised that the components have a large space requirement.
Due to extensive information and high understanding of the customers, no contracts were concluded for Hems.
Compensation for losses of EEN-production was not demanded.

3.1.2 Factory Energy Management System

Lack of understanding, why are EEG supported plants switched off:

Plant managers in the energy sector question a shutdown of an EEG-supported plant by GOFLEX, because the plant can only earn money if it is not disconnected from the grid at maximum solar radiation.
The benefits of research and development are questioned.

3.1.3 Direct Control NoHEMS (inea)

Removing the functioning ripple control receivers and the possibility of no longer being able to reduce the heating times by means of a clock, meets with resistance from the users. Through extensive explanations we were able to get the users to rethink their habits. The users were pleased about an increase in automation.

3.1.4 Direct Control NoHEMS (AAU)

Additional functions, Casa App:
The additional functions like schedule and timer are gladly accepted. Readiness to install devices that are visible and switchable from the outside. Some users do not want a third party to have access to their consumption behaviour for data protection reasons, this would require a lot of educational work and a certain amount of persuasion. Network management and energy saving benefits not understandable for users the energy saving potential or the energy flow shift is not apparent to the user.
No contracts have been concluded, there are no expenses eligible for compensation in the event of interruptions in power-on delays or program execution

3.1.5 Charging Energy Management System

Attractive design and comfortable handling enable a clear and user-friendly supervision of system operation on the system level (all components of charging infrastructure) as well as on the level of individual charging station or EV user.

No contracts were concluded, but the system records all loading operations and these could be charged.

3.2 Operation of components and subsystems

3.2.1 Home energy Management System

Users sceptical about W-Lan use to set up:

To set up the installed components, some users did not want to allow the laptop to be logged on for parameterizing the devices in their own W-Lan.
Some internet users have connected their PC via network cable and have deactivated the W-Lan function of their router.

3.2.2 Factory Energy Management System

It is also advantageous for the energy supplier or for the user of the plant to monitor the plant additionally. In this case, sensible options for an alarm system should be considered for various events.

3.2.3 Direct Control NoHEMS (inea)

The users do not notice the function of the installed devices, as they do not assume any impairment.

3.2.4 Direct Control NoHEMS (AAU)

Additional functions, Casa App:

The additional functions like schedule and timer are gladly accepted.

3.2.5 Charging Energy Management System

Website (mobile phone app) clear but slow:

The existing charging stations are easy to find and a free charging possibility is clearly visible. Reacting and updating the page takes less than a minute or even sometimes has to be updated manually.
From point of view of prosumers (EV users) the use of EV charging within the GOFLEX system seems quite complicated. In addition to insertion of departure time before each charging the user shall define also the EV type that is intended to be charged. This information is needed for determination of maximum power to be drawn by EV and further for calculation of initial charging plan and associated load flexibility parameters. If the EV user always uses the same (type of) EV, this parameter ("default" EV type) shall be inserted to CEMS database only once. If the EV user uses different EV types (this is mostly the case when a company fleet, composed

of different EV types, is used by employees), the EV type must be selected by EV user (via mobile phone app) before each charging session.

The parameters necessary for GOFLEX CEMS to operate properly (departure time, correct EV type) were not always inserted via mobile app or present in the CEMS database; consequently, for many charging sessions the flexibility offers were not formed and sent to FMAN, or the flexibility margins linked to EV type (maximum charging load) were not correct and flexibility activation requests were not properly executed.

Insertion of mentioned parameters (departure time, EV type) via smart phone requires from EV users additional actions (more complicated as a simple identification by RFID card) before each charging, which the users could estimate as unnecessary, time consuming and annoying. To optimise the system operation and to make the use of GOFLEX more attractive and simple for the users, enhanced technical solutions should be implemented which doesn't require (excessive) users' interventions before each charging.

3.3 General feedbacks

In order to get a general feedback from the prosumers, a survey was started at the end of the test period. This survey included HEMS and No HEMS.

User Survey Design:
To get an overview of how prosumer experience GOFLEX technology, we conducted a survey study at German 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.

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, washing, charging)

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 German demo-site all GOFLEX users were asked to participate in the survey. As they have different ways for interacting with GOFLEX components we also took this into consideration in the logic and distribution of the survey.

The survey was sent out via mailing list compiled by SWW and distributed to 106 users. The survey was hosted on SurveyMonkey, an online Survey collection tool. The data collection period lasted two weeks and took place at the end of January 2010. The participating households had at this time experienced GOFLEX technology running for 3 months. All collected data was anonymised.

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 46 individual persons from residential household chose to participate in the German survey. From the collected data, we can see (Figure 19B) that most participants came from residential households owned by the participants either as houses (54.35%) or flats (8.70%). Just under a third of the respondents live in rented flats (30.43%). We can also observe that all respondents came from housing occupied with more than one person, indicating that the

respondents came from multiple-family homes. Mostly male respondents (80.43%) participated from these households (Figure 19C), while 17,39% respondents were women. One respondent chose not to disclose their gender. The ages of the respondents were spread out, stretching from the age of 18 to 75 and above (Figure 19D). Most respondents were in age-range of 35-44 (34.78%), and 25-43 (26.09%), while 34,78 stated they were 45 years of age or older. One young person between the age of 18-24 participated.

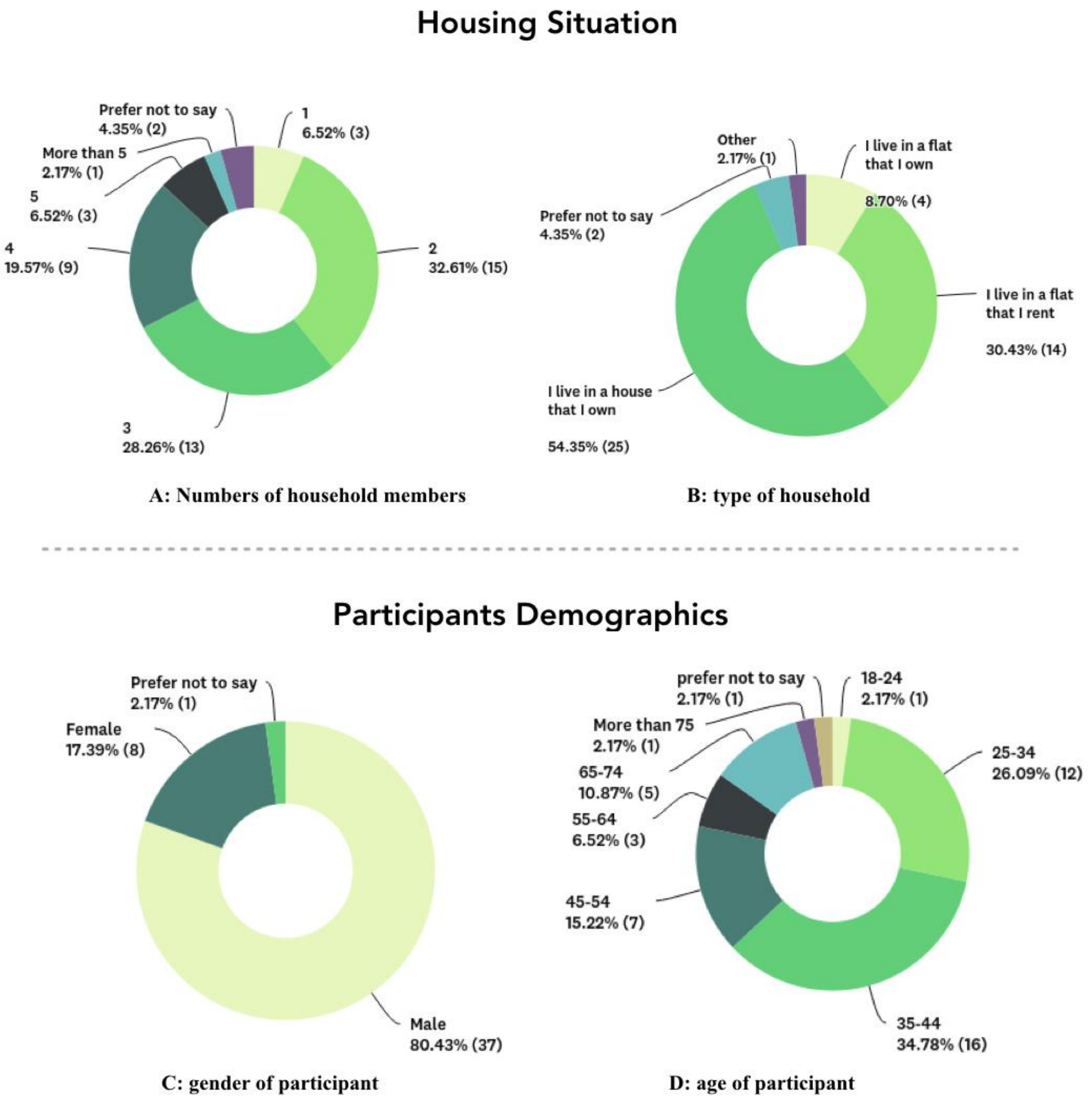


Figure 19: Main characteristics of participants and their housing situation

We asked the respondents who the main user of GOFLEX technology is in their household to determine the level of experience of interacting with GOFLEX technology (Figure 20). 56.52% reported that they are the main person responsible for controlling and interacting with GOFLEX in their households, while 13.04% reported that someone else in their household had that responsibility. 30.43% reported that GOFLEX technology is running automatically in their household.

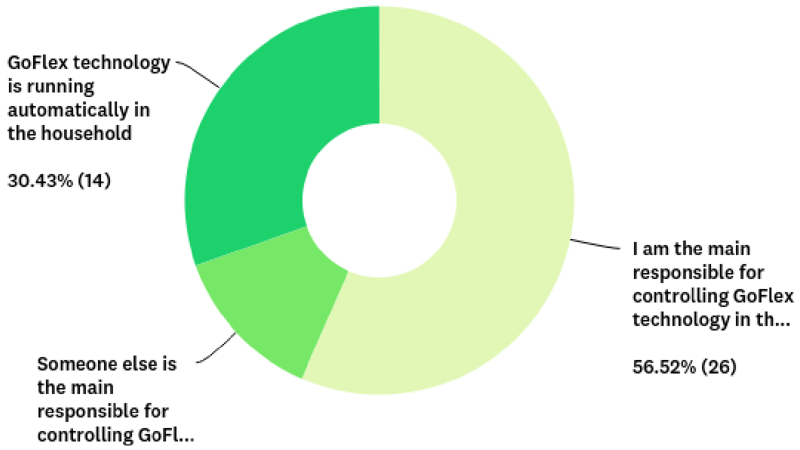


Figure 20: Experience of interacting with GOFLEX technology

The respondents were asked what motivated them to participate in the GOFLEX project (Figure 21). The respondents ranked "wanting to try out new technology" as the highest motivational factor for participating in the GOFLEX project (WA: 4.55). "Wanting to do something good for the environment" was the second-highest ranked motivational factor (WA: 4.24), closely followed by
"wanting save money on energy usage" (WA: 4.00). "Doing something good for the local community" was the least ranked factor (WA: 3.74).

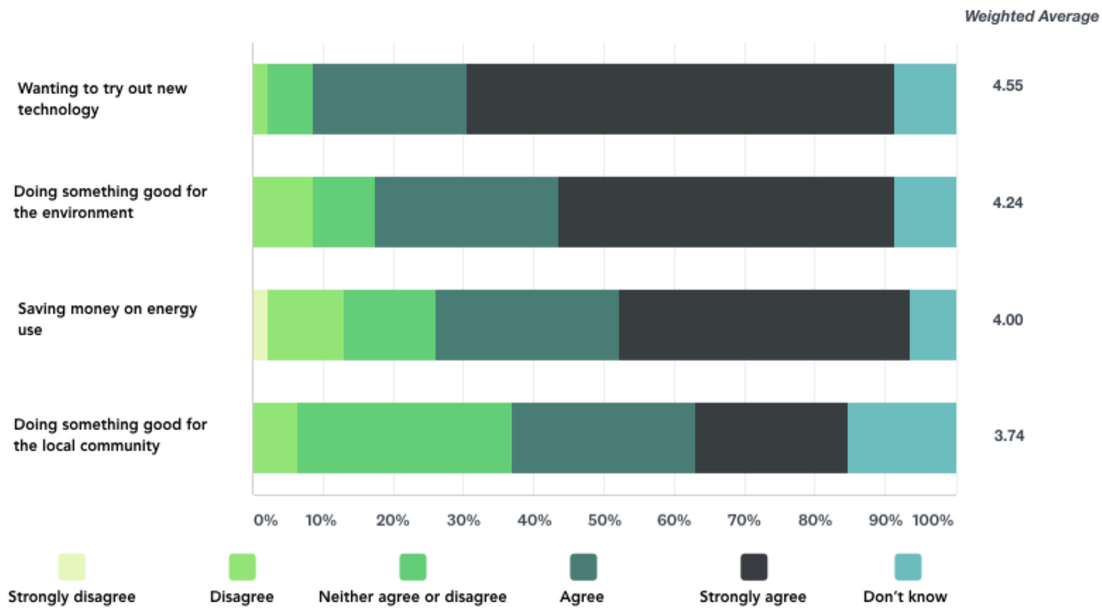


Figure 21: Motivational factors for participating in the GOFLEX project

We also asked the respondents to describe GOFLEX technology with three words. The most common words were energy, control, and comfort, closely followed by consumption, environment, flexibility, technology, efficiency, power, smart, monitoring, load, and home (Figure 22). This indicates that the respondents had a fundamental understanding of both the technical aspects of the GOFLEX project (flexibility) and how it influences everyday life (washing machines).

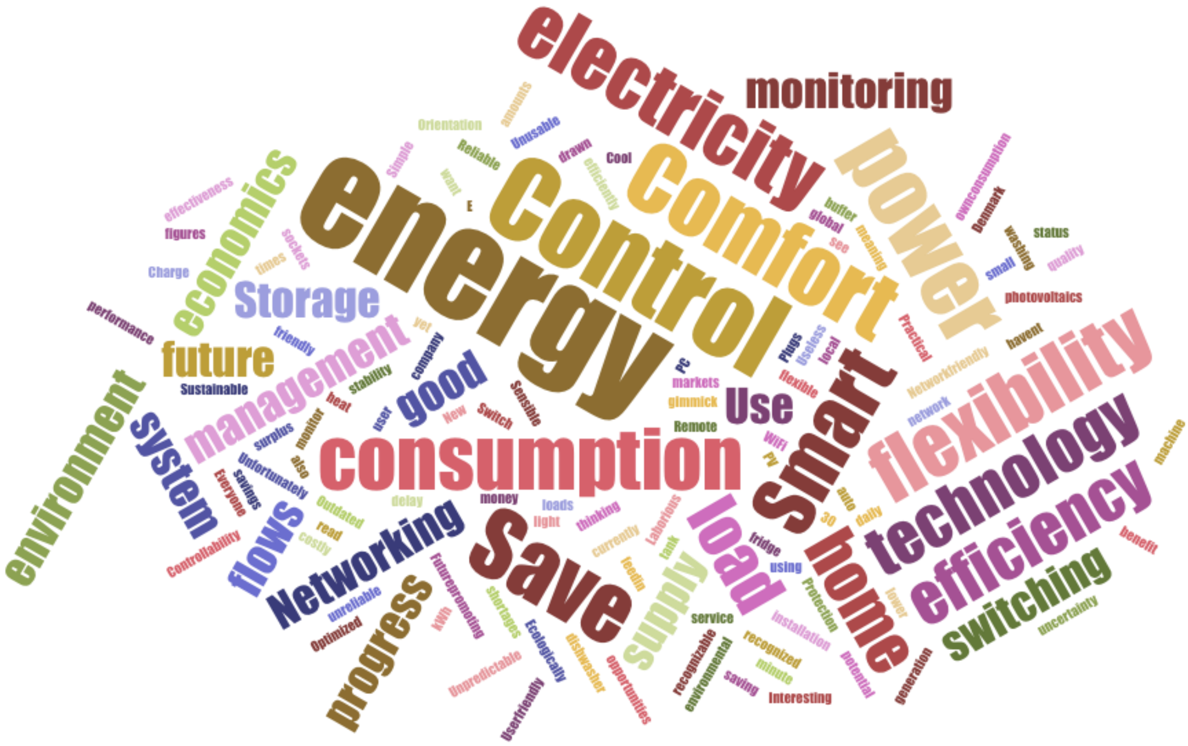


Figure 22: Word cloud illustrating the words the respondents use to describe GOFLEX technology in Germany

User experience of GOFLEX interactive components

To measure the user experience of the specific GOFLEX interactive component at the Cyprus demo-site, we asked questions about what GOFLEX technology controls in their home and how and why the participants interact with their GOFLEX interactive component.

To be able to specific questions to the different GOFLEX components the respondents were living with, we asked them what GOFLEX technology controls in their home (Figure 23). Of the all the respondents 17.39% replied that is GOFLEX technology just control their heating, thus assuming these were no-EMS (INEA) users. For the rest of the respondents we asked them specific questions related the kinds of electric devices are controlled by GOFLEX technology in their home. First, we asked how many devices were controlled by GOFLEX technology (Figure 24). The most common answer was 2 (28.95%), followed by 4 (18.42%), while 15,79% of the respondents had 1 device, and 13.16% had 3 devices controlled by GOFLEX technology. Lastly, 15,79% reported they had 5 or more devices controlled by GOFLEX technology.

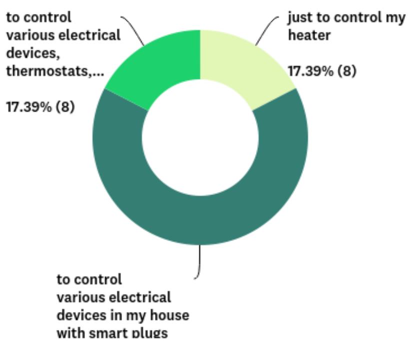


Figure 23: Electric devices GOFLEX technology controls

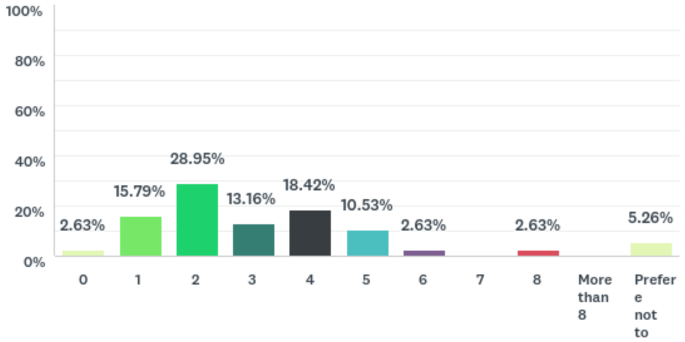


Figure 24: Number of electric devices controlled by GOFLEX technology

From the survey response, we can observe that the most common device perceived to be controlled at the German demo-site (Figure 25) is fridges (47.37%), while chargers (39.47%) and washing machines (34.21%) are perceived to be controlled by just over a third of the households. In 18.42% of the households the dish washer is perceived to be controlled, the tumble dryer 21.05%, while the heater is perceived to be controlled by 5.26% of the respondents. Lastly, 42.11% of the respondents reported that GOFLEX technology controls other devices like electric cars (5.26%), boilers (5.26%), multimedia (13.15%), various lightning (18.42%), coffee machines (5.26%) and lastly singles households reported that they have dehumidifiers, photovoltaic systems and aquariums controlled by GOFLEX technology. Also asked the respondents type of GOFLEX application they use (Figure 26). Interestingly 65.79% responded that they did not know what kind of application they use, while 7.89% reported that they use none. Some of these respondents may be from the 17.39% replied that is GOFLEX technology only controls their heating (Figure 23), thus assuming some of these were no-EMS (INEA) users equipped with no interactive components (Figure 19). However, these results do indicate that a majority of the respondents were unaware of the application used to facilitate user interaction with GOFLEX technology, suggesting it is unclear for the users of GOFLEX technology what it is they interact with.

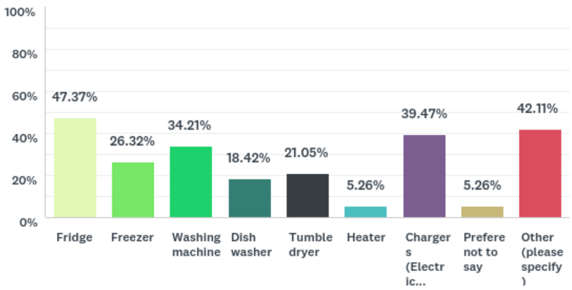


Figure 25: Respondents perception of what GOFLEX technology controls in their home

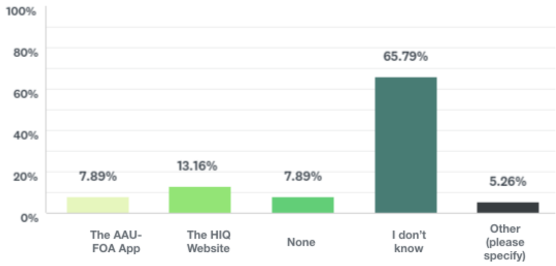


Figure 26: Respondents perception of what GOFLEX interactive components they use

Despite being unclear for respondents what type of application they interact with, we can from the survey response (Figure 27) observe 15.79% use their app daily, 21.05% either use it weekly, monthly or every quarter of the year. 10.53% responded that they never use it, while 7.89 use related to specific purposes like registering Kasa smart devices. When respondents use the GOFLEX interactive app (Figure 28), most respondents (72.97%) agrees or strongly agrees to seek information about how much energy their devices consume. This is closely followed with respondents looking at when their devices are set to run with (56.76%) agreeing or strongly agreeing with this. The weighted average of functionality related to the amount of energy the household produces and turning on/off devices, is just above the midpoint average on the scale, while the rest of functionality e.g. changing settings of devices, seeking information about their energy bill, KPI's, changing setting of their devices, and seeking personal information is just rated beneath the midpoint average at the German demo-site.

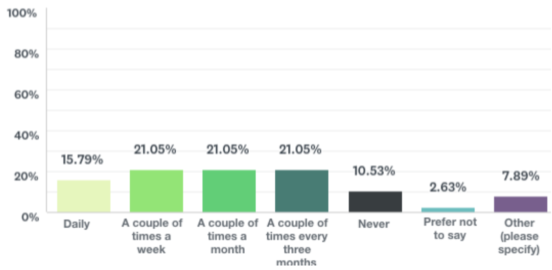


Figure 27: Number of times using the GOFLEX interactive app

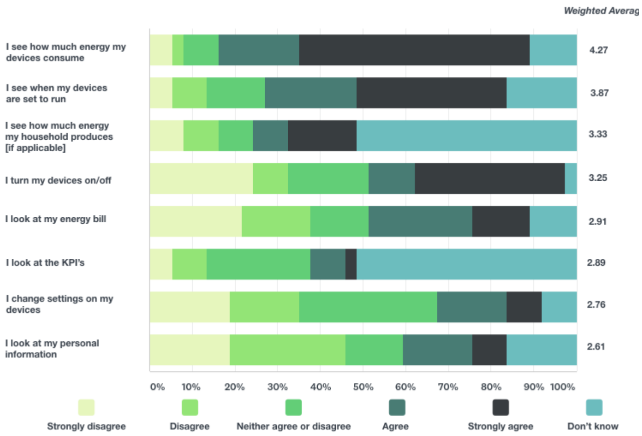


Figure 28: Use of the GOFLEX interactive app

To get an indication of the overall user experience of interacting with GOFLEX technology, we asked questions measuring the usability (how much people believe the product makes their lives easier), and desirability (how much people believe it matches with them) of GOFLEX technology (Figure 29). The usability questions had a weighted average 3.83, while the desirability questions had a weighted average 3.43. Together this indicates that the respondents perceived the overall GOFLEX technology to be average usable and desirable.

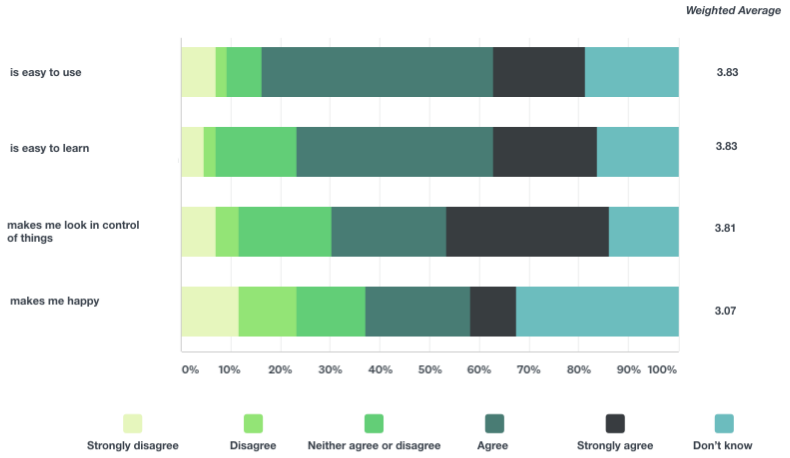


Figure 29: Overall user experience of GOFLEX technology

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 30). The respondents clearly perceived the main purpose of GOFLEX technology is to provide information about their energy use with 69.05% respondents agreeing or strongly agreeing to this.

At the same time 61.90% agreed or strongly agreed that the purpose of GOFLEX technology is help them control household appliances. However, it is interesting to observe that 69.05% of respondents agreed or strongly agreed the purpose of GOFLEX technology is to help them use less energy, while 52.38% agreed or strongly agreed that the purpose of GOFLEX technology is help them use clean energy. Despite respondents using words like flexibility and environmental when describing GOFLEX technology (Figure 22), this result could be an indication that it 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 and not to facilitate less energy usage). This suggests that in future development the overall purpose could be better ascribed in the design of technology.

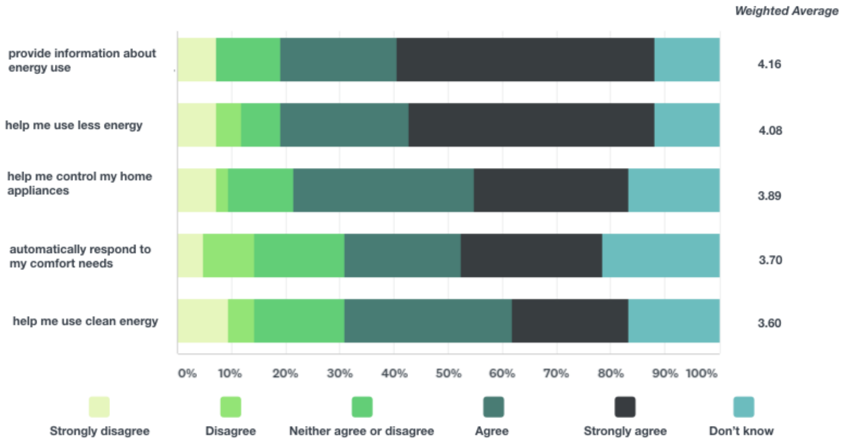


Figure 30: Perceived purpose of GOFLEX technology

We also asked respondents what they perceived to be the main benefits of GOFLEX technology (Figure 30). The respondents clearly perceived the main benefit of GOFLEX technology is to manage their energy use with 69.04% of the respondents agreeing or strongly agreeing to this. Interestingly, 50.00% of the respondents agreed or strongly agreed that the benefit of GOFLEX technology to provide comfort, while 52.38% agreeing or strongly agreeing that saving money by saving electricity is a benefit. 48.78% agreed or strongly agreed perceived that making their energy use more convenient was a benefit of GOFLEX technology, while 42.86% of the respondents agreeing or strongly agreeing that the benefit of GOFLEX technology is improve the quality of life, and 30,95% agreeing or strongly agreeing that a benefit of GOFLEX technology is to make things effortless. Saving time, provide a peace of mind, and increase the value of property all had lower weighted average of the mid-point means on the response scale.

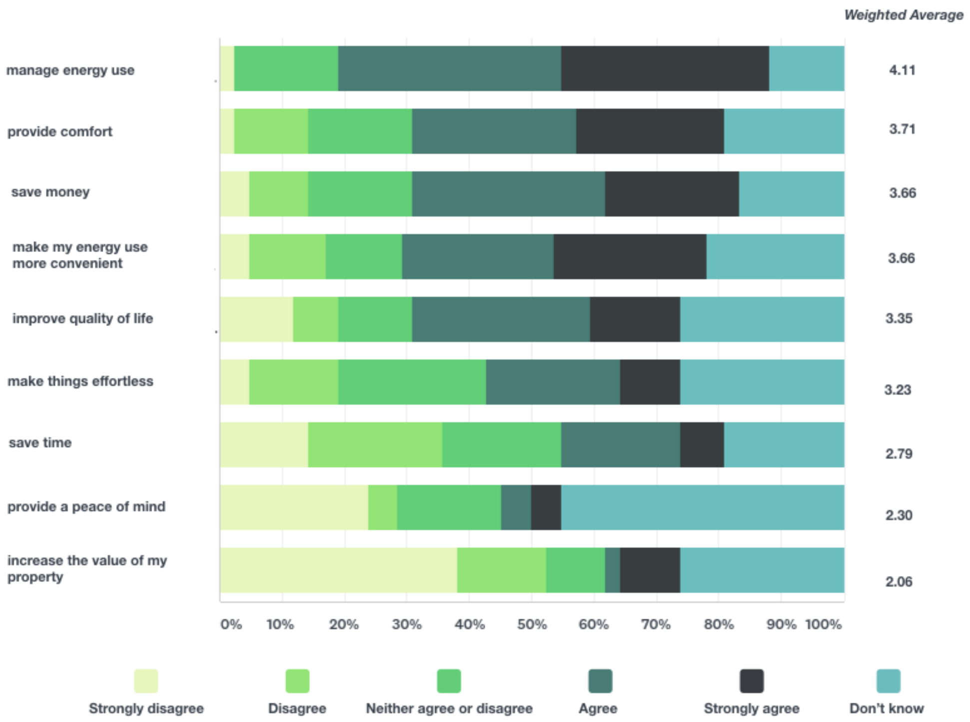


Figure 31: Perceived benefits of GOFLEX technology

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 31). The respondents clearly perceived that GOFLEX technology is designed enable households to manage their energy use with 69,67% agreeing or strongly agreeing to this. At the same time 64,29% agreed or strongly agreed that GOFLEX technology is designed to provide more information about their energy use, while 57,14% agreed or strongly agreed it to be designed to provide greater control over households' activities. Interestingly, 61,90% of the respondents agreed or strongly agreed that

GOFLEX technology is designed to manage their energy use on their behalf. This indicates that respondents are not able to distinguish between GOFLEX technology controlling their energy use on their behalf or if GOFLEX technology supports them to control their energy usage. These results imply that it is unclear for users what the balance is between system automation and user control in the design of GOFLEX technology. It suggests that designers and developers of future technology need to better convey to users where this balance lays and who is responsible for what.

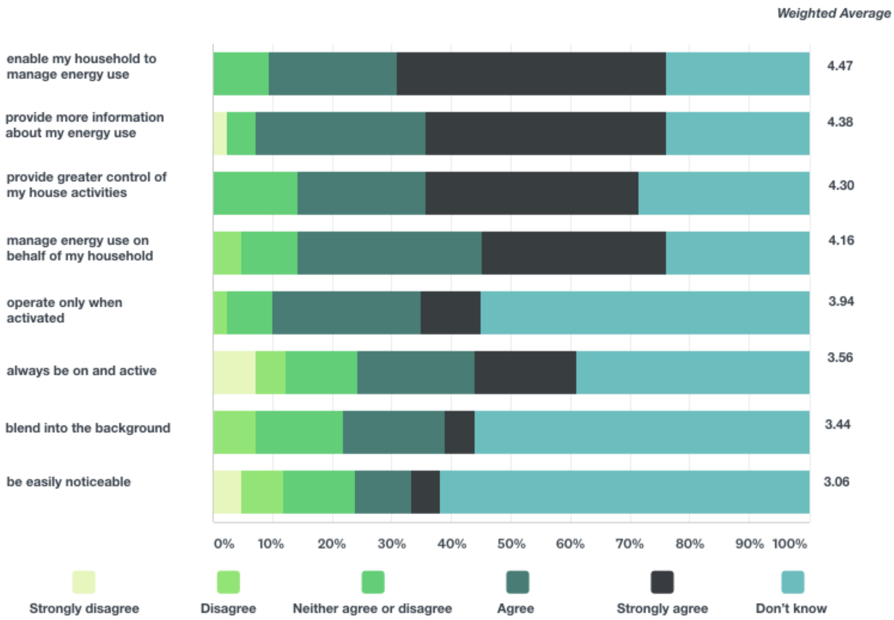


Figure 32: Perception of the design and control of GOFLEX technology

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 32). Survey respondents clearly thought that GOFLEX technology must be reliable to use. A total of 88,09% of the respondents agreed or strongly agreed with this. A further 78.57% agreed or strongly agreed that GOFLEX technology must guaranty privacy and confidentiality, while 85,72% agreed or strongly agreed that GOFLEX technology must be controlled and over-ridden by them. This indicates that data security, control over technology and reliable of the technology are features respondents at the German demo-site find to be of high importance when it comes to living along with GOFLEX technology in their everyday life. The least weighted averages of the features were managing energy use effortless and convenient and automating energy usage. This is rather interesting as these are some of the key design features of GOFLEX technology.

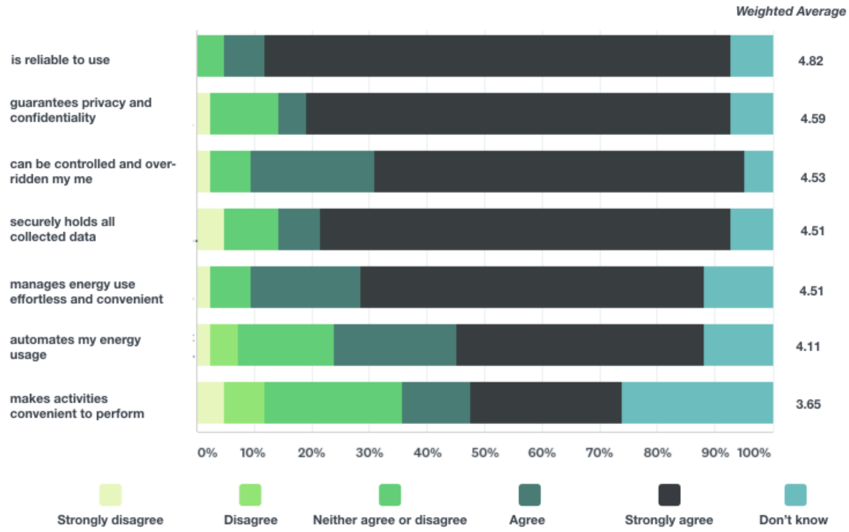


Figure 33: Perception of the importance of GOFLEX technology features for future use

To measure the respondents' perception of the kinds of risks they associate with continued use of GOFLEX technology, we asked them seven specific questions related to this (Figure 33). From this response, we can observe that the respondents at the German demo-site do not generally associate contrived use of GOFLEX technology with these risks, as most of the response items are ranked near the mid-point means on the response scale. This might be an indication of that respondents already associate GOFLEX technology as being rather trustworthy after already having experienced living with GOFLEX technology in everyday life. Still, the response indicates that users do associate continued use of GOFLEX technology with an increased risk of dependency of technology and outside experts. This suggests, that particular these risk factors could be considered in future development as most of respondents (45.24%, and 38.10%) agreed or strongly agreed on these factors being a risk in the future. The rest of the response options means were scored below to the midpoint of the response scale.

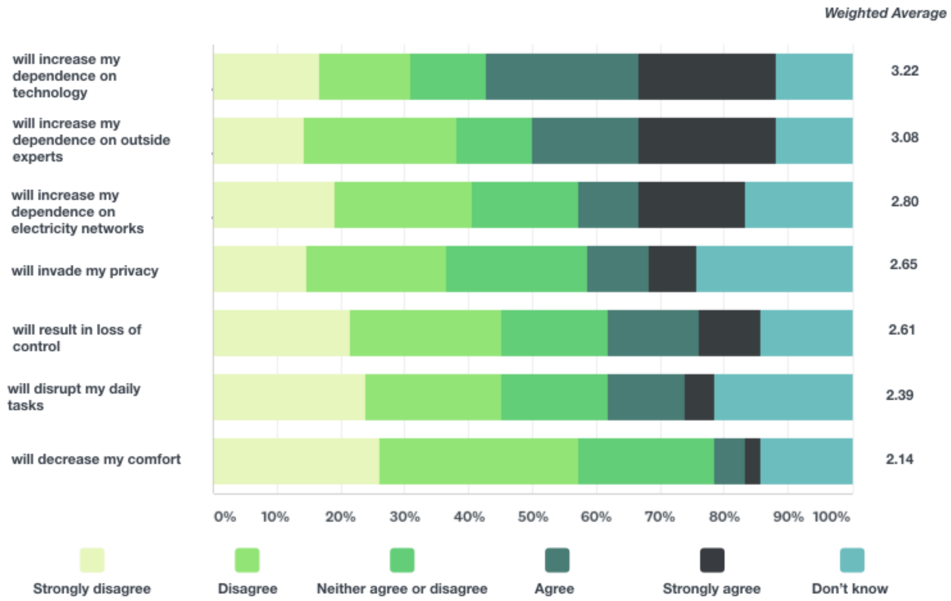


Figure 34: Perception of risks associated with continued use of GOFLEX technology.

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 35). The respondents clearly responded that general they need more information related to overall energy usage. 80.95% of the respondents agreed and strongly agreed that they need being able seek information about both general energy use, while 78.57% agreed and strongly agreed that information enable them to compare household energy usage over time were of importance. 70.73% agreed and strongly agreed that more financial information about what kind of money saving GOFLEX technology can facilitate were important. Being able seek information about renewable energy usage (green energy usage and CO2 footprint) were also ranked high by the respondents, although not as high as general energy information. For instance, being able to see how much CO2 households save using GOFLEX technology had the fourth highest weighted average of importance of the information features with 69.05% of the respondents agreeing and strongly agreeing with this. This highlights a need to properly informing users about the benefits of GOFLEX technology controlling energy consuming devices in their homes in future development. Interestingly, information about the influence of GOFLEX control were ranked lower than energy usage information. This could be an indication of that this kind of information is already accessible to these users in the applications they have access to. Being able to compare energy usage in the neighbourhood and getting information about the neighbourhood's renewable energy consumption had the lowest weighted average, with most respondents disagreeing or strongly disagreeing with these two information items being of importance.

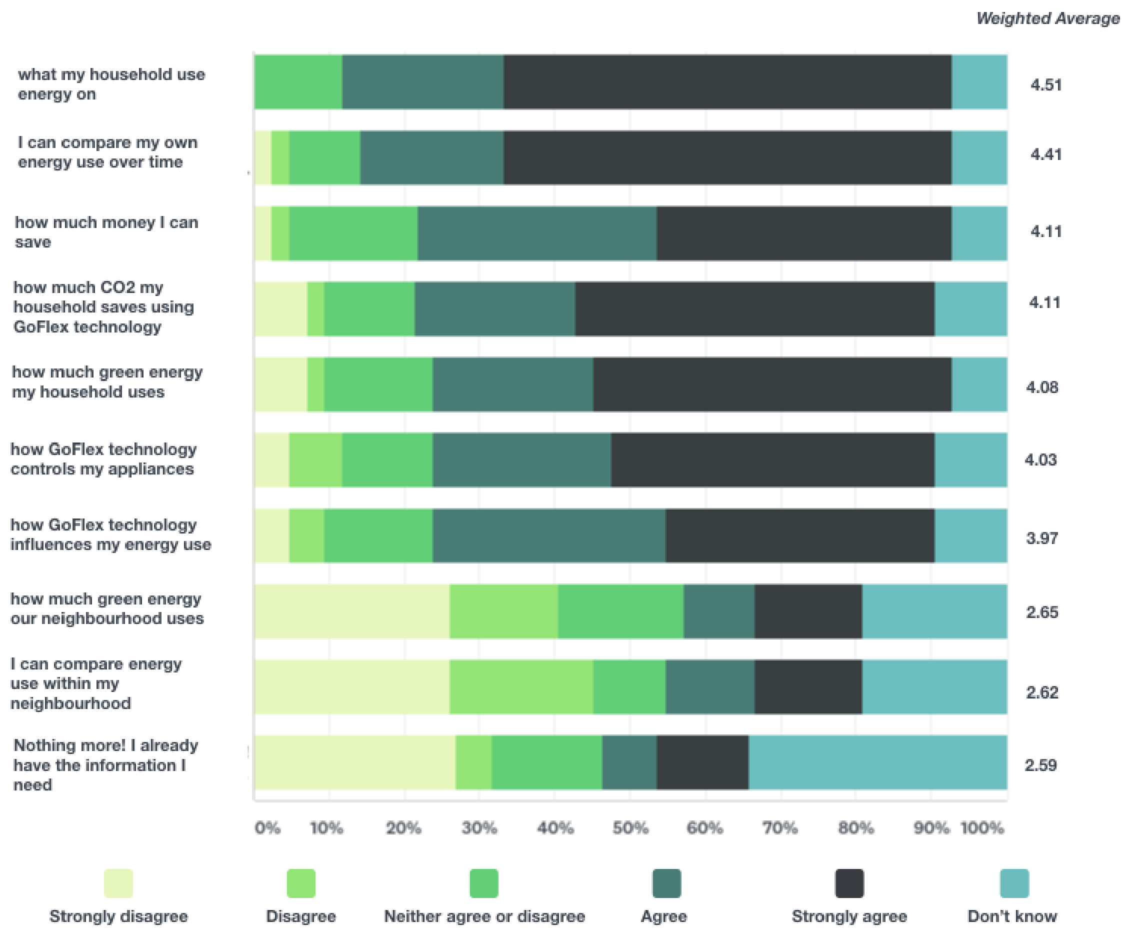


Figure 35: Perception of important information for continued use of GOFLEX technology

3.3.1 Home Energy Management System

Interest of the users, as they were informed in the workshop:

All users who agreed to have components installed at the kick-off workshop kept their word and waited for the installation.

3.3.2 Factory Energy Management System

Some plants have only few possibilities to provide flexibility according to operational requirements.

3.3.3 NoHEMS (Inea)

Removing the functioning ripple control receivers and the possibility of no longer being able to reduce the heating times via a clock meets with resistance from the users.

Through extensive explanations we were able to get the users to rethink their habits and tr new options.

3.3.4 NoHEMS (AAU)

Readiness to install devices that are visible and switchable from the outside:

Some users do not want a third party to have access to their consumption behaviour for data protection reasons, this would require a lot of educational work and a certain amount of persuasion.
Network management and energy saving benefits not understandable for users.

The energy saving potential or the energy flow shift is not apparent to the user, yet.

3.3.5 Charging Energy Management System

Charging would be easier to operate with RFID card. Flexibility calculation is enabled only with using the mobile App, which must be explained to the prosumer beforehand and requires additional actions by EV users before start of each charging.

However, the identification of EV user by RFID card doesn't enable acquisition of data about user's charging requirements (required energy, time available for charging) and EV charger's technical characteristics (EV type, linked to maximum possible charging power). Without this information the incorporation of EV charging into demand response schemes is not feasible. Using mobile phone apps 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 Technical Performance

4.1 Scale of Installation

Table 1: Scale of installation

Quantity	Target Value	Achieved Value
Number of [FEMS] Energy Management Systems	21	21
Number of [HEMS] Energy Management Systems	22	22
Number of [CEMS] Energy Management Systems	5	6
Number of [nonEMS] Energy Management Systems	154	154
Number of public electric vehicle charging stations	5	5
Number of private electric vehicles charging stations	0	1
Number of forecasting models deployed in cloud service platform		90

As shown in D9.3 there were multiple choices of functional combinations within the same group of EMS-type.

This gives a DSO the opportunity to adapt the solution to the individual need of every single prosumer or partner.

4.2 Detailed Performance Evaluation

4.2.1 Performance metric

4.2.1.1 Detailed Method

4.2.1.2 Trackable KPIs & methodology

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.

This chapter will address the technically trackable KPIs. Each KPI will be presented in the following dimensions:

- Relevant WP
- Computing System(s)
- Description from DoA
- Goal value from DoA
- Link to demo case KPIs: matching the requirements from demo sites
- Calculation method
- Time resolution
- Data needed
- Comment

4.2.2 WP9 - Service Platform (WP5) Related KPIs

Several modelling techniques were used to generate forecasts for the GOFLEX demonstrations. GAM [1], Sarima [2] and MLP [3] were used as was an ensemble technique which combines all three.
The MAPE [4] calculation was used to determine the accuracy of the forecasts generated.

Table 2: WP5 Related KPI´s

		MAPE (%) at forecast horizon		
Entity	Signal	1-hour	6-hour	12-hour
SWW	ENERGY_DEMAND	5.63%	6.91%	8.19%
SWW	ENERGY_DEMAND	1.54%	24.55%	25.32%

4.2.2.1 Scaling KPIs

Table 3: Scaling KPIs

Quantity	Target Value	Metric
Total Time Series	n/a	184
Total Time Series (Observed)	n/a	15
Total Time Series (Forecast)	n/a	169
Total Data Points	n/a	54,108,473
Total Data Points (Observed)	n/a	6,383,075
Total Data Points (Forecast)	n/a	47,725,398
Total Trained Models	n/a	90

4.2.2.2 Platform KPIs

Table 4: Platform KPIs

Quantity	Target Va-lue	Metric
Accuracy of forecasts at substation level	<10%	n/a
Accuracy of forecasts at BRP level	<5%	1,54% ✓
Service platform query response time	< 1 minute	1.25 seconds ✓
Service platform availability of observations	< 5 minutes	0.23 seconds ✓
Service platform availability of next forecast update	< 30 minu-tes	26 seconds ✓

4.2.3 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 2.7 MWh/h of positive flexibility (increase energy production or decrease energy demand) and 0.09 MWh/h of negative flexibility (increase energy demand or decrease energy production), respectively corresponding to about 12.6% and 0.4% of the peak energy demand of SWW, nearly 21.8 MWh/h, and to about 25.3% and 0.8% of the peak physical load of SWW (injection from EON), approximately 10.8 MWh/h.

4.2.3.1 Distribution grid stability through responsiveness of flexibility services

Over the period Dec 1st, 2019 through to Jan 29th 2019 DOMS service issued 5667 flexoffers (this is about one every 15 minutes), amounting to a total of about 3849.8 MWh of positive flexibility requests (increase energy production or decrease energy demand) and 122.3 MWh of negative flexibility requests (increase energy demand or decrease energy production). Over the same period there was a corresponding portfolio of about 1034.3 MWh of offered positive flexibility and 209.6 MWh of offered negative flexibility from the prosumers, amounting to 26.9% and 171.4% of the flexibility requested by DOMS.

Looking at the actually scheduled flexibility from the FMAR system, based on DOMS flexoffers, 9.7 MWh of positive flexibility and 17.2 MWh of negative flexibility were respectively required, of which 27.4 MWh (283.6 %) and 24.1 MWh (140.3%) were delivered.

4.2.3.2 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 Germany instance, as outlined in D6.4, DOMS configuration included the following state variable:

- SWW energy imbalance, defined as the difference between the total energy demand served by SWW and the energy generated from solar, wind, biomass and gas distributed plants.

The following additional 5 support variables are included in DOMS grid model for Germany:

- The energy demand supplied by the SWW grid.
- The energy generation from solar, wind, biomass and gas distributed plants within SWW grid.

This is an example of the observability data returned by the DOMS services, as queried at the time of writing this report:


```
{
  "serviceRequest": {
    "requestor": "40860c4c-6389-4d75-bca2-78b0485b06b9",
    "service": {
      "name": "getObservabilityData",
      "args": {
        "tags": [
          "xest.priority",
          "xest.likelihood"
        ],
        "time_period": {
          "from": "2020-01-23T16:44:12+00:00",
          "to": "2020-01-24T16:44:12+00:00"
        }
      }
    }
  }
}
```

```
[
   {
      "timestamp": "2020-01-23T16:45:00+00:00",
      "xest.likelihood.sww.imbalance": 0.9465993625098844,
      "xest.priority.sww.imbalance": 2.0,
      "xest.sww.imbalance": 2133.519215198899
   },
   {
      "timestamp": "2020-01-23T17:00:00+00:00",
      "xest.likelihood.sww.imbalance": 0.9708319294491412,
      "xest.priority.sww.imbalance": 2.0,
      "xest.sww.imbalance": 2242.7361513051505
   },
   […]
]
```


Figure 36 shows an example of DOMS state variable prediction for SWW energy imbalance against observations. The red- and yellow-shaded areas identify undesired operational ranges, corresponding to “congestions”.

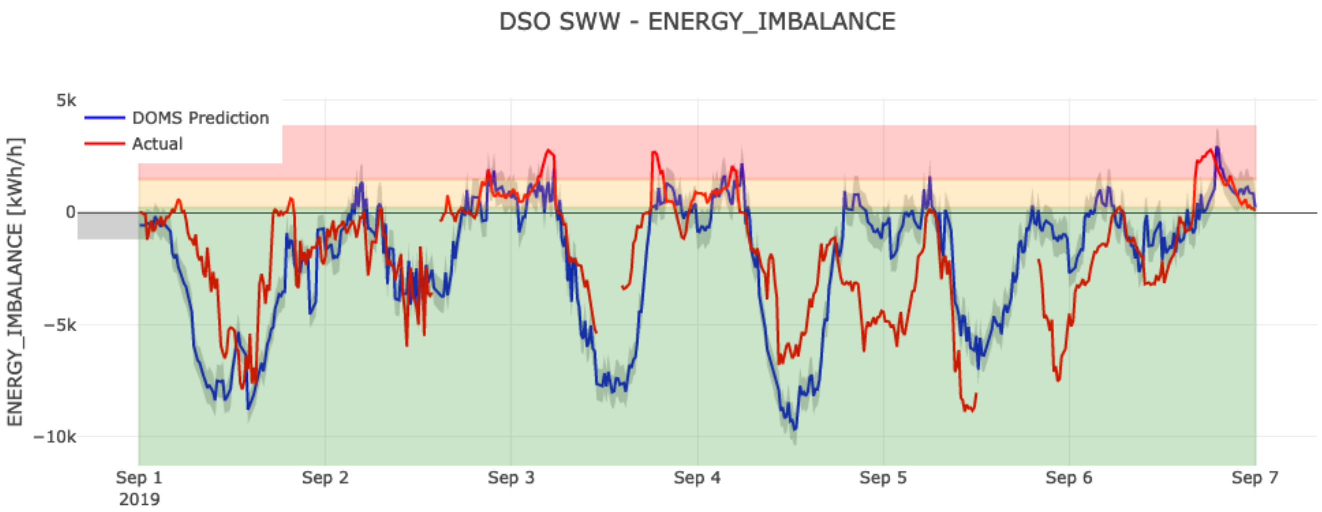


Figure 36: Example of DOMS state variable prediction

Two different metrics were proposed to evaluate the Grid state observability capabilities provided by DOMS, as defined in D6.4:

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

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

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: 96.91%
Oct 2019: 84.24%
Nov 2019: 76.05% ** (Outage caused missing week in Oct 28-Nov 5, 2019)
Dec 2019: 100.00%
Jan 2020: 85.28%
Total Observability.1 KPI = 91.19%

Observability.2 (Improvement over available metering/scada data)
Sept 2019: 1.60%
Oct 2019: 4.99%
Nov 2019: 7.77%
Dec 2019: 1.77%
Jan 2019: 1.47%
Total Observability.2 KPI = 37.01%

4.2.3.3 **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. Refer to Figure 1 for an example of the operational ranges defined for the SWW energy imbalance state variables.

The performance of DOMS congestion predictions is evaluated using typical classification metrics of Precision, Accuracy and Recall, as defined in D6.4:

$$ACCURACY = TP + TN$$

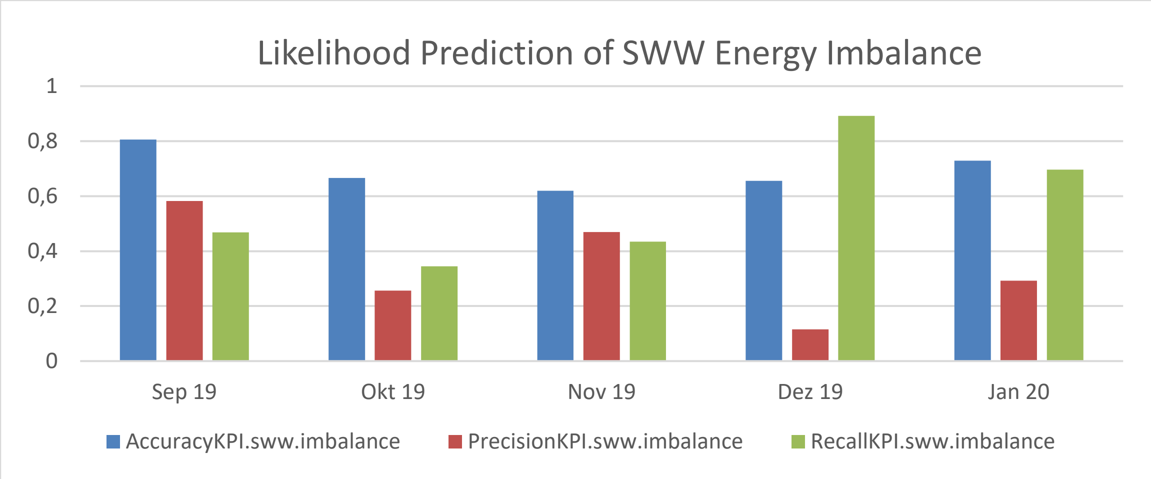
$$PRECISION = \frac{TP}{TP + FP}$$

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

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:

Table 5: Likelihood Prediction of SWW Energy Imbalance



The following total accuracy was observed:
Accuracy (Sep 2019) = 80.53%
Accuracy = 69.53% ** (shift in demand after Sep 2019, likely due to additional generation not captured in the data)

4.2.4 Electricity load adaptability level

Relevant WPs	WP2
Computing Systems	FOA, FMAN, FMAR
Description DoA	Energy demand variation (dMWh /h) with respect to peak demand (MWh/h)
Goal value DoA	>15 %
Link to demo case KPIs	KPI 1.4 Amount of flexibility achieved in kWh KPI 1.1: Number of flexibility offers traded with the DSO KPI 2.1: Number of flexibility offers traded between mi-crogrid the DSO
Calculation method	Energy adaptability level at the interval of the hour h can be expressed using the formula: $AdaptabilityLevel_h = \frac{(e_h^{max} - e_h^{min})}{e_h^{max}}$, where e_h^{max} is the maximum amount of energy that can be consumed (or produced) by Prosumer during the pe-riod of the hour h, e_h^{min} is the minimum amount of en-ergy that can be consumed (or produced) by Prosumer during the period of the hour h. When the time-shifting of energy away from the interval of the hour h is possi-ble, then $e_h^{min} = 0$ and the adaptability level is equal to 1 (100%).
Time resolution	15min
Data needed	FlexOffers
Comment	This is flexible part of controlled loads.

4.2.5 Demand response generated by virtual energy storage in demonstrated use cases in the project (during 3 months' testing & evaluation period)

Relevant WPs	WP3
Computing Systems	FEMS, HEMS, CEMS, CDEMS
Description DoA	Energy demand variation (dMWh /h) with respect to peak demand (MWh/h)
Goal value DoA	>15 %
Link to demo case KPIs	Usability of aggregation: ratio of currently available flexible power to total controlled/monitored power Energy shifting flexibility (in kWh and how many hours) for each type of xEMS KPI 1.6 Flexibility out of storage (HEMS) Activation of demand response strategies through the HEMS KPI 1.2: Activation of demand response strategies through the BEMS
Calculation method	$KPI = \sum \frac{Energy\ variation(up - down)}{Consumption\ of\ controllable\ loads}$
Time resolution	15min
Data needed	FlexOffers
Comment	Sum of all FO energy data that was sent to FOA divided by consumed energy of controllable loads.

4.2.6 Benefit for aggregator

Relevant WPs	WP2
Computing Systems	FMAN (delegated trading)
Description DoA	Increased business in supply of DR
Goal value DoA	≥ 35.000 EUR/MW/year + 200 €/MWh
Link to demo case KPIs	KPI 1.7 Earnings out of Virtual Power Plant
Calculation method	Aggregator absolute profit can be expressed as the sum of flexibility market/trading gains (C_{Market}), energy discounts or rewards to be paid to Prosumer for issuing their flex-offers (C_{FOS}), and fixed costs (C_{Fixed}): $$AggregatorProfit = \sum C_{Market} - \sum C_{FOS} - \sum C_{Fixed}$$ This profit can be normalized and expressed for a single MW of energy: $$NormalizedAggregatorProfit = \frac{AggregatorProfit}{e^{dispached}},$$ where $e^{dispached}$ is the total amount of energy scheduled / dispatched by the aggregator over a selected period (e.g., 1 year).
Time resolution	15min
Data needed	FlexOffers, schedules, metering data
Comment	Sum of all FO energy cost that was sent to FOA divided by consumed energy of controllable loads.

4.2.7 Lessen the burden of power grids through self-consumption

Relevant WPs	WP2, WP3, WP4
Computing Systems	FMAR (microgrid), HEMS (with own production), DOMS
Description DoA	MWh/h of self-consumed energy
Goal value DoA	>10 %
Link to demo case KPIs	Level of self generation in % Number of activated flexibility offers for grid congestion relief
Calculation method	WP3: $$KPI = \frac{Internal\ energy\ consumption}{Overall\ energy\ consumption}$$ WP4: $$KPI1 = 1 - \frac{Grid\ Loading}{Overall\ consumption}$$ $$KPI1 = ABS(1 - \frac{Grid\ Loading}{Overall\ consumption - Delivered\ Flexibility})$$
Time resolution	15min
Data needed	FlexOffers, schedules, metering data
Comment	WP3: Relevant for HEMS & CDEMS with own production (e.g. PV) WP4: Self-consumption is more generally defined as decrease/increase of grid load as a result of use of "flexibility" (decrease/increase of consumer demand or increase/decrease of consumer generation to cover for part of his demand).

4.2.8 Increase of prosumer involvement

Relevant WPs	WP3
Computing Systems	FEMS, HEMS, CEMS, CDEMS
Description DoA	Augmented DR (%)
Goal value DoA	>15 %
Link to demo case KPIs	
Calculation method	$$KPI = \sum \frac{Contracted\ Flex\ Energy\ (FO\ Schedule)}{Energy\ variation(up - down)}$$
Time resolution	Basic trading interval (15min)
Data needed	FlexOffers
Comment	Percentage of activated (contracted) flex energy divided by all offered flex energy.

4.2.9 Flexibility range at average occupancy of charging spots

Relevant WPs	WP3
Computing Systems	CEMS
Description DoA	% of charging load variation (without violation of user needs) compared to baseline
Goal value DoA	+10%, -30%
Link to demo case KPIs	
Calculation method	$KPI = \left[\sum \frac{Possible\ Energy\ variation\ UP}{Internal\ schedule}\right], \left[\sum \frac{Possible\ Energy\ variation\ DOWN}{Internal\ schedule}\right]$
Time resolution	15min
Data needed	Internal DOMS schedule
Comment	Sum of energy (+ or -) divided by the planned (CEMS internal) energy.

4.2.10 Flexibility range for varying parking time

Relevant WPs	WP3
Computing Systems	CDEMS
Description DoA	% of charging load variation (without violation of user needs) compared to baseline
Goal value DoA	2hrs: +-10%, 8hrs: +-25%
Link to demo case KPIs	
Calculation method	$KPI = \left[\sum \frac{Possible\ Energy\ variation\ UP}{Internal\ schedule}\right], \left[\sum \frac{Possible\ Energy\ variation\ DOWN}{Internal\ schedule}\right]$
Time resolution	15min
Data needed	Internal CDEMS schedule
Comment	Sum of energy (+ or -) divided by the planned (CDEMS internal) energy.

4.2.11 Distribution grid stability through responsiveness of flexibility services

Relevant WPs	WP4
Computing Systems	DOMS
Description DoA	Time required to activate portion of available load flexibility through DR services
Goal value DoA	30 min (>25% of DR) 1 hr (>50% of DR) 24 hrs (>100% of DR)
Link to demo case KPIs	
Calculation method	$$\frac{Delivered\ flexibility}{Requested\ flexibility}$$
Time resolution	15min
Data needed	FlexOffer, schedule
Comment	After DOMS makes prediction

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

Relevant WPs	WP4
Computing Systems	DOMS
Description DoA	Number of observed grid state variables (voltages, power flows), with respect to all possible states of interest (full observability).
Goal value DoA	> 80 %
Link to demo case KPIs	
Calculation method	$$1-\frac{Number\ of\ \text{"metered"}\ variables}{no.\ of\ all\ available\ variables}$$
Time resolution	15min
Data needed	Metering data, DOMS observability data.
Comment	

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

Relevant WPs	WP4
Computing Systems	DOMS
Description DoA	Frequency of correct prediction of occurrence of congestion
Goal value DoA	> 90 %
Link to demo case KPIs	
Calculation method	Given true-positive (TP), true-begative (TN), false-positive (FP) and false-negative (FN) rates. $ACCURACY = TP + TN$ $PRECISION = \frac{TP}{TP + FP}$ $RECALL = \frac{TP}{TP + FN}$
Time resolution	15min
Data needed	Grid metering data, DOMS observability data
Comment	

4.2.14 Accuracy of forecasts at prosumer, MV/LV transformer or substation level (energy demand, generation, flexibility)

Relevant WPs	WP5
Computing Systems	SP
Description DoA	Mean Absolute Percentage Error (MAPE)
Goal value DoA	< 10 %
Link to demo case KPIs	
Calculation method	$MAPE(\boldsymbol{y}, \hat{\boldsymbol{y}}) = \frac{1}{H} \cdot \sum_{t=1}^{H} APE(y_t, \hat{y}_t)$ $APE(y, \hat{y}) = \begin{cases} 0, & y = \hat{y} \\ \frac{\lvert y - \hat{y} \rvert}{\lvert y \rvert}, & otherwise \end{cases}$ where $\boldsymbol{y}$ denotes the time series in the forecast horizon, $\hat{\boldsymbol{y}}$ the forecast time series and y_t and $\hat{y}_t$ the resp. values at time instance t. The length of the forecast horizon is denoted as H.
Time resolution	Daily
Data needed	Forecast and meter data?
Comment	

4.2.15 Accuracy of forecasts at microgrid, BRP level (energy demand, generation, flexibility)

Relevant WPs	WP5
Computing Systems	SP
Description DoA	Mean Absolute Percentage Error (MAPE)
Goal value DoA	< 5 %
Link to demo case KPIs	
Calculation method	$$MAPE(\boldsymbol{y},\hat{\boldsymbol{y}}) = \frac{1}{H}\cdot\sum_{t=1}^{H} APE(y_t,\hat{y}_t)$$ $$APE(y,\hat{y}) = \begin{cases} 0, & y = \hat{y} \\ \frac{\lvert y-\hat{y}\rvert}{\lvert y\rvert}, & otherwise \end{cases}$$ where $\boldsymbol{y}$ denotes the time series in the forecast horizon, $\hat{\boldsymbol{y}}$ the forecast time series and y_t and $\hat{y}_t$ the resp. values at time instance t. The length of the forecast horizon is denoted as H.
Time resolution	Daily
Data needed	Forecast and meter data?
Comment	

4.2.16 Latency / efficiency of data querying

Relevant WPs	WP5
Computing Systems	SP
Description DoA	Latency / efficiency of data querying
Goal value DoA	Response to query < 1 min Availability of real-time observations < 5 min Availability of next forecast update < 30 min
Link to demo case KPIs	
Calculation method	Average duration of query invocationTime Average duration of time series ingestion Average duration of forecast model scoring
Time resolution	Ad hoc – on demand
Data needed	Time span as measured internally on the platform per function
Comment	

4.3 Other performance indicators

During the implementation of the project, we identified several additional performance indicators, which have become a part of specific solutions. Those KPIs are mostly used internally and are therefore not shared between solutions. Since they are important for efficient operation of the integrated system, we note them down in this chapter:

1. Number of active prosumers: this KPI is calculated on FMAN and FMAR and represents an estimate on how active the demonstration site is. It

can also be used for alarming functionalities in order to detect communication or other problems.

2. Number of FlexOffers in the system: this KPI is calculated on FMAR and provides an insight into prosumer involvement. The KPI is calculated for each (virtual or explicit) region on the site and also segmented by prosumer types (factories, homes, cars, ..).
3. Time KPIs: for each prosumer we monitor the time of the last contact and the last sent FlexOffer.
4. Prosumer Success rate: Percentage of the accepted FlexOffers per prosumer.
5. Prosumer Reliability Index: How well did the prosumer follow the assigned schedules in the past. It is used when selecting the prosumers to be selected in the future.
6. Avoided curtailment: equates to the energy of the contracted FlexOffers in certain time window.

4.3.1 Detailed Results

Impact indicators were defined to monitor the project performance during the demonstration period and the results are reported in the final deliverables from demonstration sites.
In order to support the evaluation process, this document will present a few selected preliminary results on the integration level. Preliminary KPI values do not present the actual project impact, since the data collection has just started at the time of writing this deliverable. We predict that for meaningful analysis, we require data collection for at least 3 months.
The most important indicator at integrated level is the "Energy Demand Variation", described in chapter 4.2.4 - Electricity load adaptability level. It is a measure of flexibility available in the system, weighted by the consumption. It is calculated on FMAN and FMAR.

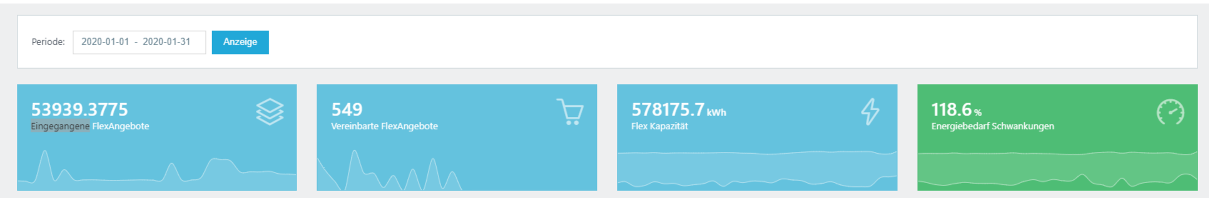


Figure 37: Example overview of KPI screen on FMAR

FMAR provides an aggregated and interval depiction of the KPI values. Figure 37 shows the aggregated view for February, which is best suited for management.

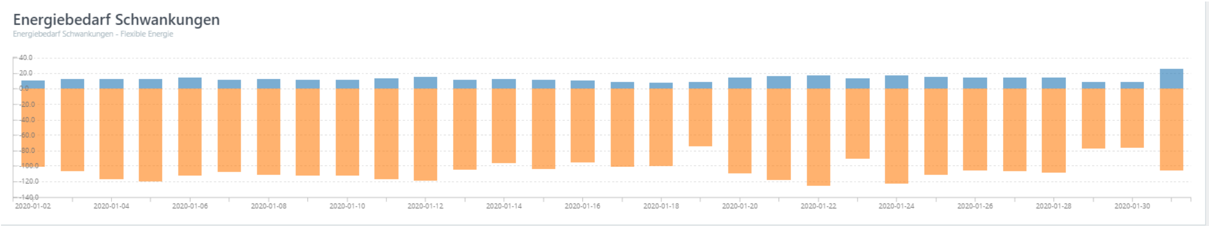


Figure 38: Detailed look at the Energy Demand Variation KPI

On Figure 38 we can observe the dynamic of the KPI for one month. The data is collected in SWW, Germany. We can observe, and the fluctuations in energy demand are clearly in the negative range. This is because considerably more energy is consumed in winter than is generated. The range in January, for example, was between 81.6% and minus 195%.

On the KPI screen we can also observe other interesting KPIs. Below we can observe the number of FlexOffers sent to FMAR for trading. Currently the system receives around 1800 FlexOffers per day in february.

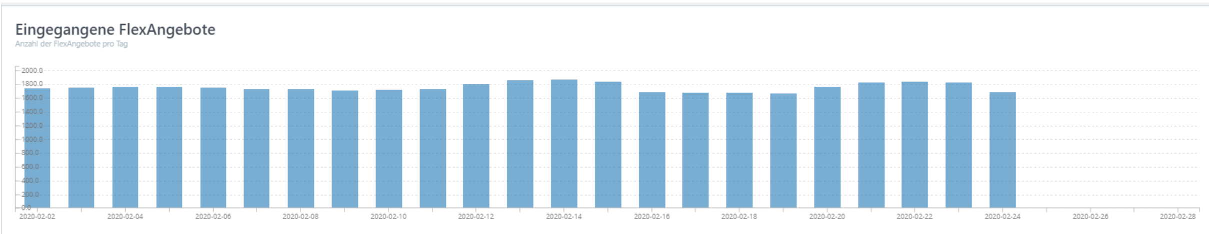


Figure 39: Number of sent FlexOffers

Activation of flexibility depends on the predictions, produced by DOMS system. The current configuration activates offers during the day. We can observe on Figure 40 the number of activations – the need for flexibility on the grid was higher at 15.00 and 17.30 of the day on 2020-01-01 (respectively 18 flex offers).

-

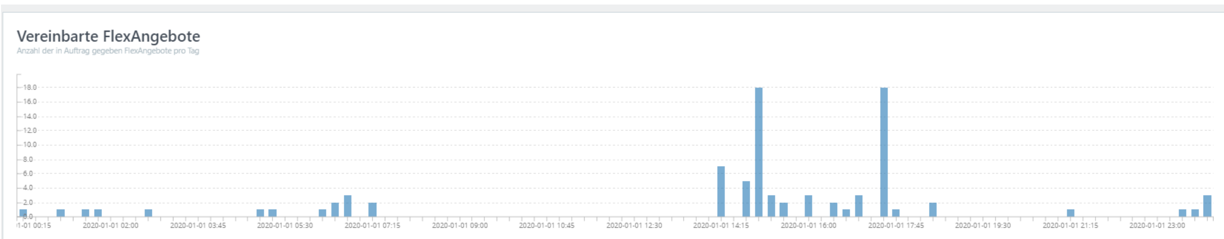


Figure 40: Activated FlexOffers

Some flexibility sources may offer higher KPI values, due to the design of the system itself. Such example are Direct Control prosumers, where we can fully control the underlying process, due to its simplicity. Mostly we are controlling night storage heaters and water heaters, where the are less unknowns and therefore the adaptability level tends to be higher. Figure

40 shows the KPI value, calculated on about 74 households. The average KPI value for one day was around 36,8%. You can see a very even curve over a period of a few days, which can be explained by the fact that the night storage heaters always store energy for a certain period of time so that it can be released over another period.

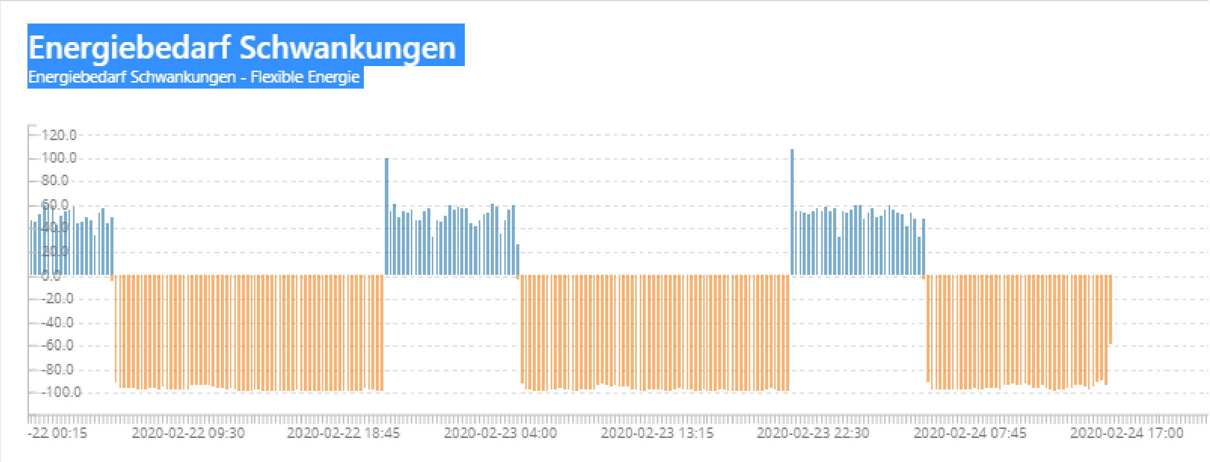


Figure 41: Energy Demand Variation on Direct Control prosumers

Non trackable accounts:

- **Safe increase of installed capacity of renewable energy sources**

  Comparison of total number of RES in 2016 and 2019

- In 2016 the capacity of RES was 24 MW; in December 2019 the capacity was 38,2 MW which makes an increase of 14,2 MW or 59,2%.**Number of new PV-installations**

- Comparison of total number of PV-installations in 2016 (537 ea) and 2019 (725 ea), means increase of 35%.**Level of self-generation in %**

  Comparison of percentage of self-generation in SWW grid in 2016 (49.117.000 kWh out of 78.627.000 kWh) 62,5% and 2018 (52.178.000 kWh out of 79.000.000 kWh) 66,1%.

- **Adaptability of energy load with respect to peak demand**

  The energy demand fluctuations from 01.11.2019 to 27.02.20 is for all active prosumers 146,3 %.

- **Estimated profit(revenue?) from supplying/activating aggregating demand response**

  Calculation with upscaled amount of flexibility out of GOFLEX system in connection with calculated value of flexibility results in 33.559.825 kWh * 0,0661 €/kWh = 2.218.304 €/year.

- **Avoided costs for congestions**

- Up to today no situation of grid congestion occurred because the grid was opulently refurbished with copper cables of larger diameters 20 years ago, makes 0€.**Reduction in peak demand**
- Comparison of peak demand 2016 (11,4 MW) and 2018 (8,9 MW) makes 22%.**Increase in self-consumed energy**

  Comparison of peak demand 2016 (21,4 MW) and 2018 (19,3 MW) makes 10%.
- **Number of new battery operators**

  Comparison of total number of battery-installations in 2016 and 2019

  28 existing batteries in SWW grid in 2016; 45 batteries in SWW grid in December 2019, accounts to 17 new batteries.
- **Number of Prosumers that provide energy data**

  Simple headcount of individual persons that provide their generation and consumption data.

4.4 Summary Performance Evaluation

We evaluated performance as described above. The results are summarized in the following table. The developed kpi's from the project are marked with a star.

Table 6 Performance metrics for GOFLEX Demonstration in Cyprus/Switzerland/Germany

Quantity	Target Value	Achieved Value
Safe increase of installed capacity of renewable energy sources	>15 %	59,2%
Adaptability of energy load with respect to peak demand	>15%	24,8%
Estimated profit from supplying/activating aggregating demand response	>€35,000/MW/year + €200/MWh	13.500€/MW/y* 42,60€/MWh*
Reduction in peak demand	>15%	13%
Increase in self-consumed energy	>10%	10%
Coverage of grid state variables of interest with distribution observability and management system	>80%	82%*
Likelihood of correct prediction of congestion	>90%	80,53%
Accuracy of forecasts at BRP level	<5%	1,54%
Service platform query response time	< 1 minute	1.25 seconds
Service platform availability of observations	< 5 minutes	0.23 seconds
Service platform availability of next forecast update	< 30 minutes	26 seconds
Variation of electric vehicle charging load at public stations	+10 / -30 %	> 30% for both directions*
Variation of electric vehicle charging load at private station, depending on parking time	2 hours: +/- 10% 8 hours: +/- 25%	+10%* +12%*
Reduction in electric vehicle charging time and peak load at private station	>15%	Not needed due to strong prosumers' networks

The planned impacts of GOFLEX come from individual solutions and their business & marketing models as well as the integrated GOFLEX system and its overall system dissemination and business & marketing model. These are measured with a set of key performance indicators (KPI).
The KPIs in the table below shall be used for all steps that SWW might reach throughout the project duration.

Table 7: Business KPI´s

Steps	Business KPIs	Target value during GOFLEX test phase
Step 1-4	KPI 1.1 Level of self-generation in % Target: 100%	75% 155%*
Step 1-4	KPI 1.2 Deviations from balance in the balance group in %	5% 0%*
Step 1-4	KPI 1.3 Amount of flexibility achievable in kWh	60.558.669 kWh 79.000.000 kWh (+)*

Step 1-4	KPI 1.4 Amount of flexibility achieved in kWh	60.558.669 kWh 33.550.825 kWh*
Step 1-4	KPI 1.5 Amount of money achieved for flexibility in EURO	10.516.000 € 2.217.710 €*
Step 1-4	KPI 1.6 Flexibility out of storage	20.000.000 kWh Not applied in project
Step 1-4	KPI 1.7 Earnings out of Virtual Power Plant (VPP)	1.000.000 € Not applied in project
Step 1-4	KPI 1.8 Earnings out of aggregation of flexibility	1.350.000 € 2.218.304€*
Step 1-4	KPI 1.9 Number of new PV-installations	>5% 35%*
Step 1-4	KPI 1.10 Number of new battery operators	10 3*
Step 1-4	KPI 1.11 Number of Prosumers that provide energy data	50 55*

5 Cost Benefit Analysis

Chapter 5 deals with the ways of calculating of different monetary issues on all stakeholder levels, starting with the business case of SWW in 2016 as a reference, comparing it with the changes out of the project and the real 2018 business data. Next step is the evaluation of volumes in terms of flexibilities and the business values. Followed by the creation of possible ROI rates resulting from flexibility achieved, combined with values calculated and CAPEX and OPEX costs assumed for setting up and operating the system as is in SWW. Finally, a list of follow-up-activities for SWW is elaborated.

5.1 Initial Planing: SWW as service provider for Prosumers, micro grids and flexible consumers

Initial planning for migration of SWW market and business rolls within project period

Table 8: Time Scale of change of roles of SWW for offering flexibility services to be implemented

Service	Step 1	Step 2	(Step 3)	Step 4
Actor/Role	(Sub-)BRP DSO (Aggregator)	BRP DSO Aggregator	BRP DSO Aggregator	BRP DSO Aggregator
Planned time for implementation	2018/19	2019	2019/20	2020

Tested in GOFLEX	Y	Y	Y	N

Coming out of the 4-step model derived from SWW Roadmap to make the maximum use of flexibility trading.

5.1.1 Summary Cost-Benefit Analysis initial

Table 9: Today´s situation – Assumed Development by trading

	2016´s situation – Assumed Development by trading	**Step 1**	**Step 3**	**Step 4**
costs	8.653.900,63	17.197.252,88	18.439.922,35	18.439.922,35
income	11.736.111,93	23.805.716,39	26.401.518,42	26.401.518,42
contribu-tion margin	3.082.211,30	6.608.463,51	7.961.596,07	7.961.596,07

The approach to cost benefit analysis that we will follow in the OGOFLEX project will be to set and carry it out largely as a substantiation of defined key performance indicators and not as the basis for defining the KPIs, and in the framework of the dissemination and exploitation plan:

i) The framework and methodology, the link to OGOFLEX business and marketing models, and the integrated contributing exploitation plans of solution providers will be carried out in the WP10 as part of task T10.4 (Marketing the GOFLEX Solutions), which will be updated throughout the project; it will be used as input to actual CBA's; and will be made part of deliverable D10.1 (Business and marketing plan). Solution providers will contribute their inputs to it as part of their exploitation plans.

ii) The actual CBA will follow the project life cycle, starting from design in the first task up to validation in the final task.

iii) The reference situation is specified in the “today`s situation” in 5.1.

iv) The todays situation is the reflection of the current market condition based on the year 2016.

v) In each CBA reference is made to and showing this basic data to avoid switching between the single pages and to show up the project progress within a single view. The yellow and green marked table elements show the development between reference situation and actual result of the business case.

For SWW there must be a profit after purchasing costs of devices and installation costs. For the prosumers: there must be return of investments after a period x taking into account the additional income from the FLEX-offers. The Flex-offers must create more money than the self-consumption of the generated energy and create no or little costs in case of load shedding.

For establishing a cost-analysis for prosumers to be combined with the possible benefits SWW needs to have an idea on how to calculate the flexibility (kWh) related investment cost per step for achieving the different equipment and capability levels of the different steps.

- Equipment Generation
- Storage
- Charging
- Energy Management
- Balancing
- Trading
- Manpower

5.2 Today's situation: SWW as service provider for Prosumers, micro grids and flexible consumers

5.2.1 COST-BENEFIT-ANALYSIS descriptions and assumptions

For this analysis we use the current state of the financial year 2016 as base for all our further projections and assumptions. Scope of this current state is the balance sheet, income statement and various statistics, for instance sales statistics, procurement statistics, generation statistics and so on.

In the year 2018 the distribution grid had a pass-through amount of electricity of 76.900.000 kWh in total. This value consists of 2 elements:

- quantity of sales in the distribution grid (the amount of energy foreign energy retailers sell to customers in our grid) = 22.800.000 kWh

- quantity of sales of energy retails (the amount of energy which sells SWW in its market role as retailer, restricted to our grid) = 54.100.000 kWh

In opposite to the amounts of electricity we insert the monetary values of income/revenue and costs/expenditures which projects in the following way:

- Income 11.125.000 €

- Costs 8.303.000 €

As result we show a contribution margin that is calculated as subtraction of income and costs. This margin will be used as indicator of the economically performance of the business cases and to demonstrate the economically development throughout the several states of the business cases.

The reference situation is specified in the so called "today`s situation" in 5.1.

The todays situation is the reflection of the current market condition based on the year 2016. In each CBA I´m referring to and showing this basic data to avoid switching between the single pages and to show up the project progress within a single view. Pleas notice the yellow and green marked table elements show the development between reference situation and actual result of the business case.

Table 10: COST-BENEFIT-ANALYSIS Approach for Todays' situation

Basics (financial year 2018)				
based on the balance sheet/income statement/statistics of the year 2016				
quantity of sales / distribution grid		22.800.000 kWh		
quantity of sales / energy retail		54.100.000 kWh		
income		11.125.000 €		
	income		11.125.000	€
costs		8.303.000 €		
	costs		8.303.000	€
contribution margin			2.822.000	€
These positions with regard to the market roles in the unbundled regulatory market environment in Germany				
amount of electricity in the distribution grid		76.900.000 kWh		
flexibility in the distribution grid	0%	0 kWh		
assumed used flexibility in this business case	0%	0 kWh		
Assumed Development by trading flexibility				
quantity of sales / distribution grid		22.800.000 kWh		
quantity of sales / energy retail		54.100.000 kWh		
income		11.125.000 €		
	income		11.125.000	€
costs		8.303.000 €		
	costs		8.303.000	€
contribution margin			2.822.000	€
These positions are regarding to the market roles				
amount of electricity in the distribution grid		76.900.000 kWh		
flexibility in the distribution grid	0%	0 kWh		
assumed used flexibility in this business case	0%	0 kWh		

5.2.1.1 COST-BENEFIT-ANALYSIS descriptions and assumptions Step 1 (aggregator of local flexibility)

SWW as DSO builds the infrastructure to facilitate local flexibility
The planed first progression of the “today`s situation” was to integrate an 8 MW storage system, which is currently still under testing, into the distribution grid.

Table 11: COST-BENEFIT-ANALYSIS: SWW (DSO) as aggregator of local flexibility

Basics (financial year 2018)						
based on the balance sheet/income statement/statistics of the year 2018						
quantity of sales / distribution grid			22.800.000	kWh		
quantity of sales / energy retail			54.100.000	kWh		
income			11.125.000	€		
	income				11.125.000	€
costs			8.303.000	€		
	costs				8.303.000	€
contribution margin					2.822.000	€
These positions with regard to the market roles in the unbundled regulatory market environment in Germany						
amount of electricity in the distribution grid			76.900.000	kWh		
flexibility in the distribution grid		0%	0	kWh		
assumed used flexibility in this business case		0%	0	kWh		
Assumed Development by trading flexibility						
quantity of sales / distribution grid			22.800.000	kWh		
quantity of sales / energy retail			54.100.000	kWh		
income			11.125.000,00	€		
income / flexibility (reserve market only load and without work)			2.982.500,00	€		
income / flexibility (trading prosumer)			2.217.710,00	€		
income / energy generation			9.614.100,00	€		
	income (incl. flex)				25.939.310,00	
costs / distribution grid			1.495.036,00	€		
costs / energy retail			6.001.175,00	€		
costs / flexibility (trading prosumer)			1.108.855,00	€		
costs / energy generation			9.614.100,00	€		
	costs (incl. flex)				18.219.166,00	
contribution margin (incl. flex)					7.720.144,00	
positions with regard to the market roles in the unbundled regulatory market environment in Germany						

amount of electricity in the distribution grid	79.000.000	kWh	
flexibility in the distribution grid	33.550.825	kWh	
"used" flexibility (prosumer) out of aggregator	6.452.082	kWh	0,0475 €
assumed used flexibility (reserve market) in this business case	25	MW	3.500,00 €
assumed generation in the distribution grid	52.178.000	kWh	0,1843 €
assumed procurement (inclusive EEG)	54.000.000	kWh	0,1193 €
avoided procurement (exclusive EEG)	4.717.644	kWh	0,0661 €

Our calculations

- average remuneration in SWW grid (based on the today`s results 2018)

water power	178.000	13.600 €	0,34%	0,0767 €	0,0003 €
wind power	16.000.000	1.113.600 €	30,66%	0,0696 €	0,0221 €
biomass power	22.000.000	4.578.200 €	42,16%	0,2081 €	0,0917 €
solar power	11.000.000	3.352.800 €	21,08%	0,3048 €	0,0583 €
cogeneration	3.000.000	555.900 €	5,75%	0,1853 €	0,0086 €
	52.178.000	9.614.100 €	100%		0,1843 €

- assumed price for flexibility

grid use charge TSO/€	1.133.973 €	
procurement TSO/kWh	23.882.164	0,0475 €

- assumed avoided procurement

procurement wholesale/kWh	54.000.000	
procurement wholesale/€	6.442.200 €	0,1193 €
thereof EEG charge	2.873.505 €	
procurement wholesale/€	3.568.695 €	0,0661 €

For SWW the calculated prize for "tradable" flexibility based on business data of **2016** was calculated with **0.0267€/kWh** and the calculated prize for avoided procurement was **0,0629 €/kWh.**
For 2018 the calculated prize for "tradable" flexibility in SWW based on business data of **2018** is calculated with **0,0475€/kWh** and the calculated prize for avoided procurement is **0,0661 €/kWh.**
Re-Calculating the 2018 Business case in electricity by using the assumptions shown, results in an **increase of contribution margin from 2.822.000€ to 7.720.144€** when introducing flexibility trading which would mean an **increase in ratio from 2,1 in 2016 to 2,7 in 2018**.
The second assumption is offering the profit for prosumer traded flexibility half and half, which would mean **1.108.855€ for the 210 prosumers/participants in one year**.

5.2.2 Traded flexibility in GOFLEX system SWW

The traded flexibility in the whole GOFLEX-System is a summary between the realized production in kWh and the realized consumption in kWh as you can see in table 8:

Table 12: Traded flexibility

Group	Realised production [kWh]	Realised consumption [kWh]
DSO	0	0
FEMS	25111,37	-49463,59
HEMS	73,24	-57,53
CEMS	0	-4096,73
Direct Control	3547,38	-11611,41
	28731,99	-65229,26
	Total:	**93961,25**

This traded flexibility from 93961,25 kwh happend between 01.10.2019 and 16.01.2020.

5.2.3 Value of traded flexibility for one year:

The value of traded flexibility for one year has to be scaled up from the data of 5.2.2. Therefore, we calculate the timeline from 5.2.2. for one year:
89864,52/10*52= 467.295,5 kwh

5.2.4 Requested flexibility in GOFLEX system SWW

The requested flexibility is the summary of the requested production and requested consumption in kwh like in capture 5.2.2. as you can see in table 9:

Table 13: Requested flexibility

requested production **[kWh]**	requested consumption **[kWh]**
168459,47	-3850833,36
367738,52	-1409715,14
2119,92	-3438,08
0	-76,25
148926,86	-500774,05
687244,77	-5764836,88
summary of the requested production and requested consumption:	6.452.081,65 kwh

This traded flexibility from 6.452.081,65 kwh happened also between 01.10.2019 and 16.01.2020.

5.2.5 Quantity and Value of requested flexibility for one year:

The value of requested flexibility for one year must be scaled up from the data of 5.2.4. Therefore, we calculate the timeline from 5.2.4. for one year:
6.452.081,65 kwh /10*52= **33.550.824,58 kwh**
Despite the initial plan of SWW Management to become full BRP and make financial use of tradable flexibility during the GOFLEX project, until today SWW still is Sub-BRP.
The value of “traded” flexibility is calculated using 0,0661€ per kWh and amounts to **2.217.710€**

5.3 Achieved flexibility and possible earnings per type of participant

5.3.1 FEMS

With a number of 21 FEMS achieving 9.242.761kWh of “tradable” flexibility at a prize of 0,0331€ ea, the value achieved in the FEMS group accounts to 305.935€. Braking the group value down to **the average FEMS the operator could have earned 14.568€.**

In terms of ROI for FEMS partners the calculation shows 11.500€ HW+11.500€ SW+ 5.000€ Inst. = 28.000€ ea for CAPEX and 500€ per year for OPEX, amounts to 29.000€ for 2 years; 29.000€ / 14.568€ = **2 years of ROI**

5.3.2 HEMS

With a number of 22 HEMS achieving 28.902kWh of “tradable” flexibility at a prize of 0,0331€ ea, the value achieved in the HEMS group accounts to 957€. Braking the group value down to **the average HEMS the operator could have earned 44€.**

This result is directly related to the lack of batteries in HEMS installations due to the breakdown of the battery in the reference installation. SWW refused to implement unreliable equipment.

In terms of ROI for HEMS partners the calculation shows 3.500€ HW+3.500€ SW+ 500€ Inst. = 7.500€ ea for CAPEX and 250€ per year for OPEX, amounts to 8.000€ for 2 years; in order to achieve **2 years of ROI** the required quantity of flexibility traded accounts to 241.692kWh per HEMS. This is not realistic for households. To achieve a breakeven with the CAPEX and OPEX figures shown above we need a period of 5 years with a 10 kW battery.

5.3.3 Direct control

With a number of 154 nonEMS achieving 3.378.440kWh of “tradable” flexibility at a prize of 0,0331€ ea, the value achieved in the nonEMS group accounts to 111.826€. If you break the group value down to the average non-EMS value, **the operator could have earned 726€**.

In terms of ROI for nonEMS partners the calculation shows 650€ HW+650€ SW+ 50€ Inst. = 1.350€ ea for CAPEX and 50€ per year for OPEX, amounts to 1.450€ for 2 years; 1.450€ / 726€ = **2 years of ROI.**

5.4 Period of Extended Observation

The Parties, as GOFLEX partners, share the interest and aim to cooperate in dissemination of the GOFLEX concept, approach and objectives into the regulatory and market framework of electricity market system to enhance the absorption of dispersed RES production and local balancing of supply and demand by using energy flexibilities; which will constitute the main attributes of the future GOFLEX community.

To this aim, the GOFLEX partners have on 26.04.2018 signed the Letter of Intent for extended observation of GOFLEX Integrated systems (Reference R.5) with the intent of specifying joint template and business conditions framework for individual Agreements for extended observation for each demonstration case of Project solution.

In preparation of this Agreement for extended observation the Parties tried to follow the Guidelines and Business Concept for Agreements for extended observation (Reference R.6 and R.4) with Cost base for services of the Parties in the extended observation to the extent permitted by compulsory national regulations, and these attached documents only serve as references.

5.4.1 Contents

Table 14: Unit count of supplied prototypes

Unit count of supplied prototypes - actual

Actually transferred to extended observation period for Germany (Use case 3)

	DemoCase		DSO&BRP&MGR		Prosumers											All		
			FOA (ITI)											FOA (FOI)			Prosumers	DSO&BRP
	Integr. system (3)	SP	DOMS- (DSO)	ATP (1) (BRP/MGR) (2)	FEMS - industr	FEMS - micro PP	installed (B)EMS	existing HEMS	Robotina HEMS	no-EMS	Robotina CDEMS	Etrel CEMS	Total ITI	no-EMS		total FOA	total	total
Use case 3 - Germany	1	1	1	1	13	10	0	0	22	84	0	6	137	75	75	**212**	210	2
Total FOA	1	1	1	1	13	10	0	0	22	84	0	6	137	75	75	**212**	**210**	**2**

Note (1) structure ATP (FMAN/FMAR) depends on the use case

Note (2) in GoFLEX project use cases, BRP (and MGR) play the role of ATP Operator. With new use cases, this may evolve into separate player

Note (3) integrated Goflex system manages a particular system of players that act as a cellular subsystem in the electricity market system (microgrid, balance group, ..). The number cellular Goflex systems will depend on actual structure of the demonstration cases

5.4.2 CAPEX

The assumed value of hardware amounts to
466.500€

The assumed value of software amounts to
450.000€

The assumed value of manpower necessary to get the system operable accounts to
810.000€

5.4.3 OPEX

The assumed value of manpower for operation of the GOFLEX systems amounts to approximately
140.000€
per year.

5.4.4 Cost per customer evaluation

The assumed CAPEX cost per customer is calculated with 1.726.500€ devided by 210 prosumers
8.221€.

The assumed OPEX cost per customer is calculated with 140.000€ devided by 210 prosumers
667€ / year.

Considering an achievable profit of 1.110.532€ only, the cash-in for one year of operation to DSO amounts to 5.288€, so the assumed **ROI** is calculated with (8.221€+667€)/5.288€ = **1,7years.**

Taking into account an achievable profit of 4.091.355€, the cash-in for one year of operation to DSO amounts to 19.483€, so the assumed **ROI** is calculated with (8.221€+667€)/19.483€=**0,5years.**

This figure is only a first rough guess for a DSO pre-calculation when planning to start flexibility business.

5.5 Follow-up actions to be undertaken in SWW in the next years

5.5.1 R&D Projects

HONOR:
The project aims at development and evaluation of a trans-regional flexibility market mechanism, integrating cross-sectoral energy flexibility at a community-wide level. The specific developments include a market mechanism for grid flexibility, industrial grade supervision solutions, data-driven state monitoring applications and cyber-security assessments. In order to develop a tailor made as well as replicable solution, community stakeholders will be involved through co-creation activities as well as stakeholder networks from Norway, Germany and Denmark. Complementing the economic and risk evaluation, simulation studies of flexibility operations and cyber-security assessments, the operation of control systems algorithms and the online monitoring and detection solutions will be implemented as demonstration in a relevant environment. The sector-coupling market mechanism will be implemented and demonstrated in an operational environment in Wunsiedel.

FEVER:
FEVER will implement and demonstrate solutions and services that leverage flexibility towards offering electricity grid services that address problems of the distribution grid, thus enabling it to function in a secure and resilient manner. The project encompasses technologies and techniques for extraction of energy flexibilities from virtual and explicit energy storage (batteries, V2G) and demand response. FEVER will leverage the potential for flexibility due to the electrification of sectors such as heating (heat pumps, district heating) and cooling (e.g. industrial refrigeration). In FEVER we will implement a comprehensive flexibility aggregation, management and trading solution that incorporates intelligence around the optimal flexibility orchestration and is capable to offer flexibility services in different markets (local, wholesale). In

addition, a peer-to-peer flexibility trading toolbox will be implemented with a distributed ledger technology enabling autonomous peer-to-peer trading. FEVER will implement a set of goal-oriented applications and tools that empower DSOs with optimal grid observability and controllability. The DSO toolbox will include advanced monitoring and automated control functions (critical event prevention, self-healing, island-mode power management, etc.). FEVER will carry out extensive demonstration and testing activities in multiple settings. For scalability assessment the project includes large scale simulations of novel market mechanisms for day-ahead and continuous trading of flexibility services, and simulations of wholesale-retail market coupling. These simulations will contribute to the quantification of the impact of flexibility services at the distribution grid level and beyond (transmission level). FEVER's holistic approach to flexibility will facilitate establishing and operating appropriate business models for all players in the market, thereby providing the EU with a secure, efficient and resilient electric grid.

EdgeFLEX:
With the dramatic growth of renewables, now is the time to revise the VPP concept. VPPs need to support not only the promotion of intermittent renewables (RES) but also the integration of all Distributed Energy Resources (DER) into the full scope of grid operations. Such a leap raises challenges: optimal combination of DER and RES in a new generation of VPPs is needed to jointly provide grid supportive flexibility with slow reaction time known from day-head and intra-day markets, as well as real-time reaction to provide fast frequency and inertial response and dynamic-phasor driven voltage control ancillary services. In a nutshell, in a DER-based power electronics-driven network VPPs need to play all the roles that synchronous machines play in a traditional system. Flexibility can be provided by going beyond electrochemical storage and exploring opportunities offered by Power2X or inverters. Demand Side Management or low-cost solutions such as Power2Heat could be deployed in a neighbourhood expanding the concept of VPPs to the concept of a Local Energy Communities. EdgeFLEX links technical solutions to societal expectations. Short reaction times can be addressed by 5G-powered edge clouds linking dispersed devices in near real-time. In this respect, a new concept of VPPs, with communications corresponding to multiple layers of dynamics, becomes possible. EdgeFLEX proposes a new architecture for VPPs deploying such a multi-layer solution, paving the way for a fully renewable energy system. VPPs are brought to a new level, enabling them to interact on markets offering various ancillary services to System Operators. EdgeFLEX will develop this next generation VPP concept and demonstrate it in the context of 3 field trials and lab tests. It will explore innovative optimisations, financial tools and business scenarios for VPPs and assess the economic and societal impact. It will actively work to remove barriers by contributing to standards and European level regulation. Remaining characters

5.5.2 Additional customers

5.5.2.1 All operators of storage heating systems

All remaining storage heating facilities (calculation goes to 250) which were not integrated in GOFLEX, yet, shall now be implemented to get an idea on the full amount of flexibility and make use of it.

5.5.2.2 PV systems of all sizes and wind generators

All remaining pv-sites and wind generators (calculation goes to 700 pv-sites and 4 windgenerators) which are not integrated in GOFLEX, yet, shall now be implemented to get an idea on the full amount of flexibility and make use of it.

5.5.2.3 Heat pumps

All 100 heat pump facilities which are not integrated in GOFLEX, yet, shall now be implemented to get an idea on the full amount of flexibility and make use of it.

5.5.2.4 CHP

All remaining CHP facilities (calculation goes to 15.000kW) which were not integrated in GOFLEX, yet, shall now be implemented to get an idea on the full amount of flexibility and make use of it.

5.5.2.5 Biomass plants

All remaining facilities on biomass (calculation goes to 3.700kW) which were not integrated in GOFLEX, yet, shall now be implemented to get an idea on the full amount of flexibility and make use of it.

5.5.2.6 AC

The ACs are not counted and registered in SWW, yet, but shall be registered and steered in the future, to get an idea on the full amount of flexibility and make use of it.

5.5.3 Invest in Storage

SWW intends to invest in battery systems of all sizes to be distributed at hotspots in the grid to optimize operation of RES, reduce power injections necessary from TSO and store energy for local balancing.

5.5.4 Business Model and Market Roll

SWW has not changed the market roll in real life, yet. But preparations are underway to define this next step to enable SWW to make monetary use of the findings and achievements out of the GOFLEX project.

6 Conclusions

With this deliverable the demo project in SWW Wunsiedel GmbH with its challenges, expectations, loads of work and experiences comes to a preliminary end. The all over solution has fulfilled the expectations to a very high degree. This is proven in the KPIs.

The results of the Cost Benefit Analysis appear very promising, even more when we consider the fact that in the project only parts of the local potential where integrated.

The consumers, prosumers and stakeholders as well as DSOs participating in the aggregation and trading of flexibility have a veritable and reliable chance of achieving new levels of business.

This technical and business approach is still far from being a turn-key solution, but the all-in-all outcomes and calculations convinced the management of SWW to decide for signing in for the period of extended observation.