D6.11 - Phase 2 Evaluation Report

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Document History

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0.1	2018-10-26	ASM	First draft TOC available
0.2	2018-12-17	UNINOVA, LINKS	UNINOVA and LINKS inputs
0.3	2018-12-20	FRAUNHOFER	Input to Professional GUI evaluation
0.4	2018-12-21	LIBAL	Input to GESSCon evaluation
0.5	2019-01-02	ALPERIA	Minor inputs and corrections
0.6	2019-01-04	FRAUNHOFER	Professional GUI Appendixes (Appendix B and Appendix C)
0.7	2019-01-21	UNINOVA	Formatting and minor corrections
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0.10	2019-01-28	UPB	Contribution to section 6
0.11	2019-01-30	LIBAL	Modification in section 2.6. Inputs to section 3.2 and 3.8.
0.12	2019-02-06	FRAUNHOFER	Corrected references in 2.4
0.13	2019-02-07	UPB	Updates on section 6
0.14	2019-02-19	LIBAL	Add comments to section 5
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0.26	2019-04-05	LIBAL	Reply to Comments on 2.6
0.27	2019-04-08	UPB	Addressed reviewer comments
0.28	2019-04-10	UNINOVA	Addressed reviewer comments and add missing sections
1.0	2019-05-02	UNINOVA	Final version, ready for submission to the EC

Internal Review History

Review Date	Reviewer	Summary of Comments
2019-04-02 (v0.20)	Michele Ligios (LINKS)	Not accepted: • The pilot's KPIs are supported through the components KPIs. However, in order to evaluate the pilots, specific pilot KPIs should be defined. • The components KPIs must be better defined with specified metrics of interest and how the current implementation fulfils the target. • At least Section 2 should be revised. • The structure of sections 4,5 and 6 should to be harmonized. • Further comments are present in the document.
2019-03-31 (v0.20)	Mihaela Albu (UPB)	Approved with recommendations: • Minor editing issues, including rephrasing for better clarity; • Recommendation to use "functionalities" instead of KPIs in sections 2 and 6. • Pointed required references
2019-04-16 (v0.28)	Michele Ligios (LINKS)	Approved under revision: • Overall the comments made in the previous revision were not addressed. However: o The test site evaluation plans will be detailed in D6.3 as well as the definition of its KPIs, while a complete and detailed evaluation of pilots will be presented in D6.12. o Components KPIs will be better specified and further refined within D6.3. • Further comments regarding the Executive Summary and the Conclusions are in their respective sections. Those comments must be addressed to have a fully accepted deliverable.
2019-04-16 (v0.28)	Mihaela Albu (UPB)	Approved: • Minor typos corrected.

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Executive Summary

This deliverable summarizes the phase 2 evaluation in all the three S4G test sites (Bolzano, Fur/Skive, and Bucharest) resulting from the planning and deployment activities.

During phase 2, it was executed the evaluation of S4G components and protypes, using the phase 2 evaluation framework and its Key Performance Indicators (KPIs). The majority of the components and prototypes were evaluated with good results, achieving the KPIs and/or the functionalities planned for phase 2.

Only one HLUC was planned to be evaluated in the Fur/Skive residential test site during phase 2. The remaining use-cases were not possible to be evaluated because core components were missing in the other test sites and planned for phase 3 (e.g. single-phase ER in the Bucharest test site; PROFEV in the Bolzano test sites). The planned HLUC-3-PUC-2: “Autonomous control of storage installed at user premises and distributed in the grid” due to the issues on the current transformer meter installation in the Fur/Skive test site. The necessary S4G components and prototypes for its evaluation were deployed and their interaction and integration were evaluated, however, due to the missing meter, it was not possible to evaluate their operation results.

All the year 2 Technical Objectives (TO) and Strategic Objectives (SO) were achieved and properly document in their respective project phase 2 prototypes deliverables, namely: D4.2 [S4G-D4.2], D4.4 [S4G-D4.4], D4.6 [S4G-D4.6], D4.9 [S4G-D4.9], D4.11 [S4G-D4.11], D5.1 [S4G-5.1], D5.4 [S4G-D5.4], D5.6 [S4G-D5.6], and D6.8 [S4G-D6.8].

This deliverable will have a final update, D6.3 – “Phase 3 Evaluation Report” (M36), where all the final S4G prototypes and test sites will be evaluated considering the final evaluation framework and KPIs, taking into account both technical and economic aspects of the use-cases and business cases defined in the project. Moreover, the last issue of this deliverable will include insight on recommendation for future pilot implementations, suggestions to changes in policies and regulations based on generated results, dedicated “views” on evaluation results and suitable to highlight relevant results and the most potentially interesting business cases for different stakeholders including at least DSOs, energy service companies interested in investing in storage aggregation, storage solutions providers.

1 Introduction

This deliverable reports the phase 2 evaluation in all three S4G test sites, resulting from the execution of tests and evaluation activities, based on year 2 evaluation framework and its respective KPIs. The following Milestones (MSs) allowed the evaluation procedure, namely:

- MS9 – "Components ready for integration in Phase 2 Test Site Platforms" was achieved with the integration of the following S4G components:
    - D4.2 – "Updated User-side ESS control system" [S4G-D4.2];
    - D4.4 – "Initial Grid-side ESS control system" [S4G-D4.4];
    - D4.6 – "Initial Cooperative EV charging station control algorithms" [S4G-D4.6];
    - D4.9 – "Updated USM extensions for Storage Systems" [S4G-D4.9];
    - D4.11 – "Initial Energy Router" [S4G-D4.11];
    - D5.1 – "Initial DSF Hybrid Simulation Engine" [S4G-5.1];
    - D5.4 – "Updated DSF Connectors for external systems and services" [S4G-D5.4];
    - D5.6 – "Initial DSF Predictive Models" [S4G-D5.6];
    - D6.8 – "Updated Interfaces for Professional and Residential users" [S4G-D6.8].
- MS10 – "Phase 2 Platform operative in test sites and ready for evaluation" was achieved after the integration of phase 2 S4G components, reported in D6.5 [S4G-D6.5].

This deliverable also reports the yearly lessons learned to facilitate the iterative process in taking re-design decisions, find solutions to errors and detected inefficiencies, identify the solutions with the highest potential for impact.

1.1 Scope

This deliverable presents the phase 2 evaluation results of Task 6.5 – "Evaluation". The final issue of this deliverable is expected on M36 (November 2019), reporting the evaluation of the final S4G prototypes.

1.2 Related documents

ID	Title	Reference	Version	Date
D2.3	Initial S4G Business Models	[S4G-D2.3]	1.0	2018-03-20
D2.5	Initial Lessons Learned and Requirements Report	[S4G-D2.5]	1.0	2017-05-30
D2.6	Updated Lessons Learned and Requirements Report	[S4G-D2.6]	1.0	2018-06-07
D4.1	Initial User-side ESS control system	[S4G-D4.1]	1.0	2017-08-30
D4.2	Updated User-side ESS control system	[S4G-D4.2]	1.0	2018-06-14
D4.4	Initial Grid-side ESS control system	[S4G-D4.4]	1.0	2018-08-30
D4.6	Initial Cooperative EV charging station control algorithms	[S4G-D4.6]	1.0	2018-08-14
D4.8	Initial USM extensions for Storage Systems	[S4G-D4.8]	1.0	2017-08-31
D4.9	Updated USM extensions for Storage Systems	[S4G-D4.9]	1.0	2018-08-31
D4.11	Initial Energy Router	[S4G-D4.11]	1.0	2018-11-02
D5.1	Initial DSF Hybrid Simulation Engine	[S4G-D5.1]	1.0	2018-02-22
D5.3	Initial DSF Connectors for external systems and services	[S4G-D5.3]	1.0	2017-09-04
D5.4	Updated DSF Connectors for external systems and services	[S4G-D5.4]	1.0	2018-09-03
D5.6	Initial DSF Predictive Models	[S4G-D5.6]	1.0	2018-08-30
D6.2	Phase 2 Test Site Plans	[S4G-D6.2]	1.0	2018-12-28
D6.5	Phase 2 Test Site Platforms and Deployments Report	[S4G-D6.5]	1.0	2018-12-28
D6.7	Initial Interfaces for Professional and Residential users	[S4G-D6.8]	1.0	2017-08-31
D6.8	Updated Interfaces for Professional and Residential users	[S4G-D6.9]	1.0	2018-08-23
D6.10	Phase 1 Evaluation Report	[S4G-D6.10]	1.0	2018-05-02

2 Evaluation of the phase 2 S4G components

This chapter presents the evaluation of the S4G components developed and deployed during phase 2, reported in D6.2 [S4G-D6.2] and D6.5 [S4G-D6.5].

2.1 Control broker

This component is located in the **communication layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated according to the KPIs associated with the goals defined as follows:

- Interconnections:
    - Enables DSF and GESSCon to send control related messages.
    - Receives and sends MQTT messages to subscribers waiting messages from the publishers (e.g. DSF, PROFESS/PROFEV). The data rate depends on the publishers.
- Security:
    - Security mechanisms are applied for access control.
- Persistence:
    - Persistence mechanisms are applied to overcome intermittent connectivity.

The mosquitto Control broker is the tool in charge of delivering the MQTT control messages sent by the applications towards the deployed sensors. It is installed on the DSF server inside the Virtual Private Network (VPN) setup to support resources interconnectivity. In order to guarantee the privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured with the following functionalities:

- *Data persistence:* in case of intermittent subscribers, an autonomous reply mechanism is applied.
- *Confidentiality:* the interactions with the current component are possible only by exploiting the digital certificate produced in the current project.
- *Privacy:* the reading and writing features within the selected broker are possible in compliance with the applied Access Control List defined accordingly to each resource role.

In phase 2 of the S4G project it has been evaluated the Control broker component by exploiting its delivery mechanism to send ad-hoc messages from a cloud publisher to client applications running on the Aggregator device of interest on the Edge layer.
The evaluation took place by using two open source tools used to *inject* and to *catch* MQTT messages, called respectively mosquitto_pub and mosquitto_sub. The mosquitto_sub software is deployed in one Aggregator and a mosquitto_pub software instance is deployed in the DSF cloud server.

The steps for the evaluation of the interconnections were the following:

1. Deployment of Control broker mosquitto software in the DSF cloud server.
2. Deployment of mosquitto client (subscriber) software in a device configured with suitable authentication.
3. Deployment of mosquitto client (publisher) software in a device configured with suitable authentication
4. By exploiting the mosquitto publisher software, send an MQTT message.
5. Check that the mosquitto subscriber software receives the MQTT message.

The interconnection evaluation lead to a KPI of 100% of success about the delivering mechanism of the MQTT messages concerning a receiver density involving less than 100 devices with a maximum rate of 1 control message per device every second.

The steps for the evaluation of the security mechanisms, after the interconnection's ones, were the following:

1. Deployment of mosquitto client (subscriber) software in a device configured with wrong or no authentication.
1. By exploiting the mosquitto publisher software, send an MQTT message.
2. Check that the newly deployed mosquitto subscriber software does not receive the MQTT message.

The security mechanisms evaluation lead to a KPI of 100% of success about the access control mechanism applied on the MQTT broker. None of the unauthorized user or application can catch any message from it.

The steps for the evaluation the persistence mechanisms, after the security ones, were the following:

1. Deployment of mosquitto client (subscriber) software in a device configured with suitable authentication and Quality of Service enabled.
2. Disconnect the mosquitto client from the Control broker.
3. By exploiting the mosquitto publisher software, send an MQTT message.
4. Connect again the mosquitto client to the Control broker
5. Check that the subscriber just connected receives the MQTT message temporarily stored on the Control broker.

Concerning a stable deployment where both software and hardware are not led to starvation of resources, the persistence mechanisms evaluation lead to a KPI of 100% of success about the persistence mechanisms applied on the MQTT broker.

2.2 Data broker

This component is located in the **communication layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated according to the following goals:

- Interconnections:
  - Enables Physical and Device layer components to send USM data related messages.
  - Receives and sends MQTT messages to subscribers (e.g. DSF-DWH) waiting messages from the publishers (USM devices). The data rate depends on the SMX (2 to 5 seconds).
- Security:
  - Security mechanisms are applied for access control.
- Persistence:
  - Persistence mechanisms are applied to overcome intermittent connectivity.

The mosquitto Data broker is the tool in charge of delivering the MQTT messages sent by the applications producing data towards the DSF-DWH cloud database. It is installed on the DSF server inside the VPN setup to support resources interconnectivity. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured with the following functionalities:

- *Data persistence:* in case of intermittent subscribers, an autonomous reply mechanism is applied.
- *Confidentiality:* the interactions with the current component are possible only by exploiting the digital certificate produced in the current project.
- *Privacy:* the reading and writing features within the selected broker are possible in compliance with the applied Access Control List defined accordingly to each resource role.

In phase 2 of the S4G it has been evaluated the Data broker component by exploiting its delivery mechanism to forward messages from Edge layer devices to the cloud Datawarehouse (DSF-DWH). The evaluation took place exploiting the OGC Wrapper and the telegraf plugin, part of the InfluxDB Tick Stack providing an interface to inject messages in the DSF-DWH.

The steps for the evaluation the interconnections were the following:

1. Activation of the telegraf tool integrated with the InfluxDB.
2. Activation of the OGC Wrapper tool deployed in one Aggregator.
3. Check that from the first message intercepted by the OGC Wrapper, its autonomous forwarding mechanisms permit the delivery of sensor data.
4. Check that the InfluxDB receives the sensor data produced.

The interconnection evaluation lead to a KPI of 100% of success about the delivering mechanism of the MQTT messages concerning a sender density involving less than 100 devices with a maximum rate of 1 data message per device every two second.

The steps for the evaluation the security mechanisms, after the interconnection's ones, were the following:

1. Deployment of mosquitto client (subscriber) software in a device configured with wrong or no authentication.
2. By exploiting the OGC Wrapper software, send an MQTT message.
3. Check that the newly deployed mosquitto subscriber software does not receive the MQTT message.

The security mechanisms evaluation lead to a KPI of 100% of success about the access control mechanism applied on the MQTT broker. None of the unauthorized user or application can catch any message from it.

The steps for the evaluation the persistence mechanisms, after the security ones, were the following:

1. Deployment of mosquitto client (subscriber) software in a device configured with proper authentication and Quality of Service enabled.
2. Disconnect the mosquitto client from the Data broker.
3. By exploiting the OGC Wrapper software, send an MQTT message.
4. Connect again the mosquitto client to the control broker.
5. Check that the subscriber just connected receives the MQTT message temporarily stored on the Data broker.

Concerning a stable deployment where both software and hardware are not led to starvation of resources, the persistence mechanisms evaluation lead to a KPI of 100% of success about the persistence mechanisms applied on the MQTT broker.

2.3 OGC Sensor Things Server

This component is located in the **communication layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated according to the following goals:

- The server provides mechanisms for discovery of resources and services.
- Registration of new OGC entities.
- OGC entities describing S4G components are available.
- Other S4G components are able to query the S4G OGC Server and get previously registered entities trough dedicated APIs.

The OGC Sensor Things Server is the tool in charge of managing the identity of the resources available in the S4G network. It is installed on the DSF server inside the VPN setup to support resources interconnectivity. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the OGC Sensor Things Server component by exploiting its resources catalogue mechanism to properly identify resources in the network. The evaluation took place exploiting the OGC Wrapper tool.

The steps for the evaluation of the KPIs were the following:

1. Deployment of the OGC Server.
2. Activation of the OGC Wrapper tool deployed in one Aggregator.
3. The OGC Wrapper starts the registration in compliance with the defined ontology exploiting proper configuration files.
4. By using a browser from an enabled device, connect to the OGC web interface and retrieve the information just provided by the OGC Wrapper.
5. By restarting the Aggregator, the repetition of the OGC Wrapper registration will not generate new resources in the catalogue.

This evaluation lead to a KPI of 100% of success about the goals of interest (registration and discovery of services) concerning the current component.

2.4 Professional GUI

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Fur/Skive** test site, and to be evaluated in 3 tracks as follows.

- The number of implemented requirements to evaluate the range of functionality derived from previous user tests and interviews (listed as following KPIs).
- Evaluating the overall system usability with quantitative measures (listed as following KPIs).
- Evaluating the system usability with qualitative feedback to get more insights on additional functionalities / application domains / etc.

The professional GUI does not do computations. It enables end-users to insert data and interact with the DSF-SE. The displayed information is mainly computed in the simulation engine; therefore, the focus of the defined KPIs for the professional GUI lies on the usability, as well as the user experience. Evaluating technical KPIs with the professional GUI is not feasible, since those KPIs should be fulfilled by the DSF-SE.

The following KPIs will be evaluated using the previously described methodology:

- 50% of specified requirements (i.e. 100% of the requirements specified for year 2 and documented in Jira) are implemented (see 1).
- From the expert evaluation (evaluation done with professionals from the usability and user experience domain, but no energy domain experts or end-users) using the 7 dialog principles of the ISO 9241-11 as heuristics, only 15% of found incidents are highly critical incidents (applying a 5-scale rating system ranging from 0 - no usability issue to 4 - highly critical incident).
- Applying the System Usability Scale (SUS) questionnaire to end-users, the outcome of the overall system usability will be at least 68 or higher (on the SUS, 68 classifies a software system as "good").

The goal of the previous described evaluation was to evaluate the usability of the professional graphical user interface (GUI) and the implemented functionality. Usability describes the “extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO 9241-210, 2010[i]).

Therefore, the actual state of the developed prototype of the professional GUI was considered. The low/mid-fidelity prototype was used to find out, if there are some interface flaws, which would prevent the users from

completing their work tasks. The main focus was to identify if the system is suitable for performing specific tasks of a grid planner and if the GUI is according to the users' expectations.
Aspects of the interface design that need to be improved because they appear confusing or misleading have been identified. In addition, it was investigated what works well with the developed interface design so that it could be ensured that these identified features would not be changed.

2.4.1 Methods & KPIs

For the evaluation various analyses were carried out. On the one hand, the implemented functional scope on the basis of the existing requirements (section 2.4.2) was analysed. On the other hand, tests with usability experts (section 2.4.3) and end-users (section 2.4.4) were conducted to detect usability problems. In particular, the end-user tests were helpful to examine the suitability of the GUI for performing tasks. From the observations and feedback of the users, important insights have been gained. The participants also completed a questionnaire - the SUS - to evaluate the interaction with the system. It was important to collect both qualitative and quantitative data.

Quantitative data is suitable for benchmarking a piece of software; therefore, the SUS questionnaire was used, as this works well with a low number of tested individuals. In the case of the professional GUI evaluation, four tests were conducted. The SUS allows to identify whether a system has a bad or a good usability based on a single percentile score.

Qualitative data allows a more explorative evaluation. In addition to using only quantitative data, identified usability problems can be described, their origin can be observed, and a potential solution can be discussed with the user or system design expert who identified the problem.
As already mentioned in D6.10 [S4G-D6.10], various KPIs were defined, which were further used to measure the level important objectives and critical success factors are achieved through iterations.
The level success factors of the evaluation of the current iteration have been fulfilled can thus be compared after as final iteration by the end of phase 3. Table 1 lists the methods used and the associated KPIs. In addition, it is noted if qualitative data were also collected.

Table 1. Methods, KPIs and qualitative data.

Methods	**Defined KPIs**	**KPI achievement**	**Additional qualitative data**
Analysis. Number of implemented requirements	50% of total specified requirements and 100% of the requirements for year 2 should be implemented (as documented in Jira and in D2.5 [S4G-D2.5] and D2.6 [S4G-D2.6)	Achieved	-
Heuristic Evaluation. Usability experts evaluate the system on the basis of approved design principles	Using the seven dialog principles of the ISO 9241-110 as heuristics, only 15% of found incidents are highly critical incidents (applying a 5-scale rating system ranging from 0 - no usability issue to 4 - highly critical incident)	Not achieved (17.46%)	-

End-user Test	System Usability Scale (SUS)[ii] questionnaire with end-users, the outcome of the overall system usability will be at least 68 or higher (on SUS, 68 classifies a software system as "good"[iii,iv])	Achieved. SUS score = 76,25 (n=4)	Thinking-Aloud, Observation, Feedback,

2.4.2 Functionality

The implemented requirements are assessed in order to evaluate the range of the planned functionality of the software derived from previous user tests and interviews. To determine the implementation status of the requirements, the issue tracking platform JIRA is used. The S4G consortium documents requirements as well as user stories, tasks and bugs on this platform to allow a consistent tracking and maintenance throughout the project.

It was defined as a KPI that 50% of the total specified requirements and 100% of the requirements attributed to phase 2 and assigned to the Professional GUI Component should be implemented.
Out of 18 requirements, 4 were identified as potential duplicates; therefore, three of the four requirements got discarded due to similar content until their formulation is reworked in phase 3. The respective requirements, which are further described, are S4G-15, S4G-44, S4G-56, and S4G-309. Out of the four, only S4G-56 was used for evaluation. As show in Appendix A, 15 valid requirements were taken into account for the overall Professional GUI evaluation.

Since maintaining the Volere requirements is an iterative process in the S4G project, the status, detail and assignee of requirements may change over time, changing the scope of necessary implementation work per component. This also happened near the end of Phase 2, where the goal of having implemented 100% of the Phase 2 requirements and 50% of all requirements relevant for the professional GUI was achieved – based on the available grid and data models at that time. Due to the ongoing project work, some of the models and responsibilities changed in the meantime, rendering 4 of the respective requirements as being potential duplicates (S4G-15, S4G-44, S4G-56, and S4G-309), not being or being only partially implemented with respect to the newly available data (S4G-31, S4G-23). However, out of 15 requirements relevant for the professional GUI, 7 were marked as being implemented by the end of Phase 2. Several of the requirements were already partially implemented; however, the requirements workflow does not allow for reporting or marking a partial implementation as a success. Despite that, the goal defined by the KPIs (50% of the overall requirements, 100% of Phase 2 requirements) has been achieved.

2.4.3 Expert Evaluation Results

In order to uncover fundamental usability problems, an expert evaluation was carried out. The developed GUI was evaluated by usability experts using established usability principles in the form of heuristics. In this case, experts are professionals from the usability area excluding specialists from the energy domain or end-users.
The evaluation was carried out by five experts, as it is assumed that they can detect 75% of the problems[v].

Since the usability experts do not have the necessary expert knowledge, the usability problems are identified independently of context and task. Therefore, the experts captured potentially critical usage situations - means critical situations that an end-user can potentially experience while interacting with the system. These potentially critical usage situations were identified and classified with the help of heuristics. The seven dialogue principles of the ISO 9241-110 were used for this evaluation:

1. Suitability for the task.

2. Self-descriptiveness.
3. Conformity with user expectations.
4. Suitability for learning.
5. Controllability.
6. Error tolerance.
7. Suitability for individualization.

2.4.3.1 Procedure

At the beginning, the experts received general information about the S4G project and about the work of a grid planner.
Afterwards they were given the catalogue of criteria (description of the seven dialogue principles ISO 9241-110) and a table in which they could write down the potentially critical usage situation, the assignment to one or more dialogue principles and a classification of the severity of the usability problem. In addition, they were able to document the positive properties of the GUI in another table.
For the classification of the severity they were given the scheme[vi] shown in Table 2.

Table 2. Severity of the finding.

Rating	Description
0	No usability problem
1	Cosmetic problem only (need not be fixed unless extra time is available on project
2	Minor usability problem: fixing this should be given low priority
3	Major usability problem: important to fix, so should be given high priority
4	Usability catastrophe: imperative to fix this before product can be released

More details about the expert evaluation can be found in the following sections.

2.4.3.2 Descriptive data

After conducting five expert evaluations, the results were summarized in a comprehensive table (see Appendix B). Double findings were consolidated. The prioritization of the incidents was finally revised according to the project objective and scope. A total of 74 incidents were uncovered. 11 findings were excluded from the analysis because they related to bugs, functionalities that were only implemented as mock-ups, no usability problems or were out of the project's scope.
The percentage distribution of the 63 relevant findings on the dialogue principles can be seen in Table 3 and the distribution on the severity level (1 – 4) in Figure 1.

Table 3. Percentage distribution of the dialogue principles among the 63 findings.

Dialogue principles	Percentage (%)
Conformity with user expectations	28.26
Self-descriptiveness	27.17
Suitability for the task	25.00
Suitability for learning	5.43
Controllability	2.17
Error tolerance	12.00
Suitability for individualization	0.00

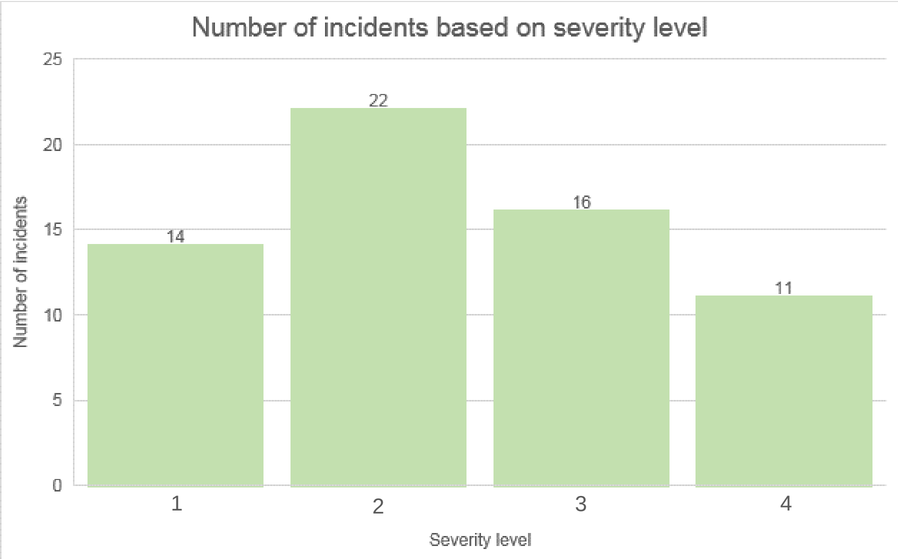

Figure 1. Number of incidents based on severity level.

Of the 63 relevant findings, 11 were rated as "4 – Usability catastrophe". The percentage distribution among the dialogue principles can be seen in Table 4. It should be noted that an incident could be assigned to several dialogue principles.

Table 4. Percentage distribution of the dialogue principles among the 11 critical incidents.

Dialogue principles	Percentage (%)
Suitability for the task	37.50
Error tolerance	25.00
Conformity with user expectations	18.75
Self-descriptiveness	18.75

2.4.3.3 Results

As KPI it was determined that less than 15 % of the findings should be classified as very critical (severity level 4 on a scale of 0 – 4). However, the result of the expert evaluation shows a percentage of 17.46% of the findings classified as very critical.
Particularly with regard to the adequacy of the tasks, critical situations were uncovered by the usability experts. However, this could be attributed to the fact that the prototype's functionality is still limited in phase 2, as the experts used the system in an explorative way rather than using pre-defined tasks. They were only instructed about typical grid planner tasks so that they could better understand the workflow. After reviewing the findings, they can be categorized with reference to the interface elements as shown in Table 5.

Table 5. Categories, total amount of incidents, critical incidents.

Categories	Total amount of incidents	Critical incidents (rated with 4)
Visualization and selection of radials	5	0
Simulation window	9	2
Results	6	1
Elements (visualization, data, interaction)	8	2
Insert elements	11	5
Representation of the grid	5	0
Tools / Modes	4	0
Search	4	0
Settings, Login, Save	7	1
Basic interaction options	4	0
Sum	63	11

Table 6 lists the critical incidents with a recommendation.

Table 6. Critical incidents and a recommendation.

Graphical functionality	Critical Incidents	ID	Dialogue Principle	Recommendation
Simulation window	Distance between number input fields is small. "Duration" text overlaps with arrow button	CI_2018/11_009	Self-descriptiveness, Suitability for the task	Input fields should be clearly identifiable and indicate which input they require. Keep sufficient distance
	There is no error message when a wrong (empty) radial is selected	CI_2018/11_016	Error tolerance, Suitability for the task	Output error message
Results	After having done a simulation, when the numbers are changed in order to make a new	CI_2018/11_023	Self-descriptiveness, Conformity with user expectations	Only update when the next simulation has been run, perhaps a history is also useful.

	simulation, the old "Simulation finished" message gets updated live, even though no new simulation was made			
Elements	No reverse function available	CI_2018/11_028	Error tolerance	Implement an "undo" function: Similar to the browser function "back".
Insert Elements	An added item cannot be easily removed.	CI_2018/11_030	Error tolerance, Suitability for the task	Implement a "delete" function: A (right) click on the icon should open a context menu with a delete function. Alternatively, there could be a delete symbol (eraser or trash can) in the tool selection.
	Elements cannot be selected to view additional context information	CI_2018/11_045	Suitability for the task, Conformity with user expectations	A click on an element should display its properties or open a context menu. (e.g. battery model)
	The user does not recognize that an item has been successfully added because the icon does not stand out well from the background or no feedback message appears.	CI_2018/11_034	Self-descriptiveness	The colour should stand out more from the background, possibly a textual feedback in the form of a push notification that does not have to be confirmed.
	The Cancel button does not work when adding an element	CI_2018/11_035	Error tolerance	Battery icon must not be displayed if Cancel was clicked
	When wanting to create a battery, cursor is on one node, but the next node gets highlighted.	CI_2018/11_039	Conformity with user expectations	Increase sensitivity of nodes. If needed, create a connection to a node afterwards. Incorrect entries should be easy to correct.
	When creating elements, no further data such as size/capacity/number of persons in the house/other can be entered.	CI_2018/11_049	Suitability for the task	When adding, it should be possible to add profiles for the respective elements. Integrate into the dialog.

				Should be changeable after initial setting.
Settings, Login, Save	When you leave the map (to the settings), everything is reset to its initial state.	CI_2018/11_069	Suitability for the task	It should be possible to switch to settings without losing the current workspace. The reverse function should also still be possible.

2.4.4 End-user Test

Three professional grid planners from EDYNA and three grid planners from ENIIG took part in the end user study. The user study was conducted as a remote test. The online meeting tool GoToMeeting was used. The test leader shared his screen and the user could interact with the system using the conductor's mouse and keyboard. The speech and the screen were recorded. The participants had to sign a consent form in advance (see Appendix B and Appendix C). Further details on the end-user test can be found in the following sections:

- Procedure
- GUI changes
- Sample
- Results
- Quantitative evaluation of the interaction with the professional GUI
- Limitations

2.4.4.1 Procedure

First the moderator welcomed the participants and gave some fundamental information about the test session. The moderator used a script for the explanation because of standardization and to ensure that nothing will be missed out. The explanation includes information about:

- the importance of their attendance and honest feedback
- the role of the moderator
- thinking aloud
- prototype with limited functions
- recording system
- process of test session

After the introduction the users were asked to complete four different tasks (see Table 8) using the developed prototype. To obtain feedback from the users, they were asked to think-aloud during the session. The think-aloud method requires participants thinking aloud as they perform a particular task. The respondents are asked to say everything what they are thinking, looking at, doing and feeling while they are working on the task. This process gives observers the opportunity to gain first-hand data on the human processing process of a task.
At the end of the test session they filled out the SUS and answered some interview questions. At the end, the moderator thanked the participants and said goodbye.

2.4.4.2 GUI changes

A partially agile approach was applied. This means that usability problems that hindered users from completing tasks to a great extent were fixed between the test sessions to allow for the detection of less severe, but relevant issues which might have been hidden by very distinct and obvious problems.
Three design problems were adapted during the tests (see Figure 2 and Figure 3). First, the simulation window was redesigned because the time entry function was not clear. Second, problems arose when the application

window was maximized, because the whole screen could only be viewed by scrolling. Therefore, the simulation area was displayed as a side panel instead of a window.
Third, the search bar was adjusted because it was not clear what could be searched for. By doing this, it was possible to verify whether a search for a node ID was expected due to the misleading design of the search bar or whether there was a requirement from professional users beyond that.

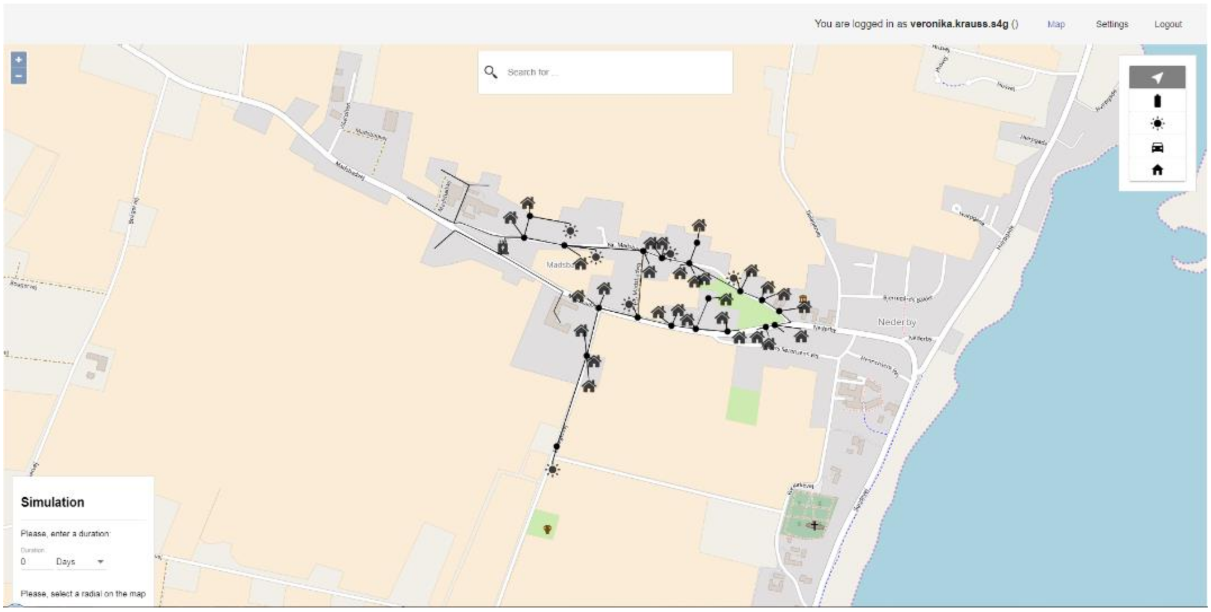

Figure 2. Previous version of the professional GUI (the "Simulation window" was only displayed halfway when the window was maximized, meaning of the labels of the input fields were not clear, the input of the simulation time was perceived as misleading, search bar was labelled with "Search for").

Figure 3. Adapted Version of the professional GUI ("Simulation" is now a side panel, input fields have been renamed, input fields were restructured, search bar was labelled with "Search for a city").

2.4.4.3 Sample

Table 7 shows the descriptive data of the sample. The sample consisted of 6 professional users.

Table 7. Descriptive Date of the sample.

Collected characteristic	Collected data
Age	29 – 43 (average = 36) years
Working Experience	2 – 11 (average = 6) years
Gender	Male (all 6 attendees)

A user (user02) has used a projector to be able to work on a larger screen. However, the resolution was changed so that he could not see the left side of the window completely. Therefore, the second task could not be solved without troubleshooting and hints from the moderator.

For another participant (user04), the simulation results could not be displayed because there was no authorization for the user. This error occurred during three sessions (user03, user04, user06). But only for one user (user04) it could not be fixed during the test, so that the user could not solve the second and following tasks, because he did not get any simulation results. In order to be able to recognize this error better, an error message should be displayed here if the authorization is missing.

Furthermore, a test session (user06) was performed as a focus group, as there were misunderstandings regarding the test procedure and several people were present. In order to use the time efficiently, the comments of all present were recorded. The test participant IDs were randomly assigned so that no conclusions can be drawn about the person.

2.4.4.4 Tasks

Within the user test, the participants were asked to complete the tasks described in Table 8.

Table 8. Tasks and number of users.

Task	Numbers of users
1. Login 1.1 Enter username 1.2 Enter password 1.3 Login (press button) 1.4 Privacy	6
2. Run a Simulation 2.1 Enter a time unit 2.2 Enter a period 2.3 Select a radial 2.4 Run Simulation (Button)	6
3. Analyse simulation results 3.1 Identify the textual and visual results 3.2 View node details 3.3 Interpret node details	5 (user01, user02, user03, user05, user06)
4. Place a storage in the grid 4.1 Identify a specific node 4.2 Identify interaction bar 4.3 Place a battery	4 (user01, user02, user03, user05)

When interpreting the findings, it should be noted that the absence of an incident from a user does not mean that he did not have this problem, but rather that he did not actively express it, or the observer did not notice it.

2.4.4.5 Results

Nothing remarkable could be noted regarding the login. The only findings of the observations were that the font size might be too small, since incorrect entries cannot be easily recognized on a small screen.
No problems could be identified with the display and confirmation of the privacy window.

For running the simulation, it turned out that after adjusting the input fields (see section 2.4.4.2) the users understood better what is needed. However, it was not always obvious to them that they first had to select a radial. The hint "Please select a radial on the map" was not recognized directly by all users.
In addition, it was noted that the database on which the simulation is based cannot be identified.
The result presentation showed that the users were able to identify the green and red nodes well and could also recognize that the red nodes are the critical ones.
It was clear to the users that they could see more information by clicking on a node or other element.
Regarding the node details, users could identify the displayed values as voltage. However, users reported that they did not understand the meaning of the values (i.e. absolute value or percentage).
They reported that the data they were shown was not sufficient to make a qualified decision. They miss data on

- Current
- Losses (one user reported this)
- Cable characteristics (distance, size, material)
- Profiles of photovoltaic systems, electric cars, households
- Balance of the Grid
- Maximum and minimum voltage level for each node

They would also like to know the reason "Why" – means that they want to know why there is a problem. In addition, they do not want to see the voltage of households, but rather the profiles (active/passive customer, consumption in kilowatts).
They also found it difficult to identify the transformer and want to be able to see more information about it.
They would also like to be able to work more flexibly with the grid - i.e. place houses where they really need to be (among other things to enter the length of the cables correctly), install new nodes, install new transformers, lay cables and, if necessary, connect to neighbouring networks.
Users have expressed positive views on the insertion of elements into the grid. They found it very intuitive and simple. They complained that they could not successfully cancel the insert dialog and could not delete added elements. In addition, users had problems marking the correct node. They want a more flexible interaction (e.g. change a connection if an incorrect entry was made). They also found it difficult to tell if an element had been successfully added. In addition, they reported that they would like to search for the ID of a node, as it is too complicated to find this information by clicking (too many nodes in a grid). It should be noted, however, that the identification of a specific node was required by the task. It has to be verified if the need really exists.
All in one, some users reported that they found the system easy to use, inserting elements and performing a simulation did not seem difficult for them. This opinion is also reflected in the analysis of the SUS-questionnaire, as shown in the following sections.

2.4.4.6 Quantitative evaluation of the interaction with the professional GUI

SUS consists of ten items and is answered on a 5-point Likert scale from 1 - “strongly disagree” to 5 - "strongly agree".
The questionnaire was only filled in by 4 users. As previous described, one user (user 04) did not get simulation results and another user did not interact with the system independently (several people were involved), and therefore in both cases there was not sufficient interaction with the system.
However, since it is generally very difficult to acquire end-users because the number of available grid planners is very small, the SUS value was calculated anyway, but should be interpreted with caution.
The average SUS score (n=4) is 76.25. A SUS score above 68 was defined as meeting the KPI defined as “professional end-user acceptability is good”; this is above the average value and can therefore be regarded as acceptable [iii]. According to the evaluation Table 9, the value achieved in the study can be considered as "good" [iii,iv].

Table 9. SUS interpretation.

<table>
<tr><th>Raw SUS Score</th><th>Grade Scale</th><th>Acceptability Range</th><th>Adjective</th></tr>
<tr><td>90-100</td><td>A</td><td rowspan="3">Acceptable</td><td>Best imaginable</td></tr>
<tr><td>80-90</td><td>B</td><td>Excellent</td></tr>
<tr><td>70-80</td><td>C</td><td>Good</td></tr>
<tr><td>60-70</td><td>D</td><td rowspan="2">Marginal</td><td rowspan="2">OK</td></tr>
<tr><td>50-60</td><td>F</td></tr>
<tr><td>40-50</td><td rowspan="5"></td><td rowspan="5">Not acceptable</td><td rowspan="2">Poor</td></tr>
<tr><td>30-40</td></tr>
<tr><td>20-30</td><td rowspan="3">Worst imaginable</td></tr>
<tr><td>10-20</td></tr>
<tr><td>0-10</td></tr>
</table>

2.4.4.7 Limitations

When assessing the validity of a remote test, it must be considered that the test conditions can only be standardized to a certain extent. The tests showed that the participants were usually not completely undisturbed, had different screen sizes or only a small screen available.
Many of these disruptive factors cannot be eliminated before or during the conduct of a remote test or even detected. In addition, the occurrence of technical faults can never be excluded (slow Internet connection, audio transmission, etc.).

2.5 DSF-SE

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Fur/Skive (residential)** test site, and to be evaluated according to the following KPIs:

- Presents an API for inserting a topology for the simulation and for running a simulation.
- Interconnects with the Professional GUI, receiving a topology for the simulation and sending back the simulation results.

The DSF-Simulation Engine (DSF-SE) was deployed on a server at Fraunhofer FIT dependencies using the architecture shown in Figure 4.

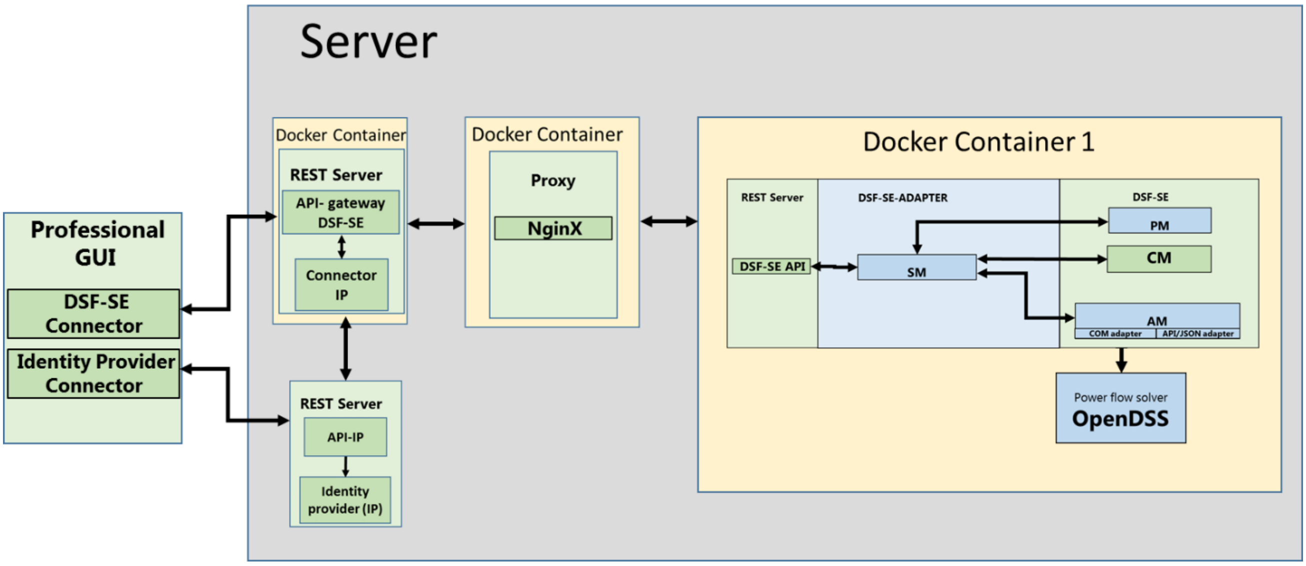

Figure 4. Phase 2 deployment architecture of DSF-SE.

The Linksmart Border Gateway together with the Keycloak agent were used for accomplishing authentication and some authorization tasks. If the authentications and authorization are done successfully, the requests are passed by to the nginx proxy. It will be in charge of managing the requests and accessing the DSF-SE API.

This architecture was evaluated by FIT together with the Professional GUI (described in section 2.4). For this evaluation, different clients were introduced manually into the Keycloak agent. The users, who tested the Professional GUI, could access to the GUI and run a simulation because they provided the correct login information. In this case, the Professional GUI got from the Keycloak agent a token, which was sent to the Border Gateway together with the request. The Border Gateway connected to the Keycloak API and requested the veracity of the token. If the token was correct, the Border Gateway provides access only to the necessary endpoints for running the simulation. This process worked successfully with the different users.

For running a simulation, the Professional GUI used the DSF-SE API. It means that the Professional GUI sent the grid topology to the DSF-SE using the “simulation” endpoint and after that, started a simulation using the “commands” endpoint of the API. This process worked also successfully while testing the Professional GUI (section 2.4), presenting the real results of the DSF-SE simulation.

2.6 GESSCon

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bolzano** test site, and to be evaluated according to the following KPIs:

- Receives data from the Data Broker.
- Exchanges data with the DSF.
- Sends Charge Schedule to PROFESS.

GESSCon is a software module running in LiBal’s Cloud. It takes forecast input and real-time input from DSF and SMX (ESS) respectively and generates an optimal ESS operation suggestion as output to PROFESS. There are connectors built outside the GESSCon core software to take care of all the input and output data, which not only can fetch data, also can format different input data into the readable format for the core GESSCon program. GESSCon fetches its input data from various data sources (DSF, Data Broker), the GESSCon core computes charging/discharging setpoints and publishes the generated setpoints via the Control Broker. The GESSCon core program is described in D4.4 [S4G-D4.4].

GESSCon uses the previous mentioned data source systems to generate PROFESS setpoints. It orchestrates its behaviour as follows:

1) All GESSCon participating test sites are determined using the OGC Server. This is achieved through an OGC Data request and filtering on the datastream name to contain the keyword "chunk_Control".
2) For each GESSCon instance:
   a) Fetch raw site data: Electricity prices, Demand (load and EV) and PV is collected from the DSF connectors. Moreover, a sample is collected from the Data Broker to obtain SoC.
   b) The raw data is aligned by resampling to required output timestamps. The alignment is done using Python Panda.
   c) The core software is implemented using Pyomo library. The aligned data is therefore adapted into pyomo compliant data model structure.
   d) The Pyomo data model is input to the GESSCon algorithm which solves the equations to generate the chargeschedule setpoints.
   e) The chargeschedule setpoints are converted to PROFESS compliant ESS control setpoints.
   f) Finally, the ESS control setpoints are delivered via the Control Broker.
   g) Save datapacket to Azure File storage for later evaluation (an example is shown in Appendix D).

2.7 DSF-DWH

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites in data collection, and to be evaluated according to the following goals:

- Collect S4G components data from pilots.
- Receives data from Data Broker at a rate of 2 to 5 seconds for each SMX involved.
- Data is stored accordingly to a timestamp provided by the SMXcore.
- Generates email alerts when data has not arrived for 10 minutes, concerning each SMX stream.

The DSF-DWH is the tool in charge of managing the collection of data produced by the resources available in the S4G network. It is installed on the DSF server inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices using the appropriate authentication providing username and password enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the DSF-DWH component. The evaluation took place exploiting the OGC Wrapper tool, the Data Broker and the DSF-DWH connector.

The steps for the evaluation of the DSF-DWH were the following:

1. Activation of the OGC Wrapper tool deployed in one Aggregator.
2. The OGC Wrapper start the data forwarding mechanism.
3. By using a browser from an enabled device, connect to the DSF-DWH connector (chronograf) interface and retrieve the information sent by the OGC Wrapper.
4. By stopping the OGC Wrapper forwarding mechanism, the DSF-DWH sends an alerting email specifying that the known streams are no more active.

This process led to the evaluation of two main KPI concerning the current component:

- Persistent collection of data (100%): it stores all the incoming messages and provides ways to retrieve these ones.
- Alerting mechanism (100%): it constantly monitors all the incoming streams and when a known one stops, after 10 minutes raise the email alert accordingly.

2.8 GridDB connector

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, providing grid related information of the **Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Grid model is available and other S4G components can download its content through dedicated REST APIs.
- This component works under request.

The GridDB connector is the tool in charge of providing the grid structure about the resources available in the S4G network. It is installed on the DSF server inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the GridDB connector component. The evaluation took place exploiting a web browser from a device enabled in the VPN.

The steps for the evaluation of the DSF-DWH were the following:

1. Activation of the GridDB connector.
2. By using a browser from an enabled device, send an HTTP GET request towards the web connector and retrieve the information of interest.

This evaluation lead to a KPI of 100% of success about the goal of interest (retrieval of grid related information) concerning the current component.

2.9 Energy Price connector

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, providing energy prices related information of the **Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Energy prices are available and other S4G components can download its content through dedicated REST APIs.
- This component works under request.

The Energy Price connector is the tool in charge of providing energy pricing values, from the wholesale market, of the S4G test sites locations. The DSOs analysed within S4G do not offer online time variant pricing schema. Currently, they still rely on fix tariffs, consequently, to achieve a unified pricing schema, spot market pricing was proposed.

The developed connector embeds in every response the information required to properly characterize the market of interest such as the currency and the measurement unit.

The energy price connector is installed on the DSF server inside the VPN. In order to guarantee the necessary privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the Energy Price connector component. The evaluation took place exploiting a web browser from a device enabled in the VPN.

The steps for the evaluation of the DSF-DWH were the following:

1. Activation of the Energy Price connector.
2. By using a browser from an enabled device, send an HTTP GET request towards the web connector and retrieve the information of interest.

This evaluation lead to a KPI of 100% of success about the goal of interest (retrieval of energy price related information). This evaluation is only valid in case of reachability of the thirty-party service exploited to gain the proper data[vii].

2.10 Fronius cloud connector

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, providing hybrid Fronius system related information of the **Bolzano, and Fur/Skive** test sites devices, and to be evaluated according to the following goals:

- Reads real-time data from the Hybrid Fronius system through the Solar WEB API.
- Forwards data towards DSF-DWH every 2 seconds.

The Fronius cloud connector is the tool in charge of providing Fronius related values about the deployment of interest in the S4G network. It is installed on the DSF server inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to directly forward its data towards the DSF-DWH exploiting the MQTT Data Broker.

In phase 2 of the S4G project it has been evaluated the Fronius cloud connector component.

The steps for the evaluation of the Fronius cloud connector were the following:

1. Activation of the Fronius cloud connector.
2. It starts the requesting mechanisms to the Solar WEB API and it forward all the received data towards the Data broker and consequently to the DSF-DWH.

This evaluation lead to a KPI of 100% of success about the goal of interest (retrieval of Fronius system real-time information). This evaluation is only valid in case of reachability of the thirty-party service, exploited to gain the proper data[viii], together with the reachability of the entire chain of elements involved in the Fronius system.

2.11 Weather forecast for PV production connector

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, PV forecast production of the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- PV forecast production can be retrieved by any S4G component.
- Exposes cloud density and temperature information through dedicated REST APIs.
- This component works under request.

The Weather forecast for PV production connector is the tool in charge of providing forecasting values within the locations of interest in the S4G network. It is installed on the DSF server inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the Weather forecast connector component. The evaluation took place exploiting a web browser from a device enabled in the VPN.

The steps for the evaluation of the Weather forecast were the following:

1. Activation of the Weather forecast connector.
2. By using a browser from an enabled device, send an HTTP GET request towards the web connector and retrieve the information of interest.

This evaluation lead to a KPI of 100% of success about the goal of interest (retrieval of Photovoltaic forecast information). This evaluation is only valid in case of reachability of the thirty-party service, exploited to gain the weather forecast data[ix].

2.12 DSF-DWH connector

This component is located in the **service layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be available in the cloud, providing collected data in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Provides DSH-DWH information by a SQL like query request.
- This component works under request.

The DSF-DWH connector is the tool in charge of providing an interface for interact with the DSF-DWH database. It is installed on the DSF server inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in both residential and commercial scenario, it has been configured to respond only from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the DSF-DWH connector component. The evaluation took place exploiting a web browser from a device enabled in the VPN.

The steps for the evaluation of the DSF-DWH connector were the following:

1. Activation of the DSF-DWH connector
2. By using a browser from an enabled device, send an HTTP GET request towards the web connector and retrieve the information of interest

This evaluation lead to a KPI of 100% of success about the goal of interest (retrieval of data collected on the DSF-DWH).

2.13 Solar radiation connector for PROFESS or PROFEV

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bolzano and Fur/Skive (residential)** test sites, and to be evaluated according to the following KPIs:

- Solar radiation and PV generation information will be fetched from an online service with a frequency defined as an input (in hours or days).

This connector uses the services of PV Geographical Information System (PVGIS)[x], which is an open source tool of the European Commission. PVGIS provides information about solar radiation and PV system performance.

It can give information about the energy generated by a PV in several places of the world. This information is free and there is no restriction for the use of it. More information can be found on D5.4 [S4G-D5.4].

The evaluation of this tool took place by running the PROFESS combined with the data provided by the solar web connector of a house in the Fur/Skive test site. The solar web connector published the data into a broker installed in a remote RPi (Fraunhofer FIT installation). The access to the data was possible through the S4G VPN. The PROFESS took this data as input for the optimization and solved the optimization problem. For that it was also needed the data from the solar radiation connector. Analysing these characteristics, the evaluation of the solar radiation connector was executed in two ways:

- Connecting to the online service, fetching the data of a respective city and publishing it into a topic in the Aggregator broker
- Linking this input to PROFESS, so the optimization problem can be solved.

The connector fetched the data from the online service every night for the next two days. With every step of the optimization, PROFESS publishes the data of the PV generation forecast for the next day into a topic in the Aggregator broker. PROFESS uses the standard SenML[xi] data format for publishing the data. This process worked successfully for 15 consecutive days. Internally, PROFESS adapted the data obtained from the online service, so it can be used into the optimization problem. This step has also worked successfully for 15 consecutive days.

2.14 Residential GUI

In S4G, the residential GUI as well as the professional GUI are designed in iterative circles in close collaboration with end-users. The following paragraphs focus on the work conducted in phase 2 and leave out the results and prototypes already described in D6.7 [S4G-D6.7] and D6.8 [S4G-D6.8], as well as D6.10 [S4G-D6.10] to minimize repetitions.

Based on the first prototypes created in phase 1 and documented in D6.7 [S4G-D6.7], prototypes of the residential GUI were created in various fidelities ranging from low-fidelity paper prototypes to mid-fidelity click dummies and mockups. Their features were qualitatively evaluated in the end of phase 1 and the beginning of phase 2 in close collaboration with people representing the user group. The recruited users were located in Germany, Denmark and Italy. Besides conducting interviews and questionnaires, also a paper prototype was tested with 3 users from Italy, with the interviews and tests conducted in both German and English. The paper prototype testing was aiming at deducing the relevance of the presented data, as well as the availability of important features. Figure 5 depicts the nationality of users as well as their technical setup. In total, 12 people (3 female, 9 male) with the mean age 47 were involved in the interview sessions. In Denmark, the interviewees owned in total 6 PVs, 2 EVs and 3 storage systems, the German participant owned 1 PV and 1 EV, the participants from Italy owned 3 PVs and 2 EVs. Regarding their technical setup, they were split in 4 user groups:

- EV – Users owning only electric vehicles (2 users)
- PV– Users owning only photovoltaic systems (4 users)
- PV_EV – Users owning photovoltaic systems and electric vehicles (3 users)
- PV_Storage – Users owning both, photovoltaic systems and storage systems (3)

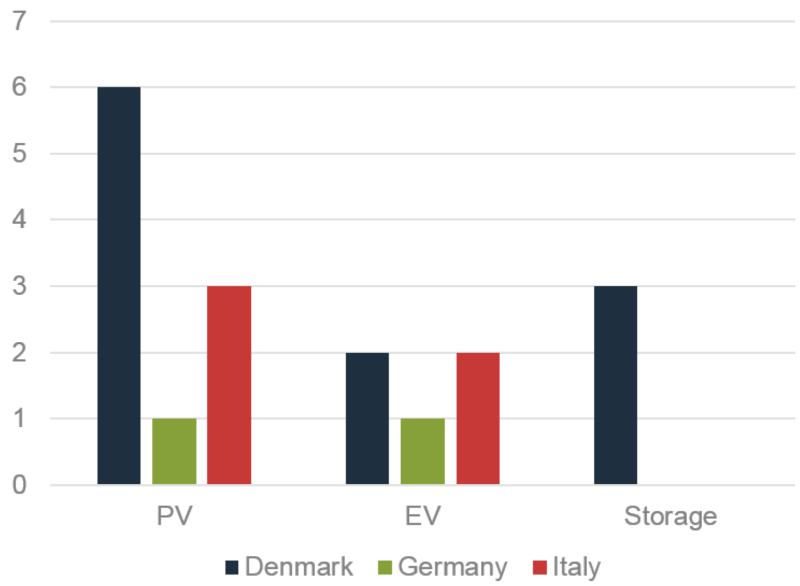

Figure 5. The number of users involved in the interviews including their nationality as well as their technical setup. Not every user had storage or an EV, but they were familiar with the topic and also interested in various aspects of self-sustainability.

The remaining of this section summarizes the interviews as well as the main results and provide an overview of the main features. The German version of the detailed interview questions is available in Appendix E.

For the interviewed end-users, the most interesting data was:

- Production, mainly comparing the actual production to a previously executed calculation, accessing the production as some sort of functionality check, accessing information about over production of the system.
- Consumption, mainly with the focus on self-consumption and over production.
- Battery SoC.

Regarding new functionalities and features, the most important ones in line with S4G were:

- Optimizing the energy consumption according to the production.
- Emails and notifications n case of price changes (addressing flexible tariffs).
- Error messages in case of system failures (addressing the PV system).
- Comparison options for data regarding the predicted production.
- Data export features, for example for Microsoft Excel to conduct further analysis.
- "Awareness" feature describing environmentally friendly behaviour with respect to energy saved, energy from their own production used, etc.

Regarding potential control strategies or automated energy distribution modes, the main findings were:

- Optimizing self-consumption
- Maximizing money saved/minimizing money spent on energy by either selling surplus energy or buying less energy from the grid

Another finding was that users tend to use tablets and smartphones to query their information, if this feature was already supported by their technical setup. In case there was no application for 3rd party devices available, the majority queried the inverter display to gather information. This is why the decision was made to create a responsive web-application that is supported by smartphones as well as tablets and laptops.

The identified needs were documented as Volere requirements in the Jira issue tracker software and prioritized for implementation.

Based on that and on the previously created prototypes described in D6.7 [S4G-D6.7], a paper prototype showing a mobile web application was evaluated with 3 users from Italy. The tasks for this test, which was conducted in German, are attached in Appendix E. The initial paper prototype is depicted in Figure 6, and its interaction can be found in Appendix G. The goal was to re-evaluate the importance of data as well as the comparison features, to gain qualitative feedback addressing features, data representation and information distribution. Additionally, a dashboard was created to allow the user to quickly get a status overview of his current system. During the test, only minor issues were revealed mainly addressing missing legends to describe graphs or misleading labels, improving the initial paper prototype (Figure 7). The identified flaws were addressed in another iteration of prototyping which resulted in a low- to mid-fidelity click dummy. The resulting software prototype is further described in D6.8 [S4G-D6.8] and is still work in progress.

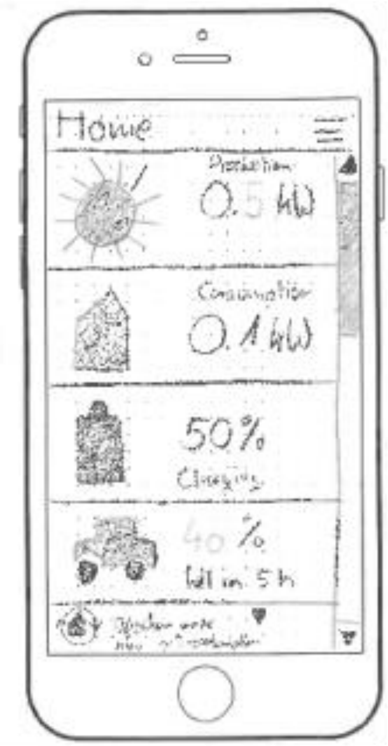

Figure 6. Early scribble of the paper prototype dashboard tested with 3 end-users in Italy.

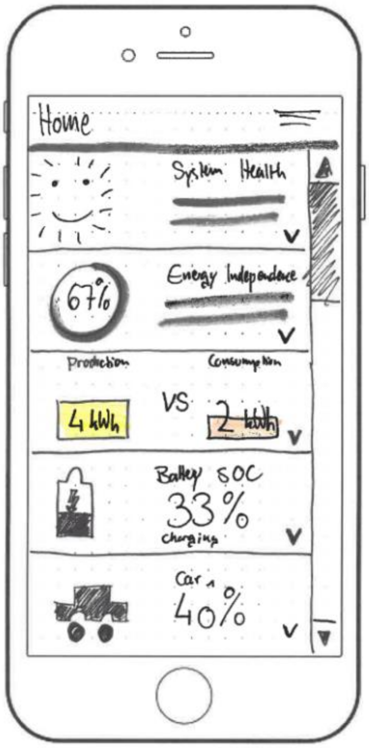

Figure 7. Enhanced paper protype after end-user evaluation.

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in **Bolzano (residential)** test site, and to be evaluated according to the following KPIs:

- Shows in real-time house production and consumption, and battery and car status (reporting time interval of 2 seconds).
- Receives real-time MQTT data from the SMXs deployed in the residential site.
- Shows historical measurements (daily, monthly and yearly view) regarding the house consumption and production and the system SoC.
- It is usable on different devices and screen sizes.

The Residential GUI is the tool in charge of providing residential user related values about its devices in the S4G network. It is installed on the Aggregator device located in the residential place. In order to guarantee the necessity of privacy and confidentiality of the data produced and used in residential scenario, it has been configured to respond only from devices requesting data from the LAN or from secure devices in the VPN for testing purposes.

In phase 2 of the S4G project it has been evaluated the Residential GUI component. The technical evaluation took place exploiting a web browser from a device enabled in the S4G VPN.

The further steps for the evaluation of the Residential GUI were the following:

1. Validation of the Fronius/SMX related data
2. Deployment of the Residential GUI
3. By using a browser from an enabled device, send an HTTP GET request towards the Residential GUI web connector and retrieve the information of interest, both historical and in real-time.
    - Log in into the system through personal credentials;
    - In the main view check the following real-time information:
        - Health status of the system (mocked for phase 2).

- Level of the house independency (i.e., a percentage value that indicates how and if the current production covers the current consumption).
- Consumption of the household.
- Production of the household.
- Charging status of the household battery SOC (i.e., plugged/unplugged);
- Charging status of the EV (i.e., plugged/unplugged).

- In the production and consumption view check the consumption and production over various time frames in a dedicated time-view.

As agreed during phase 2, the main goals of the Residential GUI were achieved exposing the previous listed functionalities. The development of the current tool focused on the first login and then the retrieval of real-time and historical data from the SMXs on the Residential deployment. It has been provided a dedicated view to inform about the SoC of the battery and if the car is currently plugged to the EV charger or not. The evaluation process, showed a proper response of the GUI and the backend managing it every time an authorized user requested some information.

The KPI metrics used are related to a correct gathering of real-time and historical data from the local data sources and the consequent exposal of the same data through the GUI. The repetition of the evaluation step and of the GUI responses, lead to a definition of the current KPI to 100%.

2.15 Aggregator broker

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Enables Edge layer components to communicate among them as well as the components in the Service and Device layer.
- Receives MQTT data from SMXs every 2 to 5 seconds.

The mosquitto Aggregator broker is the tool in charge of delivering the MQTT messages sent by the applications producing data on Device layer towards the Edge layer and vice versa. It is installed on each Aggregator device inside the VPN setup to support resources interconnectivity.

In phase 2 of the S4G project it has been evaluated the Aggregator broker component by exploiting its delivery mechanism to forward messages from the Device layer to the Edge layer. The evaluation took place exploiting the Dispatcher and the OGC Wrapper tools.

The steps for the evaluation the interconnections were the following:

1. Deployment of the Aggregator broker in each Aggregator.
2. Activation of the Dispatcher tool deployed in one SMX.
3. Activation of the OGC Wrapper tool deployed in one Aggregator.
4. By exploiting the Dispatcher forwarding mechanism send MQTT messages.
5. The OGC Wrapper receive the sensor data produced by the Dispatcher and forwarded by the Aggregator broker.

This evaluation lead to a KPI of 100% of success about the delivering mechanism of the MQTT messages concerning a sender density involving less than 15 devices with a maximum rate of 1 data message per device every two second.

2.16 OGC wrapper

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Data from USM devices is sent to cloud components accordingly to the OGC standard.
- Creates related OGC entities for its resources.
- Sends USMS data to Data Broker through MQTT every 2 to 5 seconds.
- Receives MQTT data from Control Broker sent by GESSCon and DSF-SE.
- Generates email alerts when timestamp embedded in the SMX message differs from current UTC time more than 4 hours.

The OGC Wrapper is the tool in charge of forwarding, in compliance with the chosen ontology, all the values received from the sensors in the local deployment. It is installed on each Aggregator inside the VPN.

In phase 2 of the S4G project it has been evaluated the OGC Wrapper component.

The steps for the evaluation of the OGC Wrapper were the following:

1. Activation of the OGC Wrapper tool
2. Concerning its configuration, it is able to map the known resources exploiting the OGC Server.
3. After the mapping process, every message arriving in the Aggregator Broker is forwarded towards the Data Broker
4. After the mapping process, every message arriving in the Control Broker, with the correct MQTT topic is received and processed by the OGC Wrapper

This process led to the evaluation of two main KPI concerning the current component:

- OGC registration and discovery (100%): it autonomously starts a registration or restore a previously made one with the OGC server.
- Mapping and delivering (100%): coherently with the OGC registration, it autonomously maps (locally) the MQTT topics used by the SMXs with the ones used by the service layer components. Then, it forwards all the data and control messages in both directions (upstream/downstream).

2.17 PROFESS

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bolzano, Fur/Skive (residential)** test sites, and to be evaluated according to the following KPIs:

- The effectivity of PROFESS will be evaluated through the correct working of its API.
- User can use the four main endpoints of the API: models, data source, control and command. Models for entering and managing optimization models, data source for mapping the data input, control for mapping the data output from the optimization results and command for starting and stopping the framework.
- Results of the optimization will be published with a user defined frequency into the SMX broker.

PROFESS is the tool in charge of the user-side ESS control. It uses optimization models as control algorithms and allows them to work as a house energy management system by linking inputs and outputs to the optimization model. In the case where predictions are required, PROFESS generates these predictions internally calculated from real-time data and links them to the optimization model. In summary, PROFESS orchestrates the information flow in order to convert an optimization model into a real-time optimal control system.
In order to make PROFESS reachable to the users, it possesses an API. It allows the users to interact with the tool in the four following manners:

- Adaptation and introduction of optimization models.
- Registry of data sources working as inputs.
- Registry of control setpoints, which are the outputs of the optimization.
- Commanding the tool.

In phase 2 of the S4G project, it was evaluated the use of the API and the correct working of PROFESS while integrated with the three-phase ER (described in section 2.25).

The evaluation took place using the PROFESS instance deployed in the residential use-case in Fur/Skive. UNINOVA was the partner in charge of testing the PROFESS API. For the evaluation, the software "Postman[xii]" was used for sending HTTP commands to the API. UNINOVA received from Fraunhofer FIT a template containing the information to be sent via HTTP through Postman. The information is written using the data model described in the API and can be found in BSCW[xiii]. For accessing the API in a deployed instance of PROFESS, the following endpoint should be open in a browser:

http://ip_address: 8080/v1/ui (1)

The steps for the evaluation were the following:

1. Deployment of PROFESS software in Fur/Skive made by UNINOVA
2. UNINOVA opens the API of PROFESS using the endpoint (1)
3. UNINOVA opens the template for Postman software
4. UNINOVA tests the API "models" endpoint
    a. Getting the models names already installed in the framework
    b. Erasing one model from the framework
    c. Erasing all models from the framework
    d. Introducing a new optimization model into the framework with a custom name
5. UNINOVA tests the API "data_source" endpoint
    a. Creating a new registry as MQTT input and receiving an "Id"
    b. Adding a MQTT registry with the same "Id"
    c. Adding a File registry with the same "Id"
    d. Deleting the added MQTT registry using the "Id"
    e. Creating a new registry as File input and receiving an "Id"
    f. Adding a File registry with the same "Id"
    g. Deleting the added File registry using the "Id"
6. UNINOVA tests the API "control" endpoint
    a. Adding a MQTT control registry using an "Id"
    b. Deleting the MQTT control registry using the "Id"
    c. Getting results from the framework after a command start is issued
    d. Deleting the control File results
7. UNINOVA tests the API "command" endpoint
    a. Starting the framework using the "Id" specifying:
        i. Control frequency
        ii. Horizon resolution in seconds
        iii. Horizon steps
        iv. Optimization model name
        v. Number of repetitions
        vi. Name of the solver
    b. Stopping the framework using the "Id"

The results are shown in Table 10, were all the previous operations worked.

Table 10. Evaluation results of the PROFESS API.

Endpoint	Action	Result
Deployment	PROFESS framework download and run	PROFESS framework deployed on a raspberry pi 3
V1/ui	API visualization	API was visualized on a browser
V1/models	Getting model names	Received the names of the optimization models installed in the framework
	Erasing one model	200 OK
	Erasing all models	200 OK
	Introducing a new optimization model	200 OK
V1/data_source	Creating a new MQTT registry	200 OK "Data-Source-Id": "Id"
	Adding a MQTT registry with the same Id	200 OK "Data source registered"
	Adding a new File registry with the same Id	200 OK "Data source registered"
	Deleting the MQTT registry	200 OK "Success"
	Creating a new File registry	200 OK "Data-Source-Id": "Id"
	Adding a File registry	200 OK "Data source registered"
	Deleting the File registry	200 OK "Success"
V1/control	Adding a MQTT control registry	200 OK "Success"
	Deleting the MQTT control registry	200 OK "Success"
	Getting results from PROFESS	Results from the optimization are displayed arranged per Name and Timestamp
	Deleting the results	200 OK "Success"
V1/command	Starting the framework	200 OK "System started successfully"
	Stopping the framework	200 OK "System stopped successfully"

2.18 Aggregator DWH

This component is located in the **edge layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bolzano (residential), and Fur/Skive (residential)** test sites**,** and to be evaluated according to the following goals:

- Residential user can only access own data.
- Collects residential related data provided by SMXs every 2 to 5 seconds.
- Generates email alerts when data has not arrived for 10 minutes, concerning each SMX stream.
- Provides residential information by a SQL like query request.

The Aggregator DWH is the tool in charge of collecting data from all the sensors deployed on a residential place in the S4G network. It is installed on each Aggregator inside the VPN. In order to guarantee the necessity of privacy and confidentiality of the data produced in the residential scenario, it has been configured to respond only from LAN enabled query and for debugging purposes from devices enabled in the S4G VPN.

In phase 2 of the S4G project it has been evaluated the aggregator DWH component.

The steps for the evaluation of the Aggregator DWH were the following:

1. Activation of the Aggregator DWH.
2. Activation of the OGC Wrapper.
3. By using a browser from an enabled device, send an HTTP GET request towards the web connector and retrieve the information of interest.
4. By stopping the OGC Wrapper forwarding mechanism, the Aggregator DWH sends an alerting email specifying that the known streams are no more active.
5. By using a browser from a device not previously enabled with the required security parameters, it is not able to retrieve the information of interest.

This process led to the evaluation of three main KPI concerning the current component:

- Persistent collection of data (100%): it stores all the incoming messages and provides ways to retrieve these ones.
- Alerting mechanism (100%): it constantly monitors all the incoming streams and when a known one stops, after 10 minutes raise the email alert accordingly.
- Privacy (100%): it does not allow requests from non-authorized software or users.

2.19 Technical GUI

This component is located in the **device layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following functionalities:

- It shows in real-time selected information acquired from the main meter (especially the measurements of U, I, P, Q on each phase).
- It runs locally on SMX and receives MQTT data from the SMXcore.
- The reporting rate depends on MQTT messages of SMXcore sent on localhost is between 5 and 10 seconds
- It is used for quick information during the commissioning and for monitoring operation.

The Technical GUI is in charge of providing quick analysis of real-time data, to be exploited for assisting commissioning and other customer-oriented activities which do not require further data processing. For long-term use of project outcomes, it is intended to be used the residential GUI presented in section 2.14.

The four considered functionalities have been evaluated as completely fulfilled during the phase 2. The reporting rate which has been parameterised was usually 2 seconds, as the MQTT messaging can be profiled to be sent at various cadences, from 1 second to 10 seconds or even more. A 5 seconds reporting rate has been tested as well, but for reasons related to quick information on the data evolution, the 2 seconds periodicity has been chosen as a basic feature.

The evaluation was carried out with followed steps: a) remote connection with a browser, using the 1880 port of the node-red application; b) follow-up of the technical GUI screen, especially by looking at values which are usually known, such as voltage level; c) analysis of the reporting rate, by following measurements which may change in time quicker enough to be seen difference in displaying values during periods of 5 to 10 seconds.

In Figure 8 and Figure 9 is presented a snapshot of the Technical GUI with data reported at the Bucharest test site. Figure 8 presents voltages evolution on each phase, which shows the voltage unbalance but also the quick reporting period of 2 seconds (the quickest tested situation). Figure 9 shows the active power evolution for each phase, showing a different activity on each of them.

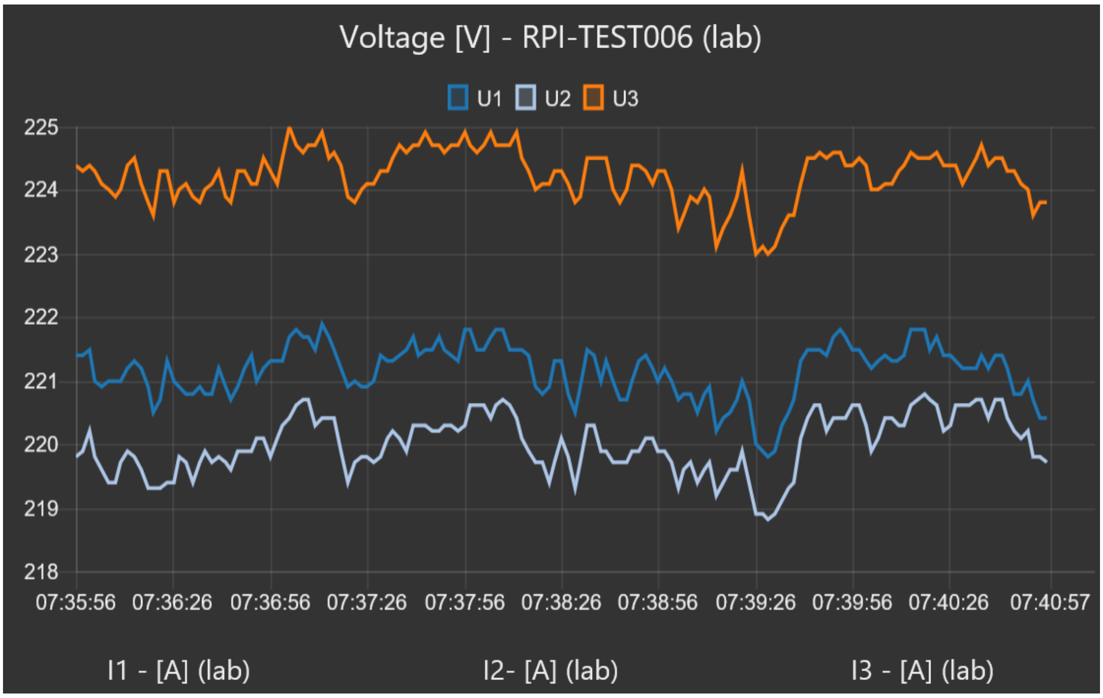

Figure 8. Technical GUI: voltage evolution.

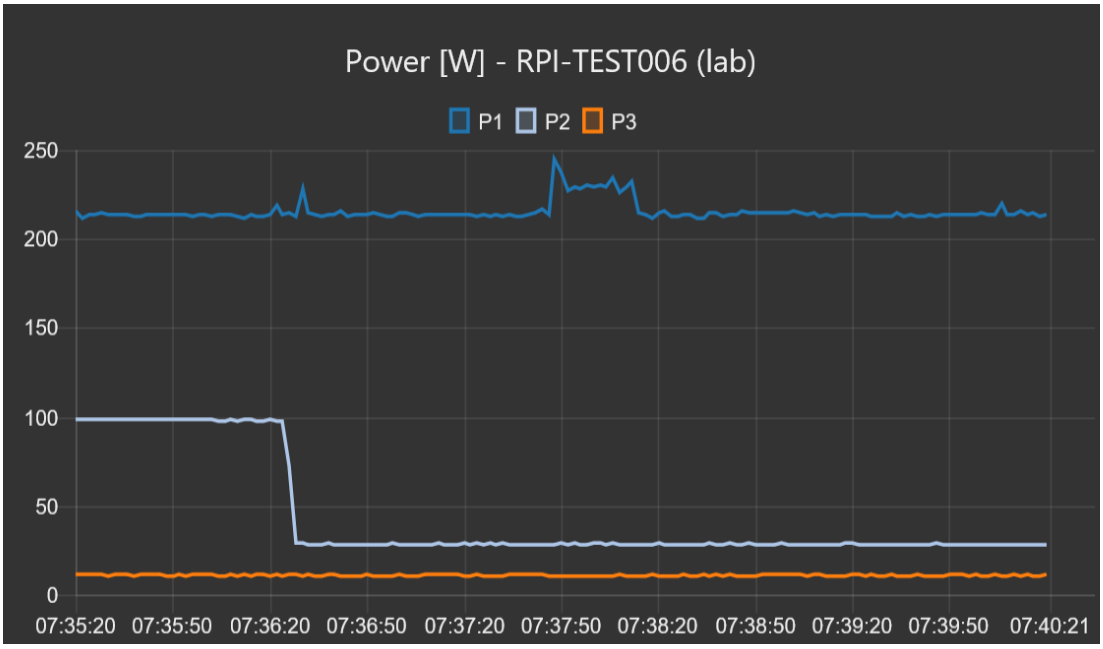

Figure 9. Technical GUI: power evolution.

For practical reasons, the assessment has been done by using the same type of MQTT message which is used also for the other purposes, such as OGC wrapper data collection. The evaluation was successful in all KPIs. Further possible refinements will be pursued in phase 3 of the project.

2.20 Dispatcher

This component is located in the **device layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following goals:

- Forwards **physical layer** data to its Aggregator and vice-versa.
- Forwards data provided by SMXs every 2 to 5 seconds.

The Dispatcher is the tool in charge of forwarding SMXcore data about the sensors of interest in a specific location of the S4G network. It is installed on the SMX.

In phase 2 of the S4G project it has been evaluated the Dispatcher component. The evaluation took place exploiting both the SMXcore and the OGC Wrapper.

The steps for the evaluation of the Dispatcher were the following:

1. Activation of the Dispatcher.
2. Activation of the SMXcore.
3. Activation of the OGC Wrapper.
4. Coherently with the frequency of the messages produced by the SMXcore, the Dispatcher tool is able to forward those messages at the same rate towards the Aggregator Broker and then to the OGC Wrapper.
5. Exploiting the reverse mechanism, by sending an ad-hoc message with a mosquitto publisher to the OGC Wrapper, it will forward all data towards the correct Dispatcher in a specific SMX and then towards the real sensor.

This evaluation lead to a KPI of 100% of success about the transparent delivering mechanism of the MQTT data and control messages received on the SMX broker. In the described process, the data rate is 2 seconds and the number of sensors managed by a single instance of the dispatcher is equal to one.

2.21 SMX broker

This component is located in the **device layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following functionality, used as indicator for the correct operation:

- Correct parametrization of SMXcore MQTT module (specific topics and payloads in JSON format).

The mosquitto SMX broker is the tool in charge of delivering the MQTT messages sent by the applications producing data. It is installed on each SMX inside the VPN to support resources interconnectivity.

In phase 2 of the S4G project it has been evaluated the SMX broker component by exploiting its delivery mechanism to forward messages between software deployed on the Device layer (SMX). The evaluation took place exploiting the Dispatcher and the SMXcore tool.

The steps for the evaluation the interconnections were the following:

1. Activation of the SMX broker tool.
2. Activation of the SMXcore tool.
3. Activation of the Dispatcher tool deployed in the SMX.
4. By exploiting the SMXcore forwarding mechanism send MQTT messages
5. The Dispatcher tool receives the sensor data produced by the SMXcore and forwarded by the SMX broker

2.22 SMXcore

This component is located in the **device layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following KPIs:

- Data is collected from monitored points and stored in dedicated secured files at 5 seconds or 10 seconds rates.
- Periodic verification through RPi Health Monitoring (for example processor temperature monitoring and amount of free disk space, which will be posted inside MQTT messages posted to the local mosquitto broker, to be able to be processed at upper levels).
- The component is ready to accommodate the resiliency local agent LESSAg, specific for the Bucharest test-site deployment; in this stage LESSAg will be tested only as a generic component integrated in SMXcore which can only retrieve real-time data from SMXcore.

During the second phase all the three KPIs have been evaluated in selected metering points, in all the three test sites (Bolzano, Fur/Skive, Bucharest).

For the first SMXcore KPI, daily records stored on the SD card have been evaluated in specific full days and metering points, and the records are according with expectations, having usually all 5 second records available. In some cases, the number of records decreased, but exceed 95% of maximum possible data in most of the situations. The temporary loss of records occurred especially in situations when different Linux running applications used up to 100% of the processor power. However, at the moment of phase 2 evaluation, there is good confidence that the collection of data will be in line with the requirements defined in D6.2 [S4G-D6.2]), section 2.5 – "Data Collection".

The second KPI has been evaluated through different adaptations in order to provide the necessary data: the processor temperature is recorded in most of the USM in the minute-based daily records. To be analysed off-line, the amount of disk space is recorded in files which are refreshed each 15 minutes and which can be analysed at upper levels. An adaptation of SMXcore which is reading the disk space information and being able to send it via MQTT has been positively evaluated in a specific SMX, and a full deployment will be made during phase 3, and in the meantime the daily evaluation of 15 minutes-based records is covering the need for disk health monitoring. Moreover, in all test sites there are already additional system health records each 15 minutes, such as monitoring the Linux log files (which can bring SD card excessive use) or monitoring the applications running at a certain time. According with the evaluation, raspberry Pi Health Monitoring has been achieved in a way which now is able to prevent the zero or near zero disk space situation.

For the third KPI, it has been tested LESSAg generic component in both SMX and in a separate simulation tool. The existing LESSAg generic component has been developed such that it can be used in both SMXcore environment and in PC environment used for simulation. The evaluation was positive. In phase 3 of the project, more developments and refinements of the LESSAg will be made and evaluated.

2.23 Energy Router South-bound SMX connector

This component is located in the **device layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Fur/Skive (residential)** test site, and to be evaluated according to the following KPIs:

- The ER SB SMX connector should publish in the SMX broker at the same rate the ER controller is sending data (2 to 5 seconds).
- The ER SB SMX connector should receive data from the SMX broker at the same rate that the PROFESS or LESSAg is publishing on the SMX broker.

The Energy Router south-bound connector is the tool responsible for receiving commands from the PROFESS or LESSAg, forward them to the ER, and to publish real-time measurements in the SMX. The commands are received in SenML[xi] JSON format and translated to the ER IEC 61850-90-7 standard. This component was successful evaluated with PROFESS in the Fur/Skive residential test site, as reported in section 2.17.

2.24 SMM

This component is located in the **physical layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and to be evaluated according to the following KPIs:

- Correct mapping of SMX configuration files in order to collect correct data from the analysed metering point: meter specific data (e.g. energy, power, current, voltage, etc.) have to be in concordance with the expected process values.

All meters used in the S4G project have been evaluated in terms of necessary mapping between the smart meter (SMM) internal data and the values which are needed in the project. Some meters had particular mapping characteristics, which asked for external processing of the raw data.

For the Bolzano meters, the mapping gave the possibility to read the real-time active power, however the sign of this power is always positive, no matter the direction of the power. This aspect became relevant in metering points which deal with PV production, where the power can change sign. The analysis of the meter showed that the sign can be inferred from the power factor value, which is negative when the active power is negative. This showed that it was necessary to map also the power factor on each phase and to read it from SMM, and that a special driver is needed to calculate the power with sign of the real power can be deducted from the power factor – also available from SMM, which has negative sign when the process active power is negative and positive when the process active power is positive. This showed that it was necessary to map also the power factor on each phase and to read it automatically from SMM, and that a special driver is needed to calculate the power with sign. The calculated power has been stored in daily files and sent inside MQTT messages with a different attribute (-9) than the power read directly from the meter (considered as raw data), which has the classic attribute (-2) associated with the COSEM code of the data (COSEM codes are part of the DLMS/COSEM standardisation family).

For the Fur meters, the active power was not specifically mapped to the external readout, however the meters could provide additional measurements through appropriate mapping in the DLSM protocol. In this situation, the additional measurements taken from SMM have been the currents, the power factor and the phase angles between voltages and currents. The current mapping allows calculation of the active power in real-time, or from the daily files which are recorded in SMX on the SD card. A driver for making the real-time calculations will be developed in the first period of project year 3, and the already recorded data can be used for calculating off-line the active power evolution in the measurement points, based on available daily files.

The previous described meter requirements have been evaluated and the mapping with meters have been made accordingly, in order to be able to get directly real-time powers from meters, or to be able to calculate it based on other meter data, such as power factor K, current I and angles between voltages and currents.

The correct mapping of relevant SMM data has been evaluated for all meters used in the project (Bolzano, Fur/Skive, Bucharest) and they are according with the meters data availability.

2.25 Three-phase Energy Router

This component is located in the **physical layer** of the S4G functional architecture. According to the phase 2 plans (D6.2 [S4G-D6.2]), this component was planned to be deployed in the **Fur/Skive (residential)** test site, and evaluated the following Load Balancing Support KPIs:

- The KPI for the ER evaluation is related with the load balancing support defining a three-phase system, the ER capability to compensate the unbalanced load currents.
- The EN50160 establishes that, under normal operating conditions, if the load is unbalanced [95 % of the 10 min aggregated values of the negative phase sequence component (fundamental) of the load current within one week are outside the range 0 % to 2 % of the positive phase sequence component (fundamental) of the load current, then correction measures should be applied].
- Load unbalance factor can also be computed dividing the positive sequence component of the three phase currents by the negative sequence component, where currents are defined by their standard aggregated values on a 10-minute reporting layer. The compensation factor (a) will quantify the ER capability to reduce the load unbalance seen on the grid side, dividing the load unbalance factor (computed on the grid side of the ER) by the load unbalance factor (computed on the load side of the ER). This indicator (a) changes between 0 (total unbalance compensation) and 1 (no compensation). The goal (KPI) is to keep the compensation factor a<= 0.05 during 95% of the time, requiring that there are sufficient local energy resources (PV generated power) to perform compensation.

The three-phase ER is a power electronics device that manages the energy transfer from/to different sources, loads and ESS. The phase 2 KPIs for the ER were not evaluated due to problems faced to install a SMM in the PCC of the Fur/Skive building where the three-phase ER is installed, as described in section 5.3. Nevertheless, the correct operation of three-phase ER was verified on-site, and detailed reported in D4.11 [S4G-D4.11].

3 Evaluation of the phase 2 S4G prototypes

In phase 2, nine prototypes have been evaluated. Each of the prototypes is related to corresponding deliverables, as follows:

- D4.2 – "Updated User-side ESS control system" [S4G-D4.2];
- D4.4 – "Initial Grid-side ESS control system" [S4G-D4.4];
- D4.6 – "Initial Cooperative EV charging station control algorithms" [S4G-D4.6];
- D4.9 – "Updated USM extensions for Storage Systems" [S4G-D4.9];
- D4.11 – "Initial Energy Router" [S4G-D4.11];
- D5.1 – "Initial DSF Hybrid Simulation Engine" [S4G-5.1];
- D5.4 – "Updated DSF Connectors for external systems and services" [S4G-D5.4];
- D5.6 – "Initial DSF Predictive Models" [S4G-D5.6];
- D6.8 – "Updated Interfaces for Professional and Residential users" [S4G-D6.8].

The description of the evaluation for each phase 2 prototype is described in the following subsections.

3.1 Updated User-side ESS control system

The Updated User-side ESS control system (D4.2 [S4G-D4.2]) presents the PROFESS and its interaction with the necessary south-bound SMX connectors. PROFESS was evaluated in the use-case in Fur/Skive, where the three-phase ER was also deployed. For the evaluation of the PROFESS code, an optimization model was developed[xiv] and included in PROFESS. It means that the optimization model can be already found inside the framework after deployment. The optimization model tries to maximize the PV energy consumption, so the energy curtailment of the PV is minimized. In this way, the household owner will benefit from maximizing the use of the energy generated by his RES.

The commands for the API were saved as a template for Postman software[xv]. By loading this template into Postman, the HTTP commands can be sent to the PROFESS API.

PROFESS was started with a control frequency of 30 seconds, using an optimization horizon of one day with a time resolution of one hour. The number of repetitions were setup as continuously with "-1". The solver used was Ipopt.

The framework was tested in the following two ways:

- The first one was reading real-time ESS SoC values while load profile and photovoltaic profile were entered as a file.
- The second one is reading all values: ESS SoC, Load power and PV power as real-time data and generating internal predictions.

The evaluation of PROFESS consisted in obtaining the control setpoints, which are the results of the optimization problem, in the registered MQTT control topics in the raspberry broker. Evaluation of the results compared with monetary revenues or real utilization of the PV will be made in phase 3.
PROFESS is working stable and the setpoints are published into the registered MQTT topics and broker. The ER can subscribe to those topics and receive the PROFESS setpoints.

3.2 Initial Grid-side ESS control system

The Initial Grid-side ESS control system (D4.4 [S4G-D4.4]), presents the prototype of the grid-side control system and its architecture. The Grid-side ESS control (GESSCon) is a decision-making module running in the cloud, deciding the energy storage system charge/discharge behaviour in the next 24 hours based on current local and grid situation.

According to section 2.6, GESSCon has been deployed in the Bolzano test site. However, some of the input data are still not available in phase 2, GESSCon is not fully functional because these input data will only be available in phase 3.

Currently on site ESS related data from SMX is not available due to the implementation of the ESS is not ready in phase 2. Moreover, some of the forecast data from DSF are also not complete. Most of the data that GESSCon receives so far, is not sufficient for GESSCon to generate a valid ESS control setpoint for PROFESS. This step will be finalized in phase 3.

3.3 Initial Cooperative EV charging station control algorithms

The Initial Cooperative EV charging station control algorithms (D4.6 [S4G-D4.6]) describes the optimization model developed for the EV charging stations control at EDYNA premises, to be used by PROFEV that will only be available and deployed during phase 3 in the Bolzano test site.

3.4 Updated USM extensions for Storage Systems

Updated USM Extensions for Storage Systems (D4.9 [S4G-D4.9]) describes the USM extension connectors to support S4G functionalities, namely:

- *ER SMX SB connector*: deployed in the Fur/Skive test site, evaluated as described in section 2.23.
- *ESS (Modbus) SMX SB connector*: this component was not yet deployed due to some issues with the ESS connection.
- *Weather forecast and load prediction connector*: deployed in the three test sites, evaluated as described in section 2.11.
- *GESSCon connector*: deployed in the Bolzano test site, evaluated as described in section 2.6.

All the USM extensions have been evaluated and proved to be functional, except the ESS SMX SB connector that was not yet deployed due to some issues with the ESS connection.

3.5 Initial Energy Router

The Initial Energy Router (D4.11 [S4G-D4.11]) describes the three-phase ER, that was successful deployed and integrated in the Fur/Skive test site. It was evaluated and integrated together with the ER south-bound SMX connector (described in section 2.23), and with the PROFESS (described in section 2.17).

3.6 Initial DSF Hybrid Simulation Engine

The Initial DSF Hybrid Simulation Engine (D5.1 [S4G-D5.1]) describes the DSF-SE which is a framework designed to run complex power flow simulations in the electrical grid of the Bolzano and Fur/Skive test sites. It was evaluated as described in section 2.5.

3.7 Updated DSF Connectors for external systems and services

Updated DSF Connectors for external systems and services (D5.4 [S4G-D5.4]) describes the different DSF connectors developed to enable the DSF to operate with DSO and third-party systems, namely:

- *Dispatcher:* deployed in all three test sites within SMXs, evaluated as described in section 2.20.
- *OGC wrapper:* deployed in all three test sites within SMXs, evaluated as described in section 2.16.
- *GridDB connector:* available in the cloud to Bolzano and Fur/Skive test sites, evaluated as described in section 2.8.

- *Energy price connector:* available in the cloud to Bolzano and Fur/Skive test sites, evaluated as described in section 2.9.
- *Fronius cloud connector:* available in the cloud to Bolzano and Fur/Skive test sites, evaluated as described in section 2.10.
- *Weather forecast for PV production connector:* available in the cloud to three test sites, evaluated as described in section 2.11.
- *DSF-DWH connector:* available in the cloud to the three test sites, evaluated as described in section 2.7.
- *Solar radiation connector:* deployed in the Bolzano and Fur/Skive test sites within PROFESS and PROFEV, evaluated as described in section 2.13.
- *Connector Enabling Hybrid Simulation:* a first version of this connector was ready in phase 2, but since the single-phase ER and the ESS at Fur/Skive grid test site will only be available during phase 3, it was not possible to execute a proper evaluation during phase 2.

3.8 Initial DSF Predictive Models

The Initial DSF Predictive Model (D5.6 [S4G-D5.6]) describes a first draft of the developed predictive models that are used in DSF and GESSCon. In phase 2, the algorithms of PV production forecast, electricity price forecast, load forecast and Electrical Vehicle (EV) consumption forecast has been selected and are undergoing for implementation, exploiting web API to fetch day-ahead market data from ENTSO-E[xvi]. Other forecast data will be in available in phase 3.

The State-of-Health (SoH) and Remaining Useful Life (RUL) algorithms have been studied in phase 2 and are implemented in the Lithium Balance Battery Management System (BMS) platform. The algorithms are only going to be tested and evaluated in a real ESS, during phase 3 in the Fur/Skive test site.

3.9 Updated Interfaces for Professional and Residential users

Updated Interfaces for Professional and Residential users (D6.8 [S4G-D6.8]) describes the developed software prototypes for professional and residential users as GUIs.is composed by two components, namely:

- *Residential GUI:* deployed in the Bolzano test site within the residential SMX, evaluated as described in section 2.14.
- *Professional GUI for GRID Planner:* available in the cloud to Fur/Skive test site, evaluated as described in section 2.4.

4 Cooperative EV Charging Scenario: Bolzano (IT) test site

This scenario is composed by the residential and the commercial case. The residential case is a private house near Bolzano, which has PV panels, an EV charging station and an ESS with its respective inverter. The commercial case is in EDYNA's headquarters garage, where 11 EVs can be charged. There are also PV panels which are directly connected to the distribution grid. The phase 2 deployment diagram is available in D6.2 [S4G-D6.2].

4.1 Phase 2 deployments evaluation results

According to D6.5 [S4G-D6.5], the Bolzano phase 2 prototypes deployment were:

- D4.2 [S4G-D4.2], evaluation available in section 3.1.
- D4.4 [S4G-D4.4], evaluation available in section 3.2.
- D4.9 [S4G-D4.9], evaluation available in section 3.4.
- D5.4 [S4G-D5.4], evaluation available in section 3.7.
- D5.6 [S4G-D5.6], evaluation available in section 3.8.
- D6.8 [S4G-D6.8], evaluation available in section 3.9.

4.2 Phase 2 KPIs evaluation results

In the Bolzano test site, it was not possible to evaluate any use-case. The evaluation was based in the components deployed during phase 2 and described in the previous section.

4.3 Lessons learned in the Bolzano test site

During phase 2, some problems emerged on the internet connection of the residential test site: due to the low voltage on one phase, the installed internet router for the project often stopped working. To solve this problem a small UPS was installed. The low voltage problem also affects the new EV charger installed by ASM. One of the reasons for this issue might be that the PV panels are not directly connected to the Fronius system but connected to two-phases (using two inverters) of the three-phase residential grid, causing the previous mentioned issue.

Another issue encountered during phase 2 was that the majority of the SMXs SD cards started to fail. The technical partners analysed the problem and decided to replace all SD cards and increase the log files recording time to 5 seconds (instead of 2 seconds). Before the SD cards started to fail, there was an increase of the SMXs temperature. The technical partners are not sure if the temperature increase was due to SD cards issues, or in the other hand, the high SMXs operating temperatures damaged the SD card. The temperatures are now being closely monitored and weekly backups of the log files are being executed to avoid losing the collected data.

It was also observed in the DSF-DWH that some SMXs stopped reading the SMM data and give the last readings until the SMXcore application is restarted, causing a data gap in the DSF-DWH because it is a time-based database. This issue is being tackled both in the SMXcore application and in the DSF-DWH with some improvements so far, but without a satisfactory resolution. Also, sometimes the SMXs starts to send wrong timestamp, making the DSF-DWH recording data with wrong date. During phase 3, these issues will be further investigated, and other approaches will be used.

Some alert applications implemented in the SMX are not working properly in the Bolzano test sites due to the proxy configuration. The consortium is trying to solve this issue, taking into consideration that the Bolzano commercial test site must be secure, to avoid some kind of cyber-security attack or to cause malfunctions in the company internet network.

5 Storage Coordination Scenario: Fur/Skive (DK) test site

This scenario features a residential test site (Fur), a grid-side ESS (Skive), and the deployment of the three-phase ER at ENIIG premises (Skive). The residential case is composed by 5 houses fitted with PV panels, ESS and its respective inverter. The grid case is one grid-side ESS installed behind the meter in the sports arena. The phase 2 deployment diagram is available in D6.2 [S4G-D6.2].

5.1 Phase 2 deployments evaluation results

According to D6.5 [S4G-D6.5], the Fur/Skive phase 2 prototypes deployment were:

- D4.2 [S4G-D4.2], evaluation available in section 3.1.
- D4.4 [S4G-D4.4], evaluation available in section 3.2.
- D4.9 [S4G-D4.9], evaluation available in section 3.4.
- D4.11 [S4G-D4.11], evaluation available in section 3.5.
- D5.4 [S4G-D5.4], evaluation available in section 3.7.
- D5.6 [S4G-D5.6], evaluation available in section 3.8.
- D6.8 [S4G-D6.8], evaluation available in section 3.9.

5.2 Phase 2 KPIs evaluation results

During phase 2, it was planned to evaluate the HLUC-3-PUC-2: "Autonomous control of storage installed at user premises and distributed in the grid" related with HLUC-3-PUC-4-BM-1: "Autonomous voltage control at household battery", in the Fur/Skive test site.

Even though PROFESS and the three-phase ER were evaluated together in the Fur/Skive test site (as described in section 3.1, it was not possible to evaluate the HLUC-3-PUC-2 measuring the voltage levels in the building PCC, due to some issues in the SMM installation, thorough described in section 5.3.

5.3 Lessons learned in the Fur/Skive test site

During phase 2, some problems emerged in the installation in the first Fur-house. The SMX stopped to send data after a month, where data communication has been stable. The SMX was restarted without any result and then brought to the technical partner for total reset. The SMX was reinstalled in the house, but failed data collection and communication after only a short week. Then also due to problems in Bolzano the technical partners decided to solve problems in Bolzano test site first and take learnings from there to the Fur house. After some months it was decided to replace the SMM in the Fur House with a new meter, since it seems as if the meter did not communicate with the SMX.

The SMX and SMM then was tested at Eniig laboratory, but the communication between the two devices were not successful and the entire system was shipped to UPB laboratory for final tests before reinstallation. Tests made in UPB showed proper functionality and the meter was shipped back to Eniig and installed in the Fur test site with help from UNINOVA. Since then the communication has been stable. And the remaining Fur Houses have got installed SMX and SMM.

Learning from these last installations are that the SMM is requiring space, sometimes unavailable, that an ordinary house does not always have room enough for an extra meter, which have given some alternative installations with respect to security and regulations. There was in one house no plug close to the main board, which then needed to be established by the electrician, and some issues have been observed when getting connected to the internet in one house. Besides this the installations went smoothly and successful in all Fur/Skive residential test site.

The three-phase ER has been installed at Eniig Premises in Skive, where Eniig has a small test PV-system. The installation of the ER went smoothly but, unfortunately, the ER has got a minor damage in its transformer during shipping to Eniig from UNNINOVA, so the ER was installed but not kept in operation before the next visit from UNINOVA, to be sure the ER was not damaged or could damage something in the installation room. The installation of a SMM in the PCC of the Skive building has been a challenge, since the main meter at Skive premises is a current transformer meter, and it is not possible (or very costly) to install the SMM in a serial connection with the existing meter. Another problem occurred, because the entire installation in Skive premises must be shutdown to install the SMM, and Eniig has fibre broadband servers in this building, which may not be shutdown. So, cutting of the installations started a long process of securing supply to fibre broadband servers, which was not obtained. At the moment, the decision was to install the SMM at the sub-board, where the ER is installed.

Another investigated solution was to clamp an infrared reader at the existing meter. This solution was rejected from the meter department in Eniig (N1), because it would give access to configurating the meter, which they could not allow.
It is planned for phase 3 to install a transformer meter (SMM) at another sub-board, closely to the main-board to be able to monitor voltage and ampere levels in the installation.

6 Cooperative Storage System Scenario: Bucharest (RO) test site

This scenario is composed by a laboratory test site where some S4G prototypes are evaluated before the field deployment. Moreover, a home hybrid energy system with DC bus will be also evaluated. The phase 2 deployment diagram is available in D6.2 [S4G-D6.2].

In this scenario, the goal is to achieve resilience for a set of loads owned/operated by a specified customer supplied from LV network. It has been promised to test the suitability of using DC supply when the loads are a combination of up to 5 (native AC) appliances. In phase 2, a number of 3 appliances have been successfully tested.

From the solution developed and implemented in phase 2, a set of KPIs has been proposed, able to evaluate the proposed solution, testing the main control algorithm by simulation, complemented by additional two storage control algorithms.

Following the research outcome in Phase 3, these KPIs will be refined or even modified according to the potentially evolved solution.

6.1 Phase 2 deployments evaluation

According to D6.5 [S4G-D6.5], the Bucharest phase 2 prototypes deployment were:

- D4.9 [S4G-D4.9], evaluation available in section 3.4.
- D5.4 [S4G-D5.4], evaluation available in section 3.7.
- D5.6 [S4G-D5.6], evaluation available in section 3.8.

6.2 Phase 2 KPIs evaluation results

For phase 2, the following KPIs were defined for the Bucharest test site, having the KPI names coded as "KPIx.y",, where x is the project phase (1 or 2) and y is the KPI number:

- KPI1.1 - USM and SMX communication, at reading intervals of 5 to 10 seconds (better time resolution may be tested on short periods).
- KPI1.2 - SMX and cloud applications communication: MQTT messages between SMX client and simulated remote MQTT client, with messages exchanged at rates of 1 frame each 5 to 10 seconds (lower or higher values up to one minute may be also tested on short periods).
- KPI2.1 - number of AC labelled appliances with demonstrated full functionality when supplied with direct voltage (220 V +-10%) for T_0=15 min; KPI2.1 ≥ 3.
- KPI2.2 - (active energy transferred from the prosumer to the DSO network averaged over T_{P_DSO}=one day) / (daily energy corresponding to nominal load of the prosumer); This KPI will be reported for different simulation scenarios and does not have a specific limitation. KPI2.2 < 5% of the contractual power considered for consumer, for an analysis window $T_a=T_{P\_DSO}$=one day, demonstration through refined simulation and applying the UniRCon algorithm; simulation is based on real and rescaled daily data records from selected project metering points and on selected prosumer's resource dimensioning.
- KPI2.3 - RES-based generation curtailment degree KPI2.3; KPI2.3<20% from produced energy for an analysis window $T_1=T_{P\_DSO}$=one day; demonstration through refined simulation and UniRCon algorithm; simulation will be based on real and rescaled daily data records from selected project metering points and on selected prosumer's resource dimensioning.
- KPI2.4 - (active energy delivered from DSO to the prosumer) / (total active energy transferred to the loads); it reflects the local use of RES-based electricity, i.e. "auto-consume"; KPI2.4 < 0.7 for an analysis window $T_2=T_{P\_DSO}$=1day; demonstration through refined simulation and UniRCon algorithm; simulation is based on real and rescaled daily data records from selected project metering points and on selected prosumer's resource dimensioning.

6.2.1 KPI1.1 and KPI1.2 Evaluation (Data availability from USM and SMX)

KPI1.1 shows the meter data availability from USM, which is using SMX to acquire data from the meter, while KPI1.2 indicates the ability to send this data to other components using a communication window of 5 to 10 seconds. KPI1 is evaluated in all phases of the project, in order to demonstrate that data is available in normal conditions with this data refresh rate.
All SMXs have been programmed to make data acquisition from the meters at a rate of 1 readout every 2000 msec. (2 seconds). Moreover, the MQTT publish frequency has been also set to 1 message every 2 seconds, while the local record in daily files has been programmed to be with a periodicity of 5 seconds, with a second file which recording some essential data every 1-minute. Specific days have been analysed (when proper conditions were met, i.e. good communication, supply, proper cabling etc.), in all the three test sites (Bolzano, Fur/Skive, and Bucharest) and also in separate laboratory environment in UPB, and it has been seen that the messages have been always transmitted or locally recorded in maximum 10 seconds. Daily recorded file showed compete days with proper records having a success rate of more than 95% per day, usually more than 99%.

For the data sent through MQTT messages, special records with the number of MQTT messages and the number of sent bytes are recorded in the 1-minute daily file of each SMX. Analysis of daily files showed similar success rate of more than 95% per day, usually more than 99%. in fully analysed daily files. Concluding, KPI1.1 and KPI1.2 have been successfully evaluated in phase 2.

6.2.2 KPI2.1 (General information related to chosen DC devices)

In order to achieve KPI2.1 established for phase 2 of the project, UPB tested several appliances (DC-internal bus) supplied directly by a DC source for a range of voltages. Table 11 presents the basic details of the devices.

In the first column and second column, the tested DTUs and their characteristics are listed, followed by DC internal feature in the third column and rated voltages (AC supply and DC internal bus, when available) in the last two columns. The printer and the desktop have an internal conversion but are inside the appliance, different from the Notebook that has a conversion before plug, thus it has been tested the charger device. Inside the desktop has a different voltage in which operate different parts as the RAM, Memory card, light, etc. So, in this case the desktop has a different value of output voltage. All information is taken from its own user manual.
The desktop and the computer monitor could be plugged into the traditional AC grid, regardless if it operates at 230 V or 120 V. The direct output voltage of those power supplies has a range of values according to the accessories to be also supplied (in the desktop there is the circuit for audio, power, etc, and not all of them operate at the same voltage).

For the printer the power consumption is different in printing mode or standby mode. For this document the tests are done in standby mode. The same for the notebook and for the desktop. The electricity consumption depends on the operations and active processes, therefore, in order to perform a consistent comparison, the test was executed without any executing process and without any other peripherals connected like beamer, mouse, USB, etc. The cell phone chargers have been tested while connected with the cell phone (charging mode).

As a conclusion, all appliances (with AC power supply having a DC internal bus) could operate with a good performance when they were supplied from an external DC source with (rated) voltage U_{DC}= 230 V.

The following sections analyse in detail the behaviour of the selected DUTs.

Table 11. DUT characteristics.

DUT	Characteristics	DC-internal	Rated voltage supply (AC)	DC output [V]
Notebook Charger	• Manufacturer: HP • Model: Compag • AC Adapter Power: 90W (19V - 4.74A) DC • Processor: Intel R CoreTM Duo	Yes	100-240V 50Hz-60Hz	19
Cell phone Charger	• Manufacturer: NOKIA • Model: 1680c • Charger type: Nokia AC-3 • Charger consumption: 0.15W • Input/output current: 100mA/350mA • Battery type: Li-ion • Battery capacity: 700mAh	Yes	100-240V 50Hz-60Hz	5

Printer	• Manufacturer: HP
	• Model: LaserJet 1022n
	• Input current: 2.5A
	• Power consumption:
	  ○ Printing mode: 60W
	  ○ Ready mode: 2W
		No	220-240V 50Hz-60Hz	-

Computer Monitor	• Manufacturer: ACER
	• Model: AL1916C
	• Efficiency: 70%
	• Power consumption:
	  ○ Normal mode: 60W
	  ○ Standby mode: 2W-230V-50Hz
	  ○ Ready mode: 1W-230V-50Hz
		Yes	100-240V 47Hz-63Hz	5-15

Desktop Power Supply	• Manufacturer: Dell. • Model: Optix 330. • Maximum Power: 280W • Processor: Intel R CoreTM Duo • Classic weight: 10.4 kg • Minimum efficiency: 65%	No	90-264V 47Hz-63Hz	3.3-5-12

6.2.2.1 Notebook Charger

The first one is the notebook charger. Figure 10 was obtained with the data collected using the procedure previously described in section 6.2.2. It shows the power trend of power with a variable direct voltage applied at the input connectors. Besides it shows the two trends, in blue when the voltage is increasing and in red when is decreasing. As is shown in Figure 10, the rated power is in a range and is not a linear or exponential trend line. It is possible to deduct that a notebook in mode ON operates within a range of the rated power.

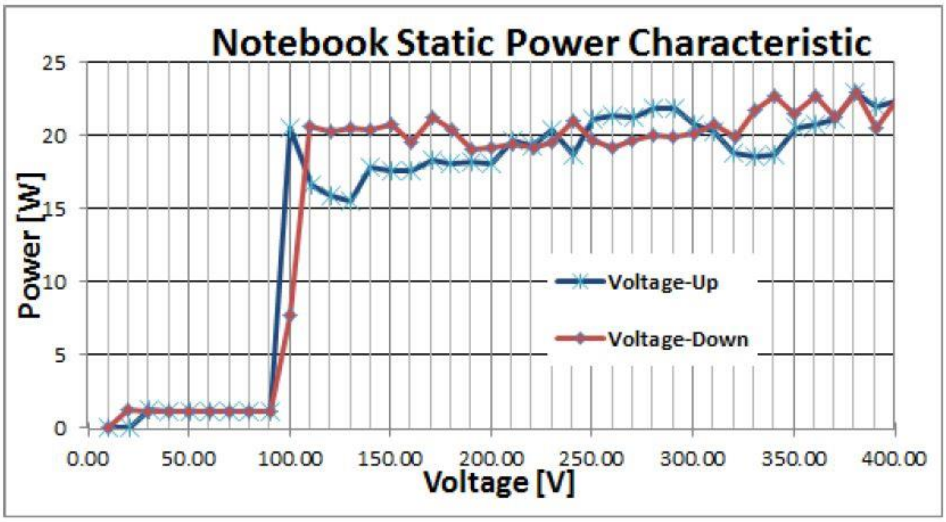

Figure 10. Static power characteristic of a notebook charger.

From the data and calculation, it is deducted that the power uncertainty is $\Delta P = 0.06W$. It is possible to make the following affirmations for the notebook operation:

1. Works up to 110 V in DC with 100% of performance.
2. The rated power is around 20W.
3. Range of voltage from 110 to 400 for both (voltage increasing and decreasing procedure, to highlight potential hysteresis due to capacitor in the power supply circuit; the time ineval to achieve steady stated has been 1 minute per measurement point).
4. Maximum Power 25W.
5. Minimum Power 15W in mode ON.

A power consumption 1.4 W is visible up to 90 V, this is due to standby mode operation or because starting the low voltage circuits such led indicators. It is noticed that the higher power consumption is for 380 V when is increasing the voltage and 340 V for decreasing voltage. For the range from 90 V to 100 V the notebook works in an intermittent mode: turns ON and turns OFF repetitively.

6.2.2.2 Cell phone Charger

The results for cell phone charger are presented in this section. Figure 11 was obtained with the data collected using the procedure previously described in section 6.2.2. It shows the trend of static power characteristic with a variable DC input voltage. Besides it shows the two trends, in blue when the voltage is increasing and in red when is decreasing. From Figure 11 it is possible to deduct a hysteresis behaviour for a high voltage. A polynomial trend line could describe the power behaviour since 10 V until 50 V. When the voltage is increasing after 300 V, the power has a significant reduction equal to one third. On the other hand, when is decreasing voltage, the power increments three times but in this case at 290 V.

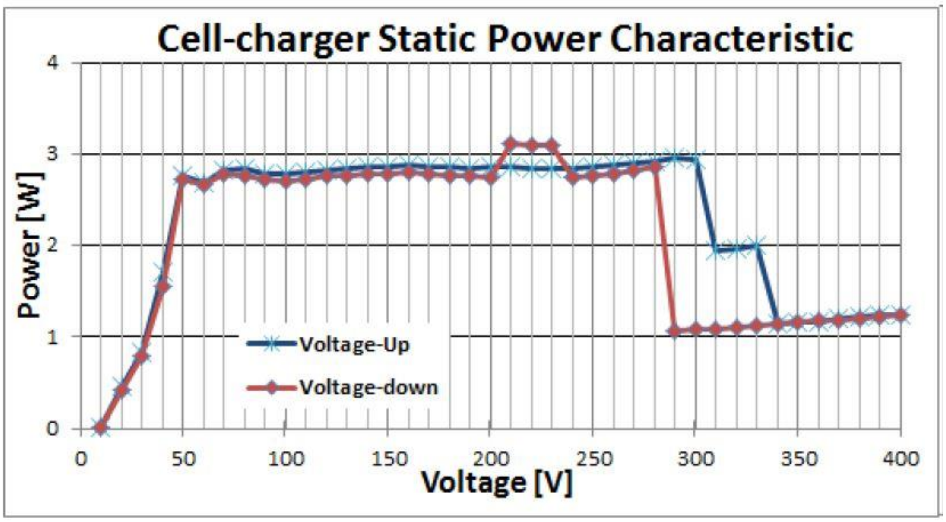

Figure 11. Static power characteristic of a cell phone charger.

Additionally, the power has a linear trend between 290 V and 400 V for decreasing voltage. The same linear approximation could be applied for increase voltage between 340 V and 400 V. The linear equation for this range is made with data of increasing voltage because it has a bigger power consumption. Also, this linear equation is valid from 290 V until 400 V for facility purpose.

From the cell phone charger data and calculation is implied that the power uncertainty is $\Delta P = 0.014W$. The R-square value for the range between 10 V and 50 V is R2 = 0:9962 and for the range from 290 V to 400 V is R2 = 0:9758. It is possible to make the following affirmations for the cell phone charger operation:

1. Operated with a limited performance between (20V – 50V) and for (300V – 400V).
2. High performance operation is reached for voltage between 50 V and 290 V.
3. Range of voltage from 50 to 290 for both (increasing and decreasing).
4. Maximum Power 3.2W.
6. Minimum Power 1W in high performance mode ON.

Operation with limited performance could damage the charger. Also, the user manual specifies the input connection for a long life of the battery.

6.2.2.3 Printer

Figure 12 was obtained with the data collected using the procedure previously described in section 6.2.2. It shows the trend of power with a variable direct voltage applied at the input connectors. Besides it shows the two trends, in blue when the voltage is increasing and in red when is decreasing. From Figure 12 it is possible to infer that the printer is in OFF mode until the supply voltage reaches 100 V. A regular power with high performance is reached up to 140 V. Up to 140 V it presents a polynomial trend line of second order. The polynomial trend equation is made with increasing voltage data, because it has a higher power consumption than with decreasing voltage. It means that increasing the voltage, the power suffers a little increment. Between 90 V and 140 V an intermittent operation is presented, turning ON and OFF constantly.

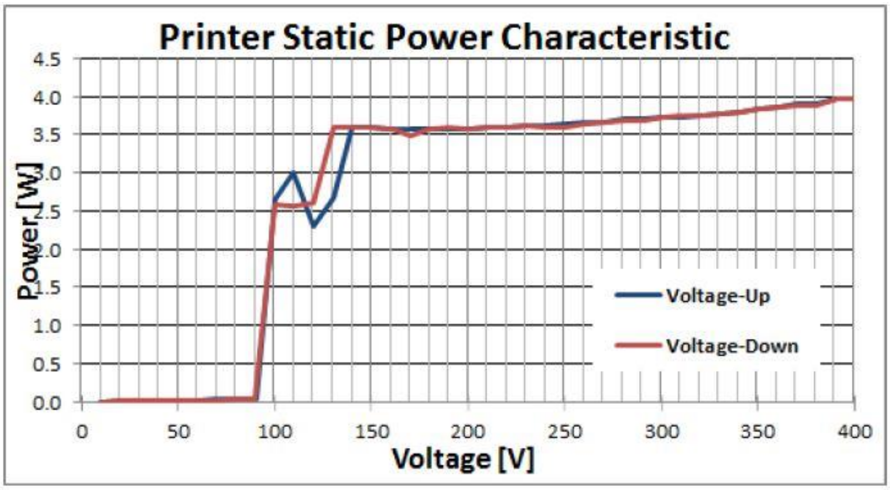

Figure 12. Static power characteristic of a printer.

From the data and calculation, it is inferred that the power uncertainty of the printer is $\Delta P = 0.01W$. The R-square value for the range between 140 V and 400 V is R_2 = 0:9946. From Figure 4.3 it is possible to make the following affirmations for the printer operation:

1. No operation under 90 V.
2. Operated with a limited performance between (90 V – 140 V). Turning ON and OFF.
3. High performance operation is reached for voltage between 140 V and 400 V.
4. Linear characteristic for voltage between 140 V and 400 V.
5. Maximum Power 3.9W.
6. Minimum Power 3.4W in high performance mode ON.
7.

6.2.2.4 Computer monitor

The results for the computer monitor testing are presented in this section. Figure 13 was obtained with the data collected using the procedure previously described in section 6.2.2. It shows the trend of power with a variable DC input voltage. Besides, it shows the two trends, in blue when the voltage is increasing and in red when is decreasing.

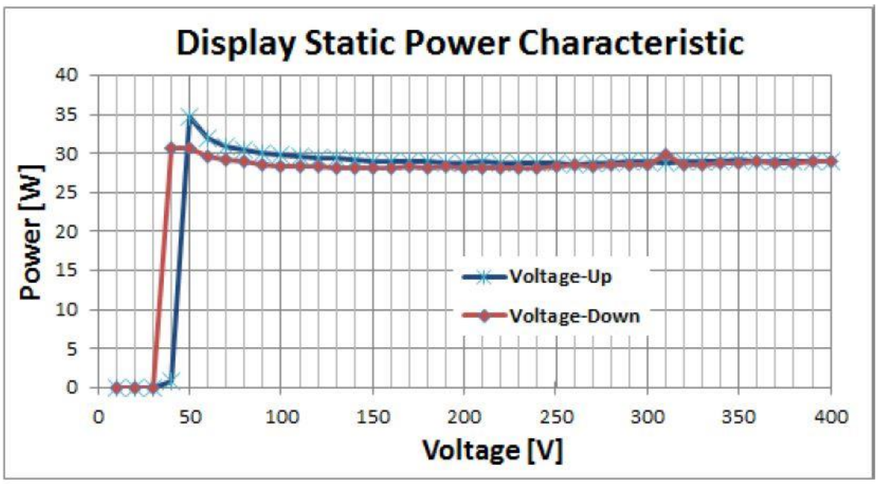

Figure 13. Static power characteristic of a computer monitor.

The computer monitor tends to have a constant power consumption. Power peaks at the low voltage after starting to operate in mode ON and before turning OFF around 30 V and 50 V. Additionally the computer monitor operates in an intermittent mode between 30 V and 50 V. It could not be understood from the chart because with this operation it is not possible to take correct measurements. After the peak the curve presents polynomial trend before arriving at a constant power consumption. The polynomial equation is of third order and uses the increasing voltage data due to high power consumption respect to the decreasing voltage data.

From the data and calculation, it is inferred that the power uncertainty of the computer monitor is $\Delta P = 0.18W$. The R-square value for the range between 50 V and 120 V is R2 = 0:9395. The equation of this range is for the increasing voltage because it has higher power consumption than at decreasing voltage. For decreasing voltage, it is possible to find an equation to describe the curve in the same range. It is possible to make the following affirmations for the computer monitor operation:

1. No operation under 30 V.
2. Operated with a limited performance between (30 V – 50 V). Turning ON and OFF.
3. High performance operation is reached for voltage between 500 V and 400 V.
4. Polynomial approximation characteristic for voltage between 50 V and 210 V.
5. Present hysteresis.
6. Maximum Power 34.6W.
7. Minimum Power 54.4Win high performance mode ON.

6.2.2.5 Desktop Power Supply

The desktop power supply has been tested, and the results are presented in this section. Figure 14 was obtained with the data collected using the procedure previously described in section 6.2.2. It shows the power characteristic when supplied with a variable direct voltage. Besides, it shows the two trends, in blue when the voltage is increasing and in red when is decreasing.

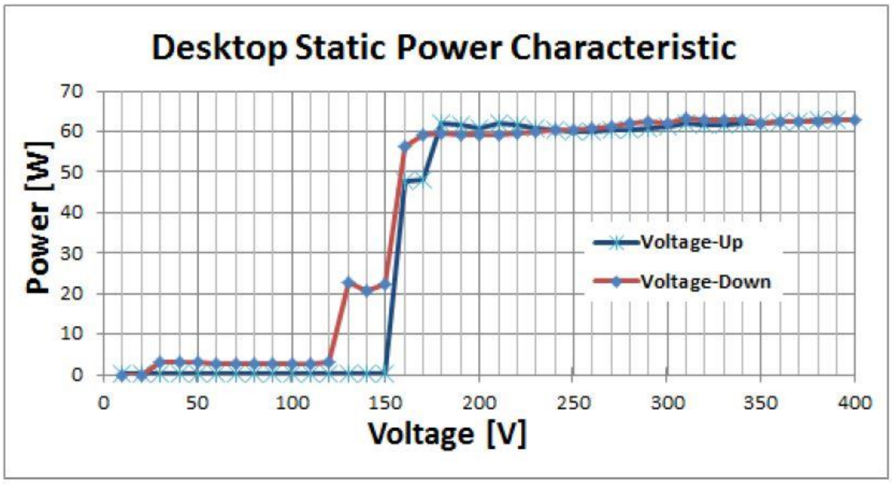

Figure 14. Static power characteristic of a desktop power supply.

The desktop tends to have a constant power consumption after rising at 190 V. There is a little hysteresis, because rising the voltage start with a 100% performance at 190 V, but when voltage is decreasing turns OFF at 160 V. For the range between 190 V until 400 V the power could be presented as constant with 63W for both increasing and decreasing.

When the voltage is decreasing, before turns OFF at 150 V change to a standby mode. The power consumption reduces to around 20 W and then at 120 V reduces again around 2.5W and after at 20 V turns OFF. Otherwise when voltage is increasing starts to operate at 170 V but until the voltage arrives at 180 V it operates with 100% of performance.

From desktop supply power it is possible to make the following affirmations of the static power characteristic for the desktop operation:

1. 63W of power under high performance up to 170 V.
2. Different curves for increasing and decreasing voltage.
3. Decreasing voltage entry in standby mode.
4. Present hysteresis.
5. Maximum Power 64.3W.
6. Minimum Power 58.4W in high performance mode ON.

6.2.3 KPI2.2, KPI2.3 and KPI2.4 evaluation (Advanced Prosumers)

The KPI2.2 to 2.4 refers to functionalities related to the advanced prosumers. KPI2.2 relates (the active energy transferred from the prosumer to the DSO network averaged over T=one day) to (daily energy corresponding to nominal load of the prosumer); this KPI has been tested for different simulation scenarios. It has been intended to obtain situations with KPI2.2 < 5% of the contractual power considered for consumer, for an analysis window T=one day, demonstration through refined simulation and UniRCon algorithm; simulations have been based on real and rescaled daily data records from selected project metering points and on selected prosumer's resource dimensioning.

KPI2.3 is looking for RES-based generation curtailment degree; This KPI is wanted to have values less than 20% from produced energy for an analysis window T_1=one day; demonstration has been made through refined simulation and UniRCon algorithm, based on real and rescaled daily data records from selected project metering points.

KPI2.4 shows the ratio between the active energy delivered from DSO to the prosumer and the total active energy transferred to the loads), reflecting the local use of RES-based electricity, It has been pursued a value under 70% for the analysis window of one day.

The basic control algorithm, Storage Control Algorithm (SCA) 1, is "UniRCon", which is main scenario considered for the project. Various simulation tests have been made for assessing the KPI2.2, KPI2.3, and KPI2.4, which showed that they are attainable if there is an acceptable ratio between the storage resource energy (kWh) and the power of locally produced energy. The results are based on the current UniRCon algorithm, which will be enhanced during the phase 3.

Different scenarios for the KPI2.2, KPI2.3 and KPI2.4 evaluation scenarios are presented in the following sections.

6.2.3.1 Scenario 1

Scenario 1 has the following characteristics:

- Energy production is simulating a PV production based on recorded PV evolution with an appropriate scaling factor to cope with the house consumption.
- The energy consumption is simulating a real consumption pattern, by using a real consumption profile recorded in the project, with some adaptations such as appropriate scaling for the test purpose.
- The prosumer's battery has a capacity of 12 kWh, a Depth of Discharge (DoD) of 10%, an efficiency during charging of 95% and an efficiency during discharging of 97%.
- The power of the inverter used for bidirectional energy flow between the battery and the prosumer's internal network (bidirectional power flow) is set to 2500 W (2.5 kW)

- This scenario 1 uses the battery control algorithm named UniRCon (SCA1), which has as main target to keep the advanced prosumer without injection of energy towards the main grid.
- The setup has been designed such that the total daily energy production from PVs is not exceeding the total energy consumption during the day; this has been obtained by adequate scaling of real production and consumption profiles at one-minute granularity, from records obtained in the project.

The PV production of around 16 kWh in a day, with partially clouded periods, which is suggesting a 3.5 to 4 kWp installed PV power, after using the rescaling factors. This shows that the scenario 1 deals with a factor between energy of the battery (12 kWh in this scenario) and the installed PV power of 2.5 to 3 kWp.

Figure 15 and Figure 16 present the chosen situation, the parameters evolution during the whole day and the daily energies obtained during the selected time period of one day. It can be seen in Figure 15 that the total energy which can be obtained from the PV, based on the meteorological conditions (E_PV_met = 16.057 kWh) is lower than the total daily consumption (E_cons = 24.217 kWh)

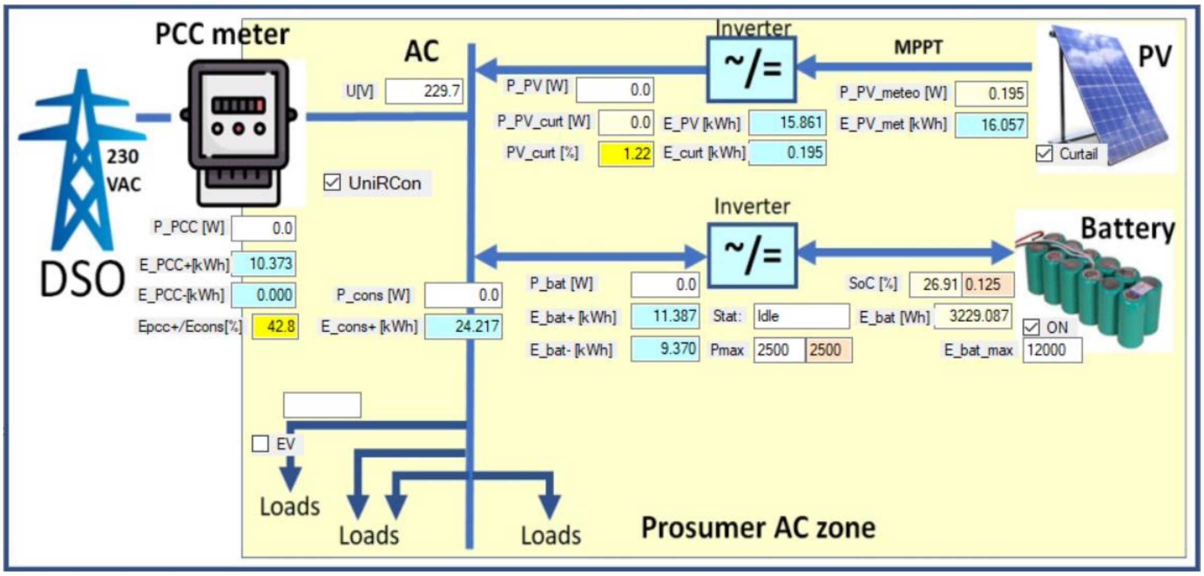

Figure 15. UniRCon SCA1: Scenario 1 environment and results.

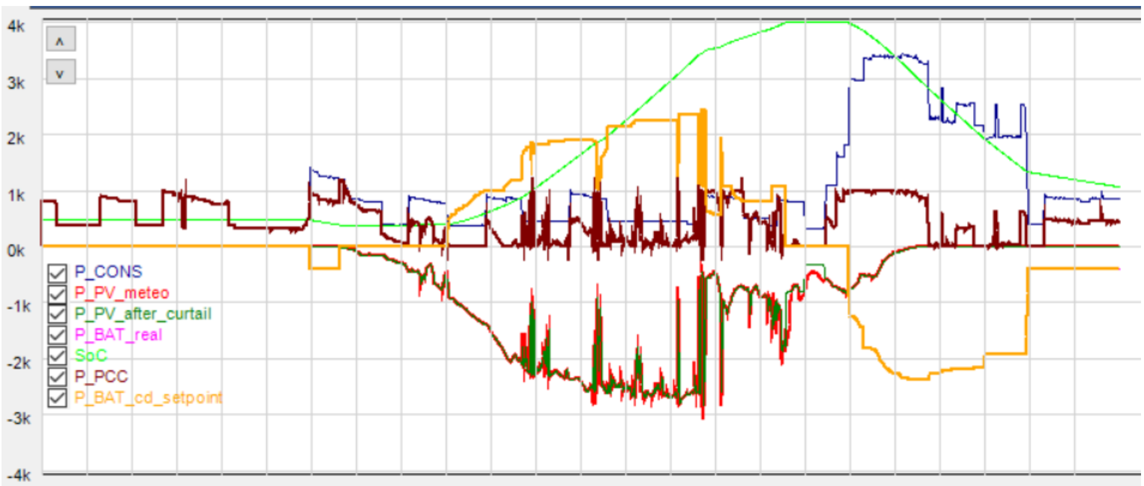

Figure 16. UniRCon SCA1: Scenario 1 evolution of parameters.

The following calculations were made:

$KPI2.2 = K_{USER\_E\_BACK} = E_{PCC-} / E_{CONS} = 0.0 / 24.217 = 0\%$ (6.2.3.1)

$KPI2.3 = K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO} = 0.195 / 16.057 = 1.22\%$ (6.2.3.2)

$KPI2.4 = K_{USER\_E\_DSO} = E_{PCC+} / E_{CONS} = 10.373 / 24.217 = 42.8\%$ (6.2.3.3)

$K_{AUTO\_CONS} = E_{PV} / E_{CONS} = 16.057 / 24.217 = 66.3\%$ (6.2.3.4)

Where E means daily energy and USER is the prosumer. The daily energy balance can be also verified:

$E_{CONS\_TOTAL} = E_{INJECT\_TOTAL}$ (6.2.3.5)

where:

$E_{CONS\_TOTAL} = E_{CONS} + E_{BAT+}$ (6.2.3.6)

which means that the total consumption is given by the real consumption associated to the prosumer's loads connected to the internal network of the prosumer, to which is added the energy absorbed by the battery during the charging mode (E_{BAT+}), which is also considered as a consumption.

$E_{INJECT\_TOTAL} = E_{BAT-} + E_{PCC+} + E_{PV}$ (6.2.3.7)

which shows that the total energy injected in the prosumer's internal network is the sum of the following energies:

- The energy produced by the PV panels.
- The energy released from the batteries when it is in discharging mode.
- The energy consumed from the distribution grid, which is seen from the internal prosumer's grid in the category of a "produced energy"; this approach is also true, as this energy is in fact produced somewhere in the main grid and transported through the distribution grid to the prosumer.

It results:

$E_{CONS} + E_{BAT+} = E_{BAT-} + E_{PCC+} + E_{PV}$ (6.2.3.8)

By introducing the energy values resulted from the integration during the whole day, displayed in Figure 15, the following values are obtained:

24.217 kWh + 11.387 kWh = 9.370 kWh + 10.373 kWh + 15.861 kWh

which verifies the equality by making the summations on both parts:

35.604 kWh = 35.604 kWh

To be observed that the calculations use only positive values from the energies, no matter if they are consumption or production. This is a typical situation when using billing meters, as these devices have also only registers with positive values, and the sign of the energy index is given based on the interpretation of the measurement.

6.2.3.2 Scenario 2

Scenario 2 has the following characteristics:

- The simulation of local energy production with PVs has the same evolution as in the first scenario.
- The simulated energy consumption has the same profile used in scenario 1.
- The prosumer battery storage energy system has a smaller capacity than in scenario 1, meaning of 10 kWh; all other battery related parameters remain unchanged (DoD, efficiencies).
- The power of the inverter associated to the battery storage remains the same as in scenario 1.

Figure 17 and Figure 18 present the environment situation and the data evolution, as well as the daily energies obtained during the time period of one day.

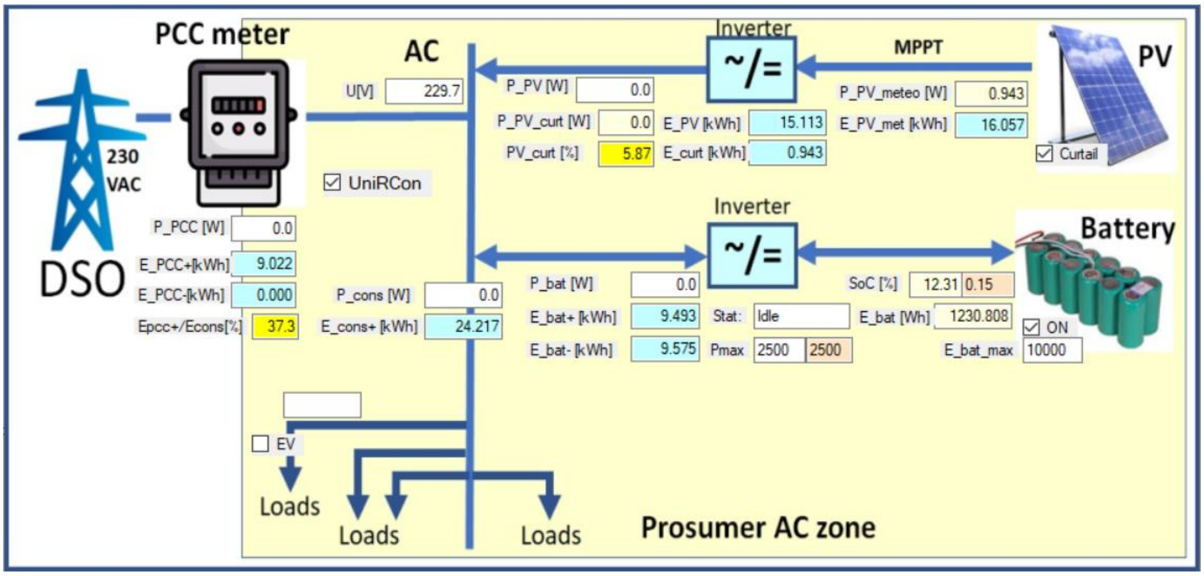

Figure 17. UniRCon SCA1: Scenario 2 environment and results.

Figure 18. UniRCon SCA1: Scenario 2 evolution of parameters.

The following calculations are made, based on the results of running the scenario 2 simulation:

$KPI2.2 = K_{USER\_E\_BACK} = E_{PCC-} / E_{CONS} = 0.0 / 24.217 = 0\%$

$KPI2.3 = K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO} = 0.943 / 16.057 = 5.87\%$

$KPI2.4 = K_{USER\_E\_DSO} = E_{PCC+} / E_{CONS} = 9.022 / 24.217 = 37.3\%$

$K_{AUTO\_CONS} = E_{PV} / E_{CONS} = 16.057 / 24.217 = 66.3\%$

By using the relations (6.2.3.5) – (6.2.3.8), it can be verified also in this scenario the total energy balance; in this case, the daily balance of energy can be expressed with the formula (6.2.3.8) and has the following specific values:

$$E_{CONS} + E_{BAT+} = E_{BAT-} + E_{PCC+} + E_{PV}$$

It results:

$$24.217 \text{ kWh} + 9.493 \text{ kWh} = 9.575 \text{ kWh} + 9.022 \text{ kWh} + 15.113 \text{ kWh}$$

which checks the energy conservation law:

35.604 kWh = 35.604 kWh

6.2.3.3 Scenario 3

Scenario 3 has the following characteristics:

- The simulation of local energy production with PVs has the same evolution as in scenario 1.
- The simulated energy consumption has the same profile used in scenario 1.
- The prosumer battery storage energy system has a smaller capacity than in previous scenarios, meaning of 8 kWh; all other battery related parameters remain unchanged (DoD, efficiencies)
- The power of the inverter associated to the battery storage remains the same as in scenario 1.

Figure 19 and Figure 20 present the environment situation and the data evolution, as well as the daily energies obtained during the time period of one day.

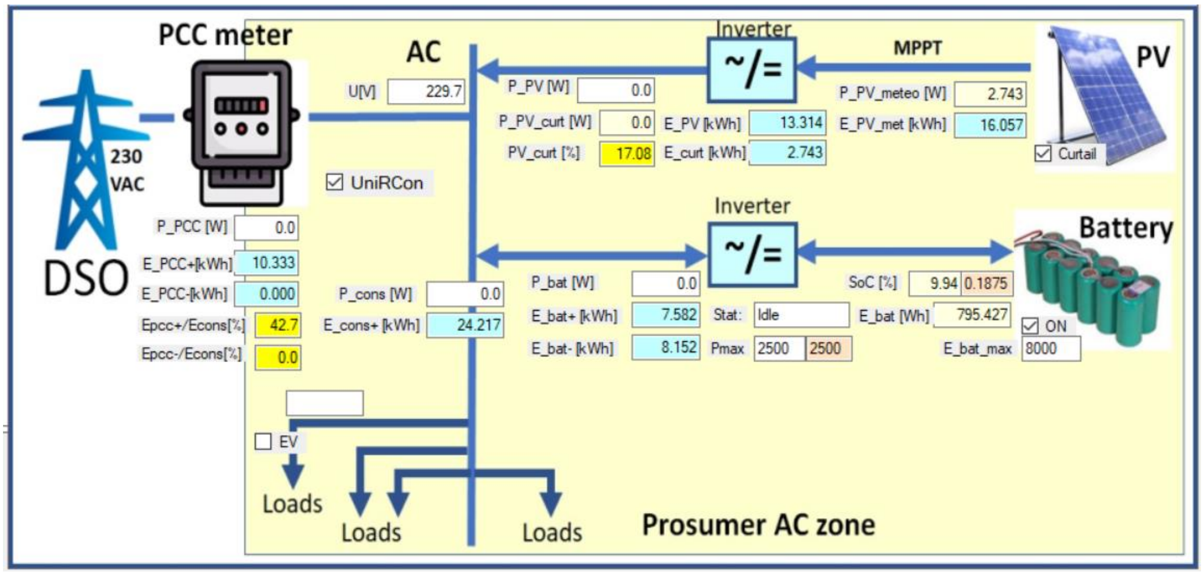

Figure 19. UniRCon SCA1: Scenario 3 environment and results.

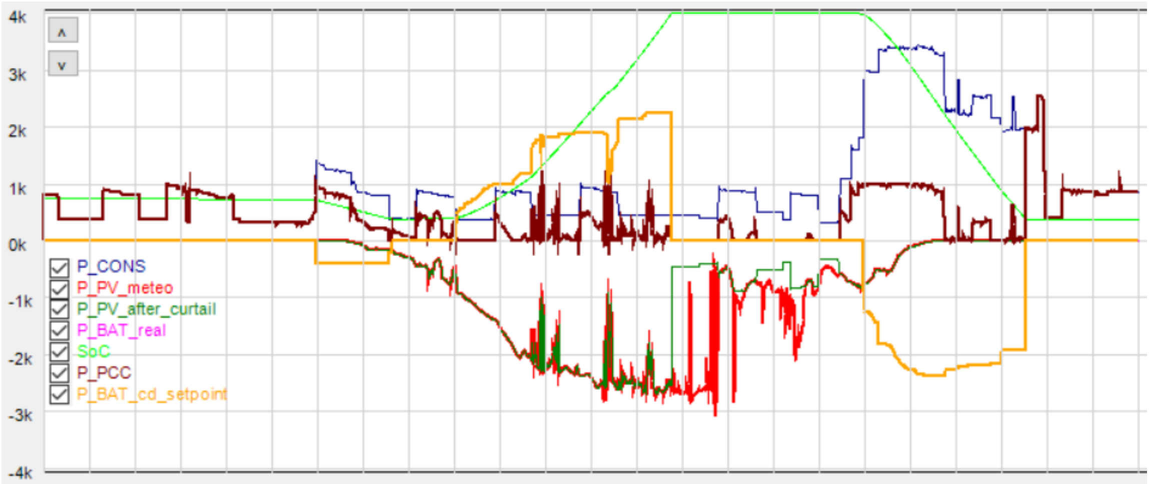

Figure 20. UniRCon SCA1: Scenario 3 evolution of parameters.

The following KPIs are calculated based on the simulation results:

KPI2.2 = $K_{USER\_E\_BACK}$ = E_{PCC}- / E_{CONS} = 0.0 / 24.217 = 0%
KPI2.3 = K_{PV_LIM} = E_{PV_LIM} / E_{PV_METEO} = 2.743 / 16.057 = 17.08%
KPI2.4 = $K_{USER\_E\_DSO}$ = E_{PCC}+ / E_{CONS} = 10.333 / 24.217 = 42.7%
K_{AUTO_CONS} = E_{PV} / E_{CONS} = 13.314 / 24.217 = 54.97%

6.2.3.4 Scenario 4

Scenario 4 of the UniRCon local storage control algorithm is also presented, using a different consumption pattern, as depicted in Figure 21 and Figure 22 for changed load pattern.

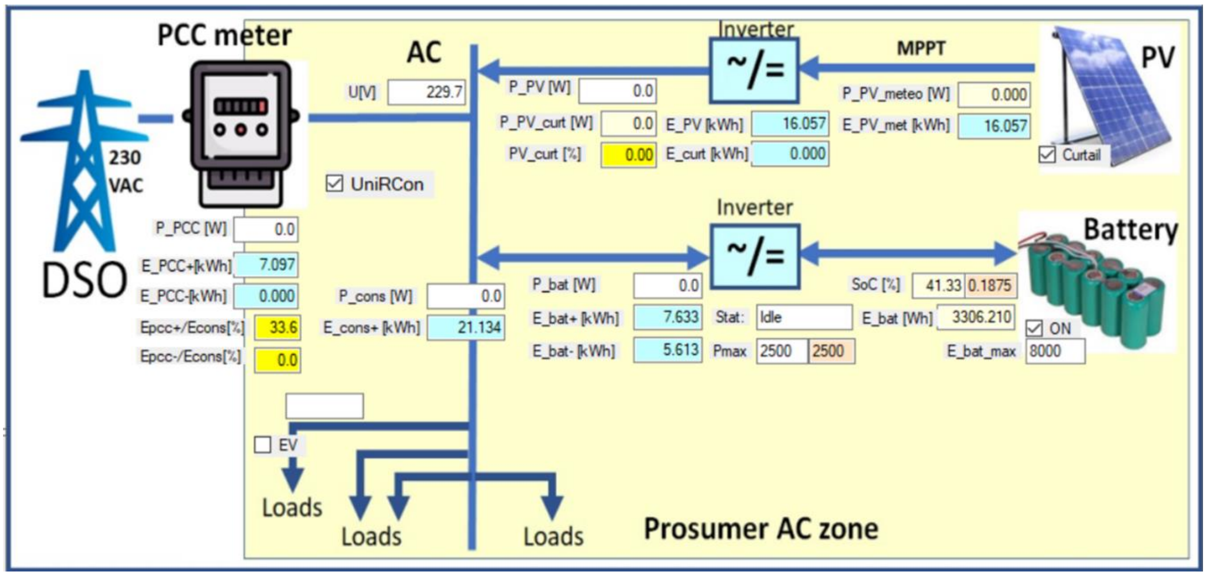

Figure 21. UniRCon SCA1: Scenario 4 environment and results.

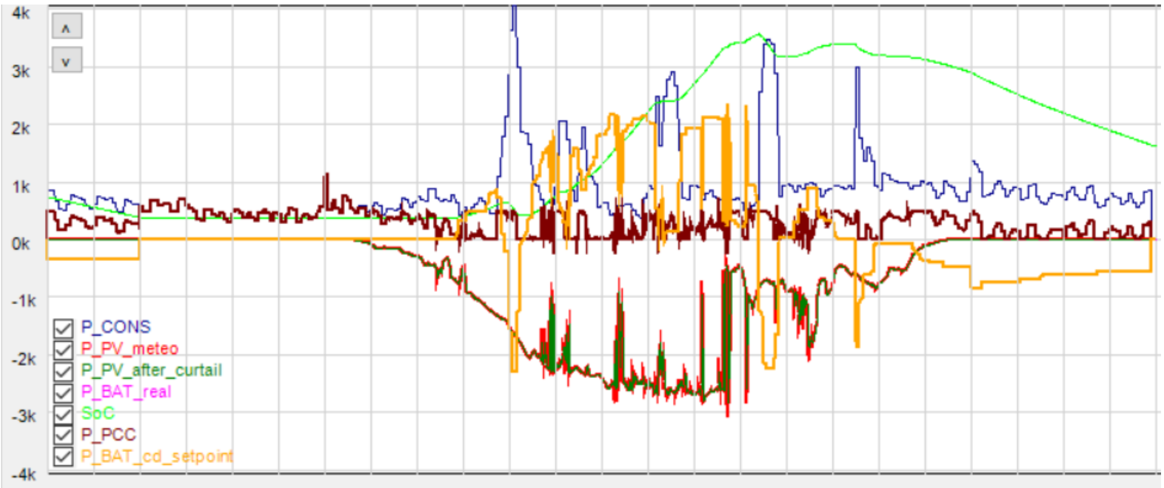

Figure 22. UniRCon SCA1: Scenario 4 evolution of parameters.

The calculations for SCA1 scenario 4 are as follows:

$KPI2.2 = K_{USER\_E\_BACK} = E_{PCC-} / E_{CONS} = 0.0 / 21.134 = 0\%$

$KPI2.3 = K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO} = 0 / 16.057 = 0\%$

$KPI2.4 = K_{USER\_E\_DSO} = E_{PCC+} / E_{CONS} = 7.097 / 21.134 = 33.6\%$

$K_{AUTO\_CONS} = E_{PV} / E_{CONS} = 16.057 / 21.134 = 76.0\%$

6.2.3.5 Scenario 5

Scenario 5 of the UniRCon local storage control algorithm is also presented, using the same consumption pattern of scenario 4, and using also a different PV production pattern, as depicted in Figure 23 and Figure 24 for changed pattern also for the PV production.

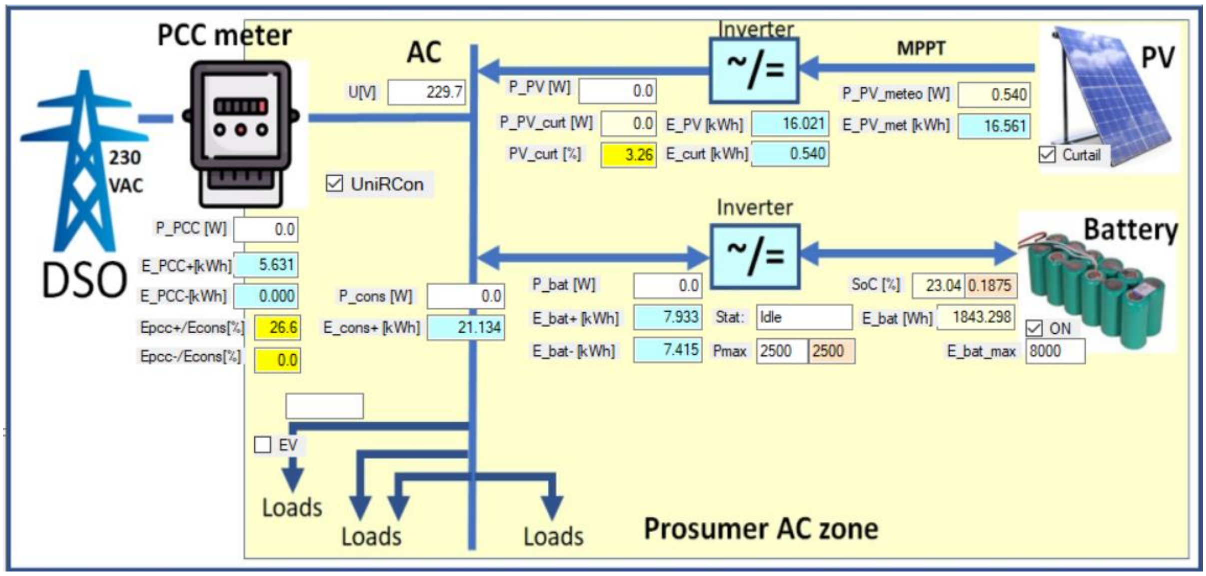

Figure 23. UniRCon SCA1: Scenario 5 environment and results.

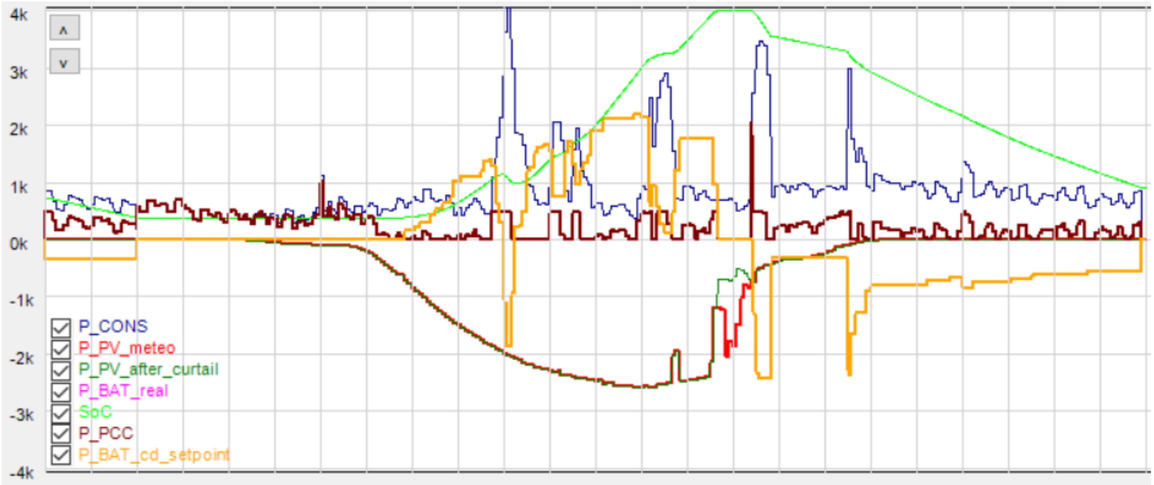

Figure 24. UniRCon SCA1: Scenario 5 evolution of parameters.

The calculations for SCA1 scenario 5 are as follows

$KPI2.2 = K_{USER\_E\_BACK} = E_{PCC}- / E_{CONS}$ = 0.0 / 21.134 = 0%

$KPI2.3 = K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO}$ = 0.54 / 16.057 = 3.26%

$KPI2.4 = K_{USER\_E\_DSO} = E_{PCC}+ / E_{CONS}$ = 5.631 / 21.134 = 26.6%

$K_{AUTO\_CONS} = E_{PV} / E_{CONS}$ = 16.057 / 21.134 = 76.0%

6.2.3.6 SCA2 and SCA3

Two additional storage control algorithms have been developed, with the purpose to compare the KPIs during the refinements of the basic storage control algorithm for UniRCon and to make eventual improvements of the basic algorithm inspired by some characteristics of the other storage control algorithms which prove to have interesting behaviour in some particular cases. The following two test are evaluating these control algorithms.

SCA2 relies for its storage control on the hourly forecast of the PV production, thus trying to absorb in the battery the energy forecasted to be produced in the next 24 hours. SCA3 considers that in addition to the PV production forecast, it is also available the consumption forecast, and that both hourly based profiles are used to control the battery schedule.

Therefore, in SC2 and SC3 it is considered that there are services available to produce in advance forecasts for the RES production (SCA2) or for both RES and consumption behaviour. Additional SCA situation using only the consumption forecast will be also considered in project phase 3. A tool for producing forecasts of consumption based on similarity with full days of consumption already recorded is in initial phase of development (the application is an off-line similarity tool, named Profiles Similarity Tool (ProSiT). To be noted that SCA2 and SCA3 are checked in terms of the SCA1 KPIs, except KPI2.1 which is specific only to UniRCon, meaning to control that no energy is injected back in the main grid. SCA2 Scenario 1 environment and results are presented in Figure 25 while the parameters evolution is depicted in Figure 26.

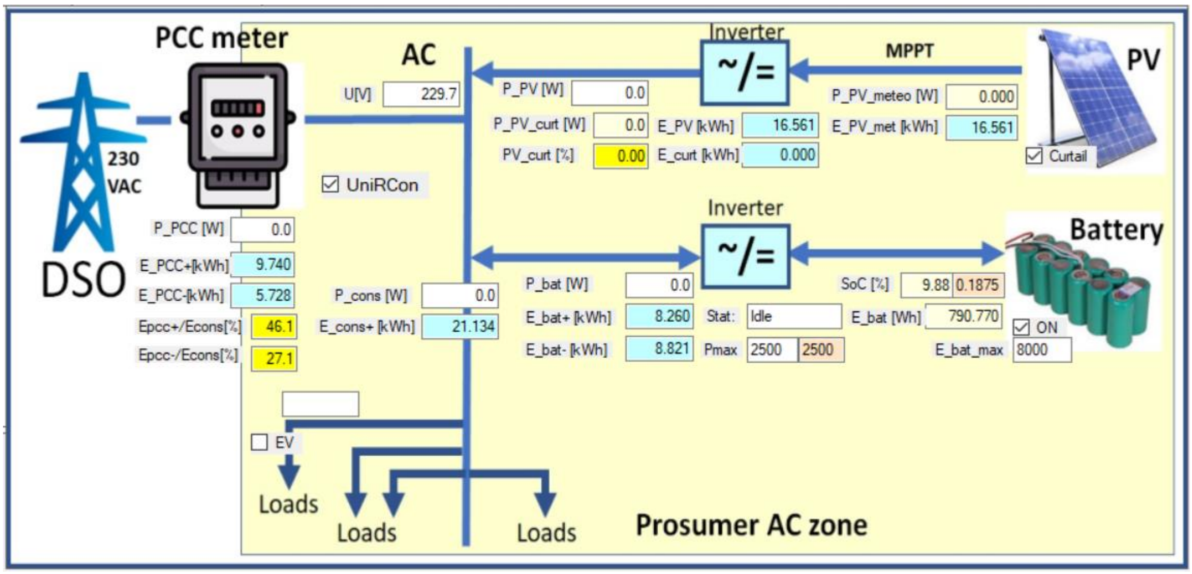

Figure 25. PV forecast driven SCA2: Scenario 1 environment and results.

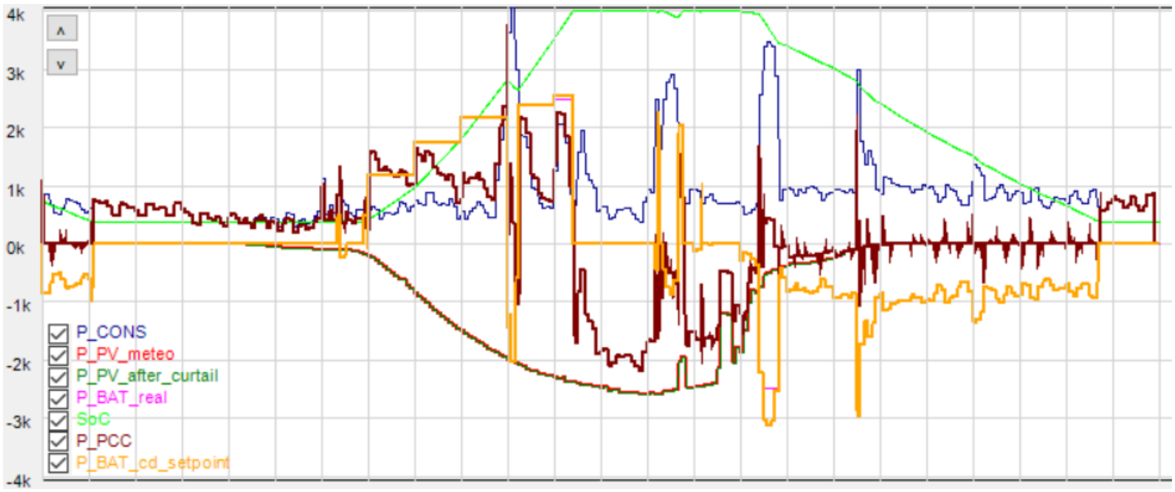

Figure 26. PV forecast driven SCA2: Scenario 1 evolution of parameters.

The calculations for SCA2 scenario are as follows:

$KPI2.2 = K_{USER\_E\_BACK} = E_{PCC-} / E_{CONS} = 5.728 / 21.134 = 27.1\%$

$KPI2.3 = K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO} = 0 / 16.561 = 0\%$

$KPI2.4 = K_{USER\_E\_DSO} = E_{PCC+} / E_{CONS} = 9.740 / 21.134 = 46.1\%$

$K_{AUTO\_CONS} = E_{PV} / E_{CONS} = 16.561 / 21.134 = 78.4\%$

SCA3 Scenario 1 environment and results are presented in Figure 27 while the parameters evolution is depicted in Figure 28.

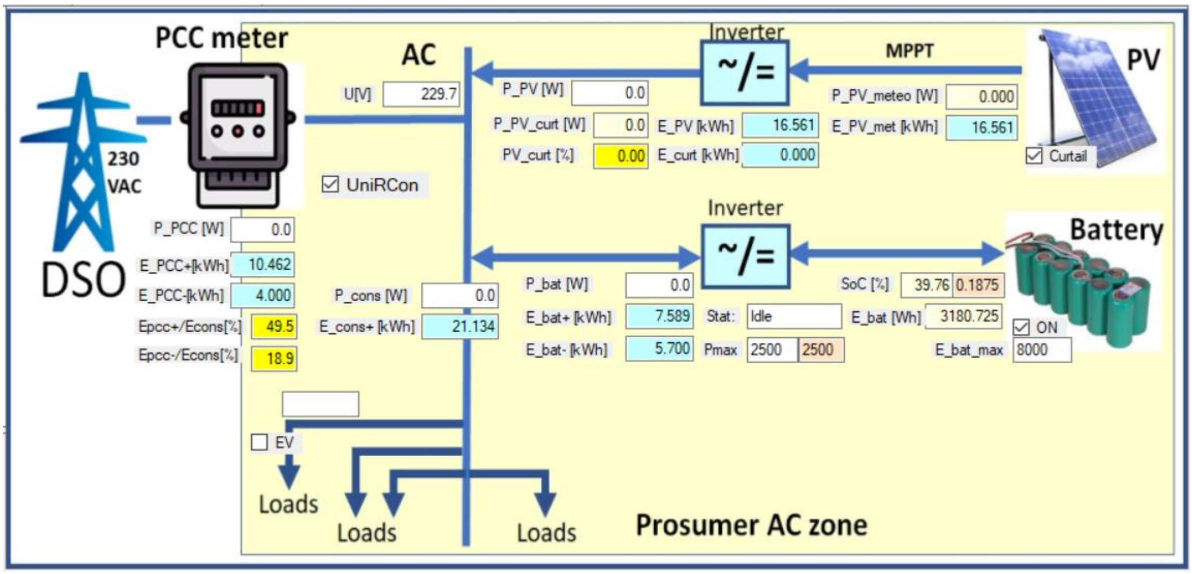

Figure 27. PV and Consumption forecast driven SCA3: Scenario 1 environment and results.

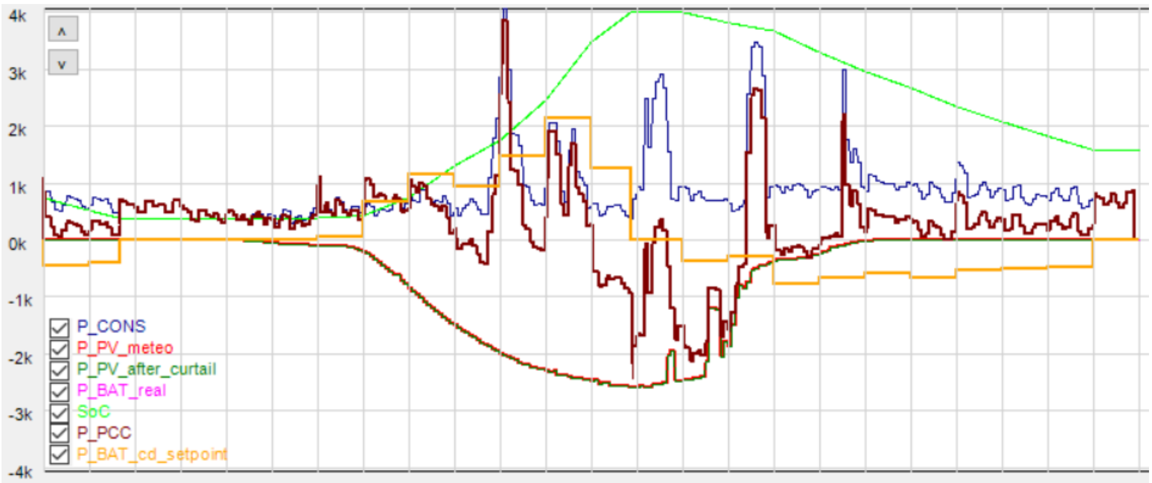

Figure 28. PV and Consumption forecast driven SCA3: Scenario 1 evolution of parameters.

The calculations for SCA3 scenario are as follows:

KPI2.2 = $K_{USER\_E\_BACK} = E_{PCC-} / E_{CONS}$ = 4.00 / 21.134 = 18.9%

KPI2.3 = $K_{PV\_LIM} = E_{PV\_LIM} / E_{PV\_METEO}$ = 0 / 16.561 = 0%

KPI2.4 = $K_{USER\_E\_DSO} = E_{PCC+} / E_{CONS}$ = 10.462 / 21.134 = 49.5%

$K_{AUTO\_CONS} = E_{PV} / E_{CONS}$ = 16.561 / 21.134 = 78.4%

6.2.3.7 Results

A supplementary KPI, related to self-consumption ratio, is also considered in the evaluation, labelled as KPI2.5. Table 12 presents the different KPIs results. In the given scenarios, all selected KPIs which are using the UniRCon storage control algorithms are respecting the requested scenarios. It can be also observed that KPI2.3 to KPI2.5 are verifying the condition in all studied scenarios, including in the ones using SCA2 and SCA3.

Table 12. KPIs evaluation results.

Control algorithm	KPI2.2 = $K_{USER\_E\_BACK}$ Cond: < 5%	KPI2.3 = K_{PV_LIM} Cond: < 20%	KPI2.4 = $K_{U\_E\_DSO}$ Cond: < 70%	K_{AUTO_CONS} (KPI2.5)
UniRCon SCA1 Scenario 1	0%	1.22%	42.8%	66.3%
UniRCon SCA1 Scenario 2	0%	5.87%	37.3%	66.3%
UniRCon SCA1 Scenario 3	0%	17.08%	42.7%	54.97%
UniRCon SCA1 Scenario 4	0%	0%	33.6%	76.0%
UniRCon SCA1 Scenario 5	0%	3.26%	26.6%	76.0%
SCA2 Scenario 1	27.1%	0%	46.1%	78.4%
SCA3 Scenario 1	18.9%	0%	49.5%	78.4%

The KPIs will be pursued also in the phase 3, with a more complex set of scenarios, and correlations between the resources, the algorithms of controlling the resources and the KPIs will be reported in the phase 3.

6.3 Lessons learned in the Bucharest test site

The records of daily files and the overall SMX activity has shown disturbed activity in specific periods in Bucharest test site, but also in Bolzano, due to logging features and due to the overlapping of various applications under development which may have been influenced reciprocally (there have been observed periods with a higher use of RPi system power, up to 100%, which brought a slower reaction of usual cyclical tasks).

Moreover, in the initial period of phase 2, there have been situations when the communication between SMX and the SMM became blocked on long periods, needing a restart of the SMXcore service. This situation happened with specific newer meters, even if in some older versions the communication was much more robust.

Regarding the KPIs for advanced prosumers, the simulations showed that the self-consumption ratio and the small injection in the grid are much depending on the local resources for storage. The following measures have been taken, which are lessons learned for the final phase:

- The reason of high logging in the Linux machine was basically due to high data reporting of applications, especially from SMXcore, in the system console, while the SD card became nearly full and even full in a small number of situations. To mitigate this, a less stressing policy of Linux logging has been implemented and the applications are in analysis for reducing or cutting the console outputs, while important data for the application health can be obtained on application logs, e.g. recorded every 1 minute or every 15 minutes;
- An additional awareness has been brought by the fact that node-red based technical GUI can also provide console-based or other system-based printouts, which also may be responsible for increasing the logging activity of the Linux environment. The lesson learned was that for each application developed or installed need a proper management about every single instruction providing output

- For the applications inter-influence, the following measures are considered for phase 3:
    - Test of applications in a separate system, before large deployment.
    - Progressive deployments in the SMXs.
    - Restarts and applications deployments will be better coordinated, such that inter-influences are seen on smaller number of systems and measures can be taken.
- For the health of systems (RPi based, used for research purpose), additional records have been considered (e.g. processor temperature) in the Bolzano and Bucharest test sites, while they will be also deployed in all SMXs.
- For the communication with the SMM, after in-deep analysis, it has been observed that for the meter models which produce a blockage needing restart, a setup with additional delays between requested messages gave a much more robust communication, bringing an acceptable reliability in almost all situations. For this, the basic driver for DLMS communication with the meters, which is an open source developed by a third party, has been successfully adapted in order to cope with such situations. To be noted that same type of meters in older versions did not showed such blocking features, which brought the possible explanation that newer meter firmware may have more functionalities but slower response on the serial interface, due to higher internal duties. The whole experience showed that each type of meter and even each new lot of the same meter model, requires analysis, mapping of data and tuning of real-time communication. This activity has been performed to all meters used in the project, having achieved successful results.
- For acceptable KPIs related to UniRCon functionality of the advanced prosumer, the storage resource (in kWh) is needed to be higher than the kW power installed in local PV production, usually with a ratio of at least two. This situation shows the importance of storage technology and of its level of penetration in order to ensure paradigm changes towards resilient prosumers and energy communities. One important lesson learned was that daily files with records available for later analysis have been shown to be extremely useful, for two important reasons: a) data has been recorded and made available also in situations when remote communication was down for some period, situation which occurred also in the Bucharest test site, due to the mixed use of the infrastructure for project purpose but also for teaching; b) daily records have been essential for making simulations with the UniRCon storage control algorithm and with other algorithms, in order to develop, refine and test against KPIs the functionality of the components. Moreover, these advantages have been shown to be useful in all project test sites, giving it as well a level of project lesson learned.

7 Status of the year 2 KPIs

Table 13 gives the status of KPIs for year 2.

Table 13. Year 2 KPIs status.

Obj. #	Indicator	End of Y2 Target	Y2 Status	Achievements/Description
TO1	Prototypes supporting S4G interfaces and Models for storage coordination	9	Achieved	Prototypes developed: • D4.2 [S4G-D4.2] (updated version of D4.1 [S4G-D4.1]) • D4.4 [S4G-D4.4] • D4.6 [S4G-D4.6] • D4.9 [S4G-D4.9] (updated version of D4.8 [S4G-D4.8]) • D4.11 [S4G-D4.11] • D5.1 [S4G-D5.1] • D5.4 [S4G-D5.4] (updated version of D5.3 [S4G-D5.3]) • D5.6 [S4G-D5.6] • D6.8 [S4G-D6.8] (updated version of D6.7 [S4G-D6.7])
TO2	Sets of distributed and centralized storage control algorithms prototypes developed	4	Achieved	Three control algorithms are achieved in Bucharest test site, by simulating: 1. A simplified local storage control algorithm for an advanced self-resilient prosumer becoming UniRCon (HLUC-1-PUC-2). 2. A storage control algorithm for prosumer based on PV production forecast in deciding the local battery schedule. 3. A storage control algorithm for prosumer with PV and local battery having available a 24 hours forecast for both the PV production and for the consumption. 4. An algorithm for LVDC networks with storage is reported in a conference paper entitled: Adaptive distributed EMS for small clusters of resilient LVDC microgrids[xvii]
TO2	Systems embedding S4G predictive control algorithms	3	Achieved	PROFESS, GESSCon, LESSAg

TO2	Systems considered by the S4G predictive control algorithms	Residential storage DSO-side storage	Achieved	Grid-side ESS control system and User-side for residential and DSO-side ESS control system, LESSAg for advanced resilient prosumer
TO3	Test deployment of Unbundled Smart Meter prototypes	Bucharest Bolzano Fur	Achieved	Bucharest, Bolzano, and Fur/Skive
TO3	Systems fully integrated with the unbundled smart meter	Home (production and consumption) meters Energy Router Residential storage	Achieved	• Fur/Skive residential test site in the 5 houses PCCs, and in the three-phase ER. • Bolzano residential test site: PCC (net-metering), and in the ESS. • Bucharest test site: laboratory EB105 PCC.
TO4	Test deployments of Energy Router prototypes	1	Achieved	The three-phase ER was deployed in the Fur/Skive test site, as described in D4.11 [S4G-D4.11].
TO5	Availability of DSF components	50% of related specifications implemented	Achieved	This KPI had been achieved
TO5	DSF Features supported	Analysis by simulation Optimization	Achieved	This KPI had been achieved (D5.1 [S4G-D5.1]).
TO6	Number of different cases evaluated in test sites Bucharest/Bolzano/Fur	3	Achieved	Evaluation of the residential and professional GUI with end-users and interface design experts, as described in section 2.14 and section 2.4, respectively. The tasks used for evaluation cover aspects related with the use cases: HLUC-2-PUC-1, HLUC-3-PUC-1, and HLUC-3-PUC-4.
SO1	Number of residential/professional users engaged in test sites	6 residential 5 professional	Achieved	• 6 professional users were involved in both test sites (Fur/Skive (5) and Bolzano (1)) providing inputs to the professional GUI. • 16 residential users were involved in M26 and M27, when a user questionnaire was conducted in the Fur/Skive and Bolzano test sites.
SO2	Number of Business cases proposed/evaluated	2	Achieved	15 business cases were proposed, as described in D2.3 [S4G-D2.3].

SO3	Number of complete techno-economic planning cases analyzed using the DSF	2	Achieved	Three scenarios have been selected in the DSF-SE economic model: the baseline scenario (scenario 0) with only grid strengthening (and different levels of PV penetration), the scenario 1 with grid strengthening and different levels of storage penetration at household side (i.e., prosumers) and, finally, the scenario 2 with storage at sub-station level deployed by DSO.
SO4	Number of inputs proposed to EU or regional policy- related, traditional or open standardization initiatives	2	Achieved	• Standardisation initiatives through ASRO (CEN-CENELEC representative in Romania): the standard for connecting generators EN50549-1 and 2 to low and medium voltage grid • National policy in Romania for prosumers through ANRE (Romanian Energy Agency): proposal for connecting the prosumers with financial support
SO5	Number of inputs Lessons Learned, and recommendations published towards security- and privacy-related initiatives	2	Achieved	Lessons Learned for year 1 (D6.10 [S4G-D6.10]) and year 2 (in this deliverable) are available, No Recommendations have been published.

8 Summary of year 2 Lessons Learned

8.1 Summary of the LL collection and evolution process

The S4G Lessons Learned (LL) are being collected throughout the whole project to ensure a consistent enhancement of the overall project development. In general, the collection process consists of 6 steps:

1. **Collection**: Collection of LL is done with respect to both internal and external sources. Collection is organized per work package.
2. **Verification**: LL are verified regarding their correctness, significance, validity, and applicability by the respecting WP leader.
3. **Storage**: LL will be stored on the Confluence wiki page https://confluence.fit.fraunhofer.de/confluence/display/S4G/Lessons+Learned+Repository.
4. **Dissemination**: LL are reported in D2.5 [S4G-D2.5], D2.6 [S4G-D2.6], and D2.7 [S4G-D2.7]. All project partners are encouraged to consult the repository.
5. **Reuse**: WP leaders are responsible to consult the LL repository to take them into account at least before any major decision has to be made.
6. **Identification of improvement opportunity**: relevant LL will lead to new and/or updated requirements, which will be taken into account during the development cycle. Final requirements as well as LL are to be reported in D2.7 – "Final Lessons Learned and Requirements Report" (M30).

More detail about the LL collection and improvement process can be found in D6.10 [S4G-D6.10] as well as D2.5 [S4G-D2.5] and D2.6 [S4G-D2.6].

In addition to the LL reported in the following section, this document features LL per test site. Those LL can be found in the sections 4.3, 5.3, and 6.3, and will not get repeated in this section.

8.2 Sample LL from Year 2

LL in S4G consist of the following information:

- **Category**: For categorizing the LL learned, classification codes are being used:
    - *RTD*: Research oriented
    - *PRO*: Process oriented
    - *SWD*: Software development experience
    - *ARC*: Architecture oriented
    - *NET*: Network oriented
    - *SEC*: Security oriented
    - *TST*: Testing result
    - *INT*: Integration experience
    - *VAL*: Validation experience
    - *REG*: Regulatory
    - *IWU*: Interaction with (end) user
    - *DIS*: Dissemination and Exploitation
- **S4G Partner**: abbreviation of the partner who experienced the LL.
- **Experience and Knowledge gained**: short description of the gained experience and knowledge that led to the final LL.
- **Lesson Learned**: One sentence describing what to do to not encounter a similar problem.
- **Analysis of Lesson Learned**: Further explanation of what went wrong and how to compensate or countermeasure the negative impact.
- **Requirement(s) affected**: Keys for affected requirements as they are collected in Jira.

The resulting LL are documented in tabular form as seen in Table 14.

Table 14. Sample of the reported LL for Year 2 per WP.

Category	S4G-partner	Experience and knowledge gained	Lesson Learned	Analysis of Lesson Learned	Requirement(s) affected
WP 2					
PRO	FIT	Having preliminary system requirements as a basis for development is difficult since they might turn out to be malformed or contradicting standards as the project progresses and the knowledge about the domain and legal limitations increases.	Form initial requirements in a way that they are still applicable as the project evolves to be able to show progress.	Initial requirements turned out to be not applicable after the first architectural and legal drafts and continuously needed to be reworked.	all
PRO	EDYNA	The elaboration of a valuable business model requires clear understanding of the Italian regulatory framework, especially for DSOs.	It is important to involve in the project a person with knowledge of the Italian regulatory framework	In this way the elaborated business models are more realistic	/
WP 3					
ARC	ISMB	Including a common information model generates significant modifications to the overall architecture.	Technical objectives have to be considered since the beginning on every design face.	A common information model was not considered during architecture design and it added extra components in the architecture.	all
PRO	UPB	Common information model was (is) an important topic of discussion and in order to match all the needs and initial	The decisions involving further development of components and	In this way the continuous progress of the project is achieved.	/

		proposals, some standards and protocols have been in depth analysed and debated.	communication needs to be rationally and commonly taken in a reasonable time.		
WP 4					
RTD	FIT	Sample data from local nodes is important for developing optimization strategies	Sample data from application scenarios is needed for optimization models	Sample data should be taken as soon as possible in the project, so effective algorithms are developed.	/
PRO	ISMB	Retrieved data from EV charging stations contain errors.	Data pre-processing is needed for stochastic modelling and predictions	/	/
WP 5					
INT	ISMB	EB#SMX interface confuses about the adapter implementation.	An adapter cannot be developed between a component and the MQTT broker.	Adapter cannot be developed if data flows are not well defined.	S4G-
SWD	FIT	OpenDSS was developed for Windows and it states problems for deployment on the server. A framework had to be used for deployment.	Simulator software for DSF-SE should run on Linux for easy deployment on the server	The best option for the deployment on the server is the selection of open source tools running on Linux or that can be adapted to Linux	/
WP 6					

PRO	ENIIG	Reinstalling the SMX and cable was repeatedly necessary due to connection loss caused by unknown reasons.	Installation instructions have to be clearly defined and well written: An additional error-log on the SMX might help searching for appropriate solutions.	Hardware and installation instructions should be excessively tested in the lab mimicking a real setup before being installed in private houses.	/
PRO	EDYNA	During the test in the private house we lost the communication with the SMX and between SMX and meter	All the components should be checked properly in terms of robustness and reliability	/	/
WP 7					
DIS	UNINOVA	The project video and flyer should be released during year 1 (even if updates are provided nearly the end of the project)	The dissemination process should start in an earlier phase of the project	Starting in an earlier phase, it will allow the early engagement of the project stakeholders, creating a set of early followers that can help to disseminate the project.	/

9 Conclusions

This deliverable summarizes the phase 2 Evaluation in all the three S4G test sites (Bolzano, Fur/Skive, Bucharest), resulting from the evaluation activities performed during phase 2, as defined in the planned evaluation framework and its KPIs (D6.2 [S4G-D6.2]).

The majority of the evaluation was performed as planned, achieving the S4G components and prototypes KPIs. However, it was not possible to evaluate the planned HLUC-3-PUC-2: "Autonomous control of storage installed at user premises and distributed in the grid" due to the issues on the current transformer meter installation in the Fur/Skive test site, as reported in section 5.2 and section 5.3. The necessary S4G components and prototypes for its evaluation were deployed and their interaction and integration were evaluated, however, due to the missing meter, it was not possible to evaluate their operation results.

All year 2 TO and SO were achieved, as detailed in section 7. The yearly lessons learned are also presented in section 8, to enable the learning iterative process, and support the year 3 planning.

The final issue of this deliverable in M36 (November 2019) will report the phase 3 evaluation, considering the final evaluation framework and KPIs, taking into account both technical and economic aspects of the use-cases and business cases defined in the project.

Acronyms

Acronym	Explanation
AC	Alternating Current
API	Application Programming Interface
BMS	Battery Management System
COSEM	Companion Specification for Energy Metering
DC	Direct Current
DLMS	Device Language Message Specification
DoD	Depth of Discharge
DUT	Device Under Testing
DSF	Decision Support Framework
DSF-DWH	Decision Support Framework Data Warehouse
DSF-SE	Decision Support Framework Simulation Engine
DSO	Distribution System Operator
ER	Energy Router
ESS	Energy Storage System
EV	Electric Vehicle
GUI	Graphical User Interface
HTTP	HyperText Transfer Protocol
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LL	Lessons Learned
MQTT	Message Queuing Telemetry Transport
MS	Milestone
OGC	Open Geospatial Consortium
PCC	Point of Common Coupling
PROFESS	Professional Real-time Optimization Framework for Energy Storage Systems
PROFEV	Professional Real-time Optimization Framework for Electric Vehicles
ProSiT	Profiles Similarity Tool
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
RAM	Random Access Memory

RES	Renewable Energy Sources
REST	Representational State Transfer
RMS	Root Mean Square
RPi	Raspberry Pi
RUL	Remaining Useful Life
S4G	Storage4Grid
SCA	Storage Control Algorithm
SMX	Smart Meter eXtension
SO	Strategic Objectives
SoC	State of Charge
SoH	State-of-Health
SQL	Structured Query Language
SUS	System Usability Scale
TO	Technical Objectives
UniRCon	Unidirectional Resilient Consumer
UPS	Uninterruptible Power Supply
USM	Unbundled Smart Meter
VPN	Virtual Private Network
WP	Work Package

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Appendix A Professional GUI Phase 2 requirements

Table 15. Professional GUI Phase 2 Jira requirements.

Issue	Description	Evaluation action
S4G-5	The DSF-SE shall be able to simulate scenarios where EV Charging Stations are coordinated	**Evaluated**
S4G-7	The strategic grid planner shall be able to select the portion of interest of the grid topology to be used as scenario to calculate optimal ESSs positioning	**Evaluated**
S4G-8	The strategic grid planner shall be able to import and select historical data of interest in the DSF-SE	**Evaluated**
S4G-15	The S4G project should use standardized data models if applicable (i.e. from IEC, ISO, CENELEC or similar standards)	*Discarded*
S4G-22	DSF-SE should be able to use load profiles entered through its API	**Evaluated**
S4G-23	Professional users shall be able to view simulation results from the DSF-SE	**Evaluated**
S4G-30	The professional GUI should help the DSO-Grid-Planner to test the placement of new ESS	**Evaluated**
S4G-31	The DSF-SE should be able to simulate the electrical grid	**Evaluated**
S4G-40	Upon any data import operation, the DSF user shall be aware about privacy constraints associated with secondary re-use of data.	**Evaluated**
S4G-41	Access to data shall be protected	**Evaluated**
S4G-42	Access to all S4G components must be secured implementing to state-of-the-art AAA solutions	**Evaluated**
S4G-43	The DSF-SE shall offer a dedicated API	**Evaluated**
S4G-44	The DSF-SE shall allow to export optimal set-points found by optimization/simulation in open format	Discarded
S4G-56	The DSF-SE shall allow to export simulation results in open format	**Evaluated**
S4G-116	The professional user is able to take into account the real-world topology when he works on the grid topology	**Evaluated**
S4G-304	The professional GUI should be able to use scaling factors for the penetration level of elements in the grid	**Evaluated**
S4G-305	Data shall be collected, stored and protected based on EU and national legislation in Italy and Denmark	**Evaluated**
S4G-309	The professional GUI should enable the user to export simulation results in an open data format	*Discarded*

Appendix B Professional GUI Evaluation – Expert Evaluation

Table 16. Expert evaluation results.

Category	Potentially critical situation	Dialogue principle	ID	Prioritisation	Idea for improvement
Visualization & selection of radials	The potential user is annoyed that after running a simulation he cannot run a second simulation (potentially with a different duration), because he has to make unnecessary entries (the corresponding radial is not selected anymore, and he has to reselect it) and needs more time for the task and for error correction (if he wants to correct the entered duration).	Suitability for the task, Error tolerance, Self-descriptiveness	CI_2018/11_001	2	A new run of the simulation for the same network section should not require any selection of the radial. Potentially a "Run again" button or hold the radial selection until explicitly changed. If applicable, it should be possible to select the radial on a higher level.
	The potential user is annoyed that he has to switch from the "simulation panel" to the map in order to select a radial because he has to cover a longer navigation path.	Suitability for the task, Conformity with user expectations	CI_2018/11_003	2	Integrate "Select Radial" into the simulation window, so that a selection of the radial is also possible by an input in the Simulation window. As visual feedback, the selected radial turns blue. (create an alternative input option)
	The potential user is annoyed that it is so difficult to identify the network sections because he cannot directly detect the radials. They only become visible after you have clicked on them and the representation does not get better when zooming in.	Conformity with user expectations, Self-descriptiveness	CI_2018/11_004	2	1. Mouse Over > fat line 2. Zoom In > Lines are getting broader
	The potential user is annoyed that he does not know that he has to choose a radial, because he does not notice the hint message.	Self-descriptiveness, Suitability for learning	CI_2018/11_008	3	Highlight text or show animation if the greyed-out button "run simulation" was clicked unsuccessfully.

	The potential user is annoyed that after adding a photovoltaic system, he first has to click on the mouse pointer again in the menu in order to select the radial for a simulation, because he can make incorrect entries too quickly and this represents superfluous work step.	Suitability for the task	CI_2018 /11_005	2	A click on the radial line should always select the whole radial in order to be able to run the simulation again.
Simulation window	The potential user is annoyed that he cannot easily see what input is required to start a simulation, because the distance between number input fields is too small. (e.g. "Duration" text overlaps with the arrow button).	Self-descriptiveness, Suitability for the task	CI_2018 /11_009	4	Maintain sufficient distance
	The potential user is annoyed that he does not understand what input is required, because the terms "duration" and "entity" are not clearly understandable. "Entity" as heading for the selection of year/month/day is misleading.	Conformity with user expectations, Self-descriptiveness	CI_2018 /11_011	2	Change labels
	The potential user is annoyed that the input of the simulation time is so complex because no values are present.	Suitability for the task	CI_2018 /11_012	2	Use a value as preselection (e.g. 10 years) if there is a frequently used simulation time.
	The potential user is annoyed that he does not understand what input is required to enter the simulation time, because the time input fields are too complex, and he does not know if how many and what inputs are required and if they are interdependent (it looks like you have to enter two separate values).	Self-descriptiveness	CI_2018 /11_013	2	The time selection should be simplified (perhaps separate rows for weeks, months, years and below the selected total time).

	The potential user is confused that he can enter all possible values for the simulation time because he does not know whether the time specification is really correctly considered. Consider the upper limits of a simulation duration. Is 1500 years plausible?	Error tolerance	CI_2018 /11_014	1	Limit input of the field to reasonable entries. Display of the upper limits if the entered value exceeds a reasonable value. Error message. Automatic correction of the input if a typing error is obvious. Support function.
	The potential user is confused that he can run a simulation with a negative time specification, because he cannot see how the negative value flows into the simulation or whether the minus is ignored. It is possible to choose -2 years (generally a negative number) for a simulation. All goes well according to the system.	Error tolerance	CI_2018 /11_015	3	see CI_2018/11_014
	The potential user is confused that he can press the "Run Simulation" button and nothing happens because he expects a result. The button is clickable when the time has been entered but no Radial is selected.	Error tolerance	CI_2018 /11_016	4	Highlight note "Select Radial". Button should not be clickable.
	The potential user is confused that he cannot select a radial because he is not aware that this only works in "select mode" and he is currently in an "add mode". Why is the simulation block visible and the duration fields enabled when battery-, EV-, and other non-pointer modes are selected, where one cannot do a simulation anyway?	Suitability for the task, Self-descriptive ness	CI_2018 /11_017	3	Make possible user actions more visible. Make selected mode more visible. Do not show simulation window if no simulation can be executed.

	The potential user is confused that the message "Abort simulation" sounds so technical because it sounds strange to him.	Conformity with user expectations	CI_2018/11_018	1	"Abort simulation" is too technical. Interrupt, cancel, or something less emotionally loaded for the general population could be used instead.
Results	The potential user is annoyed that he cannot hide the simulation results and cannot compare the results of different simulation runs because the simulation input and the results are displayed in the same window.	Conformity with user expectations	CI_2018/11_019	2	Clearly separate simulation results from input for new simulation Line or integration of a small cross (icon "close") at the top right Alternative: Simulation results are displayed in a separate window, so a history can be displayed if necessary.
	The potential user is irritated that in the first sentence within the results it is stated that the simulation was executed because the heading already says this.	Conformity with user expectations	CI_2018/11_020	1	For the first movement I would wish something more meaningful, e.g. "Simulation successful(ly finished).)
	The user is annoyed that he cannot hide the simulation results (textual and visual) because he would like to view the net without results being displayed.	Suitability for the task	CI_2018/11_021	2	It should be possible to hide the simulation results. If necessary, reset to start point (restart).
	The potential user is confused because he does not understand whether the results have already been updated (without having pressed the button), because after entering a new simulation time, this is already displayed in the results area. The old "Simulation finished" message gets updated live, even though no new simulation was made	Self-descriptiveness, Conformity with user expectations	CI_2018/11_023	4	Simulation results may only be updated as soon as the simulation has actually run through.
	The potential user is annoyed that he is not explained exactly why a node has been marked as critical because he does not see the reason for it.	Suitability for the task, Self-descriptiveness	CI_2018/11_025	3	Display of several data values. Highlight critical value. If necessary, instructions on how to improve the network.

	The potential user is annoyed that displaying simulation results is so difficult because it takes a lot of time to select the right node via mouse click.	Suitability for the task	CI_2018 /11_026	2	Increase the sensitivity of the nodes. Display simulation results when hovering over a node.
Elements	The potential user is annoyed that he cannot move elements because he is restricted in his interaction with the system in this way and the system appears very inflexible.	Conformity with user expectations, Error tolerance, Suitability for the task	CI_2018 /11_027	3	Allow drag and drop of existing and newly added elements in the map.
	The potential user is annoyed that he cannot identify the transformer because he does not know what to look for (the symbol is not explained to him) and the icon is not easy to find (does not contrast well).	Self-descriptiveness	CI_2018 /11_029	3	Mouseover. Tooltip. Different colour. Function: "Mark all transformers"
	The potential user is annoyed that he ca not remove an added element because he ca not correct his wrong entries or try different scenarios.	Error tolerance, Suitability for the task	CI_2018 /11_030	4	A (right) click on the icon should open a context menu with a delete function. Alternatively, there could be a delete symbol (eraser or trash can) in the tool selection.
	The potential user is confused, because the tooltip of the "X" in the node pop up does not fit to his expectations, because it contains "Node info" and not "close".	Conformity with user expectations	CI_2018 /11_074	1	Tooltip = "Close"
	The user is irritated that elements cannot be selected to display further context information because he would have expected further information.	Suitability for the task, Conformity with user expectations	CI_2018 /11_045	4	A click on an element should display its properties or open a context menu. (e.g. battery model)
	The potential user is confused that when clicking on a battery an empty tooltip is displayed, because he does not know what this	Conformity with user expectations	CI_2018 /11_042	1	No tooltip or tooltip with useful information (model, status etc.)

	means (system error, error in the battery).				
	The potential user is annoyed that he cannot change the battery model because he cannot test the effect of the different battery models and correct incorrect inputs (can only be set initially at the moment).	Suitability for the task, Error tolerance	CI_2018 /11_041	3	Context menu.
	The potential user is annoyed that the removal of already existing items is not possible because he cannot work flexibly with the network.	Suitability for the task	CI_2018 /11_031	2	see CI_2018/11_030
Insert elements	The potential user is annoyed that no backward function is available because he cannot correct his entries.	Error tolerance	CI_2018 /11_028	4	Insert a button similar to the browser button (back). Short cut.
	The user does not recognize that an item has been successfully added because the icon does not stand out well from the background or no feedback message appears.	Self-descriptive ness	CI_2018 /11_034	4	There should be a textual feedback (which does not require active confirmation, e.g. a small push message) and the design of the symbol should be adapted so that it is more visible. A sound can be used additionally. Icon colour black (to differentiate new vs. already present: for example: Use of frames / shading)
	The potential user is confused that after clicking on "abort" in the "add dialog" the element nevertheless appears in the net, because it is now not clear to him whether he has successfully aborted the action or not.	Error tolerance	CI_2018 /11_035	4	The icon of the element must not be displayed if "Cancel" was clicked.

	The potential router is irritated because the dialogue looks so unfamiliar when adding a photovoltaic system. (Concerns all insert dialogues)	Conformity with user expectatio ns	CI_2018 /11_036	1	Customize dialogs. Use dialog only if additional entries have to be made (if delete/undo function is available the dialog is superfluous if no additional entries are made). Wording should be consistent.
	The potential user is confused that when adding a photovoltaic system, this must be confirmed again by a dialog step, because he cannot enter any additional information.	Suitability for the task	CI_2018 /11_037	2	see CI_2018/11_036 Configuration for PV follows, therefore a different interaction within the dialog arises
	The potential user is irritated that while the house building mode is activated, clicking on the map sometimes does nothing, but sometimes adds a house and connects it to a node, because it is not clear to him why this happens. This always seems to happen when you click on the map and then directly hover over a node again. The selection of connection points is inaccurate / partly offset.	Conformity with user expectatio ns, Suitability for learning	CI_2018 /11_038	3	Simplify and standardize interaction. Increase sensitivity of nodes. Place the element where desired, then draw the line.
	The potential user is confused that when adding a battery, the cursor is on a node, but the next node is marked because he does not know how to handle it.	Conformity with user expectatio ns	CI_2018 /11_039	4	Increase sensitivity see CI_2018/11_038
	The potential user is confused that the tooltip is "EV charging station", but when he creates one, the system asks for "Create EV?" because this is inconsistent, not necessarily understandable and simply wrong because they do not build a car. (Similar, but less important in PV)	Conformity with user expectatio ns, Self-descriptive ness	CI_2018 /11_054	3	Use consistent wording. Use abbreviations with caution.

	The potential user is annoyed that he cannot provide any further information when creating elements because he would like to provide information about the size, capacity, number of people in a household and other details.	Suitability for the task	CI_2018/11_049	4	Enabling the specification of usage profiles
	The potential user is confused that he ca not place an element where he wants and then draw the connection, because without this interaction possibility the exact position of an element cannot be determined (may depend on real user).	Conformity with user expectations, Controllability	CI_2018/11_040	3	see CI_2018/11_038
	The potential user is annoyed that when adding a battery, no model is pre-selected because he has to make an additional entry.	Suitability for the task	CI_2018/11_043	2	If a model is often used, confirm it as a preselection.
Representation of the grid	The potential user is confused that several elements lie on top of each other at the same node because he cannot distinguish between them.	Self-descriptiveness	CI_2018/11_044	3	The elements should be next to each other or alternatively obviously stacked, whereby a click on the stack could present the elements next to each other. Allow moving the elements to position them as desired.
	The potential user is irritated that clicking on the transformer opens a window with its properties, unlike the houses.	Suitability for the task, Conformity with user expectations	CI_2018/11_046	2	It should also be possible to display information for the transformer.
	The potential user is confused that when clicking on a node that is marked red/green, it changes colour because he cannot see if the node has been marked as critical.	Conformity with user expectations, Self-descriptiveness	CI_2018/11_047	2	Mouseover already shows the Information-window. The colour of the node remains the same (red or green).

	The potential user is annoyed that when the map is zoomed out, it becomes unclear because he can no longer receive any information.	Self-descriptiveness, Error tolerance	CI_2018/11_066	2	Hide icons at zoom level x. If required by the user, place a coloured overlay over the areas/areas in which he has access rights/tasks or something like that.
	The potential user is irritated because he thinks he can place the houses on the map in relation to the house number.	Conformity with user expectations, Suitability for learning	CI_2018/11_048	3	Guided-Tour could fix this (for first login and callable on demand) -> Out of Scope. Clean up background map
Tools / Modes	The potential user does not understand how he should interact with the system, because in the mode selection only the name of the element is displayed, but not that a click on the icon activates a mode.	Self-descriptiveness, Suitability for learning	CI_2018/11_050	2	Tooltips must be longer and clarifying. (Add ...)
	The potential user is confused that the tooltips are displayed too quickly and overlap (too much animation), because he cannot assign the tooltips correctly to the corresponding elements.	Suitability for learning	CI_2018/11_052	2	show slower, not directly as mouse moves over it.
	The potential user is confused that the icon of the house building mode does not match the house icon on the map (chimney).	Self-descriptiveness	CI_2018/11_055	1	Use same icon.
	The potential user is confused that the selection mode icon does not match the mouse pointer.	Self-descriptiveness	CI_2018/11_056	1	Use same icon.
Search	The potential user is confused that he cannot search by house number.	Controllability, Conformity with user expectations, Self-descriptiveness	CI_2018/11_057	3	It is important to open the search in all directions (address search, customer number, search for transformers / etc.) Verify which searches make sense. e.g. Search by node ID

	The potential user is irritated that the search box is so much larger than its input area, because he cannot clearly recognize which input is required or how he should interact with the input area.	Conformity with user expectations	CI_2018/11_058	1	Adjust the field size to the input
	The potential user is confused that he is not shown what he can search for, because he does not know which search entries are useful and which results he can expect.	Self-descriptiveness	CI_2018/11_059	2	Replace the placeholder " search " with " street, city" or something, so that it becomes clear.
	The potential user is confused that the placeholder is not recognisable because he cannot identify what the search field is useful for.	Self-descriptiveness	CI_2018/11_061	2	Increase contrast
Settings, Login, Save	The potential user is confused, because the icon "attributions" is misleading, because "i" is associated with "information" and not with a reference to the source.	Self-descriptiveness, Conformity with user expectations	CI_2018/11_062	1	*Use a different symbol. *Show text directly. *Use "Source" as label for the link.
	The potential user is annoyed that clicking on the link opens it in the same tab because he has not purchased it and so leaves the map.	Error tolerance	CI_2018/11_063	2	Links should automatically open a new tab
	The potential user is irritated that all changes have disappeared after logging out and logging back in.	Suitability for the task	CI_2018/11_068	3	Save function.
	The potential user is annoyed that after switching to the settings, the map was reset to the initial state because he did not want to leave the map.	Suitability for the task	CI_2018/11_069	4	It should be possible to switch to settings without losing the current workspace.

	The potential user is confused that when switching from "Change settings" to "Back to s4g client", he returns to the settings because he expects to get to the map view.	Conformity with user expectations	CI_2018/11_070	1	Check navigation path
	The potential user wonders why there is a () behind the user name.	Self-descriptiveness	CI_2018/11_075	1	Ensure that there is always a role name. Or insert a label "Role:" instead of the brackets. If none is defined, "unknown" or similar.
	The potential user is irritated that if the last page before logout was Settings, he will end up within the Settings after logon. Is this desired by users or do they expect to go straight to the map upon login?	Suitability for the task	CI_2018/11_071	1	Check navigation path
Basic interaction options	The potential user is irritated that the cursor does not change to a hand when held pressed in order to signal the gripping because he cannot clearly recognize which interaction possibilities are available for him.	Conformity with user expectations, Self-descriptiveness	CI_2018/11_072	3	expectation conformity: In other systems it is usually a hand.
	Zoom functionality by double click came unexpectedly	Conformity with user expectations,	CI_2018/11_065	1	Note that it is not only possible to zoom using +/-. I do not know where to place it right now.
	Some of the elements can be used by keyboard, e.g. simulation panel. Others, e.g. popups to show node details, can only be used by mouse. Be consistent	Conformity with user expectations, Suitability for the task	CI_2018/11_073	2	Enable operation of the pop-ups by keyboard (tabs). Selection of the different modes via shortcut.
	When resized full screen on a wide screen, Simulation window disappears. Because scrolling is used for the map, user cannot scroll with the mouse. If not familiar with scrollbars, user will be lost.	Self-descriptiveness	CI_2018/11_076	3	Avoid Scrollbar - Do not use more space than the screen

Appendix C Professional GUI Evaluation - Results usability-test with end-users

Task 2: Run a simulation

Table 17. Positive findings - Task 2: Run a simulation.

Category	Positive findings	Task	User comments	Affected users	Reference to expert finding
Simulation window	After changing the input fields (see section GUI changes): The users do not report any problems when entering the time span.	2.2	User03: "I can here select time unit "Years ". And a period of time "	User01, User03, User05	-

Table 18. Problematic situations - Task 2: Run a simulation.

Category	Problematic situations	Task	User comments	Affected users	Reference to expert finding
Simulation window	Users have problems entering the simulation time because they could not identify the input fields (distance too small; GUI was adapted - see section GUI changes)	2.2	User04: "We cannot enter 10 years anywhere. We can only select years as a duration."	User04, User06	CI_2018/11_009 CI_2018/11_013
	A user does not understand the meaning of the simulation time (but it may depend on the imitated simulation results)	2.2	User02: "But I do not know what it means with "days, months, years". What difference does that make in the simulation. That is not transparent either, I think."	User02	-
Visualization and selection of radials	Users do not recognize that they have to select a radial before they can run a simulation	2.3	User03: "And for run a simulation, what can I do? "	User03, User04, User06,	CI_2018/11_008
	Users do not notice the message "Please select a radial on the map" (but it may depend on the too small screen)	2.3		User02, User03, User04	CI_2018/11_008
	A user does not know how to select a radial	2.3	User05: "I have to select a radial. But I do not know"	User05	CI_2018/11_003 CI_2018/11_004
	It is not clear to the users that if they are in a certain mode (e.g. inserting batteries), they cannot select a radial.	2.3	User03: "I have to select a radial. How can I select a radial?"	User03, User04	CI_2018/11_005 CI_2018/11_017

			User04 "I am putting storages in all the time right now."		
	Users have difficulty identifying a radial		User01: "I am trying to find the radial."	User01, User03,	CI_2018/11_004
Settings, Login, Save	Error message if authorization is missing	2.4	-	User03, User04, User06	-

Task 3: Analysis of simulation results

Table 19. Positive findings - Task 3: Analyse simulation results.

Category	Positive findings	Task	User comments	Affected users	Reference to expert finding
Results	Users can detect that there is a difference between the red and green dots and that the red marked nodes are the critical ones.	3.1	User01: "I think the red one is the one with problems in. The green is the one where is no problem."	User01, User02, User03, User05, User06	-
	Users can immediately notice that he is getting results by clicking on a node	3.2	-	User01, User02, User03, User05, User06	-
	Users need voltage values	3.3	-	User03, User06	-
	Users can interpret the displayed results as voltage	3.3	User03: "Also here can I read the three different voltage phases on the node of different points "	User01, User02, User03, User05, User06	-
Basic interaction options	A user has direct access to the usual interaction options (map shifting, zooming)	3	User01: "It is look like, that it is easy to use, and it is simple to move around in the map due the normal fast cuts"	User01	CI_2018/11_065

Table 20. Problematic situations - Task 3: Analyse simulation results.

Category	Problematic situations	Task	User comments	Affected users	Reference to expert finding
Results	Users cannot interpret the meaning of the voltage values	3.3	User03: "I do not know what it is. Is it the voltage deviation? I do not know.	User01, User02,	-

			[...] Or is this the voltage expresses in kilowatt?" "The number – is it percentage or is it an absolute value? I do not know [...] I do not understand the value here, so I cannot say if it was enough or good or bad."	User03, User06	
	A user reports that the voltage values are given with too many numbers.	3.3	User01: "It is a large number. Too much numbers. "	User01	-
	User are missing the unit of voltage values	3.3	User03: "Or is this the voltage expresses in kilowatt? " User02: "So if we have 400-volt grid – than I would expect it say either two percent or 10 percent below the average 400 volts or maybe 40 volts below "	User02, User03	-
	A user is missing information about maximal level of the voltage and minimum level of voltage in this period of 10 years	3.3	User06 "Maximum and minimum for each node – that is very important to know"	User06	-
	A user finds that the values of all 3 phases are too much	3.3	User06: "But if you have DSO the difference between phase one and two and three is normally not so important [...] the three phases are normally balancing	User06	-
	A user wants to see the analysis results in comparison/a history	3.3	User01: "It would be nice to see what it was before and what is it now [...] A value before the battery and value after battery.	User01	-
	A user finds that the display of the voltage values on each house does not make sense	3	User06 "For an example for DSO it is normally to have the voltage on the nodes not on every counter"	User06	-

	Users are not sure how the simulation works and where the data comes from.	3	User06: "What kind of information is that? Does this mean that the program makes a calculation on the truth of 10 years?" [Quote has been translated into English] User02: "For what do you need a specific period of time – is it based on old data, is it based on the old combine witch the new – or where do you get your data from "	User02, User06	-
	Users are missing information about current	3	User01: "Different calculations – not only the voltage level, but also the current or maybe the power in the system."	User01, User02, User03, User05, User06	-
	Users are missing information about the current in the line	3	User01: "Yes, it is how much power in the cable if it is overloaded or if it is not. If the current is too big to the cable size. Then I want to know it."	User01, User06	-
	A user is missing information about short circuit current	3	User02: "The short circle current that is relates to uses. We have some minimum demands – concerning how big it must be as a minimum.	User02	-
	A user is missing information about maximal value of the current (minimal is not so important)	3	User06: "Maximum value of the current in this, is 10 years. Minimal current is not so important."	User 06	-
	A user is missing information about voltage dips	3	User02: "We have some larger installations […] where you maybe have some over current problems or under current problems. […] How large is the voltage dip in these critical areas?"	User02	-
	A user is missing information about losses	3	User06: "Losses have the meaning of the economic business of the	User06	-

			distribution. Voltage has the meaning for the customers"		
	A user wants to be able to identify the balance point of the grid.	3	User06: "Of course it is very important for us to know where the focus of the network is. Because the network can also be a balance network, but it can also be that it has a big focus somewhere and the other customers are e.g. very small. "[Quote has been translated into English]	User06	-
	Users want to be able to see "the reason why"	3	User01: "I cannot see why this one is green and the other one is red. " User02: "So, pin point what the actual problem is and what would make sense in this situation to do with the grid."	User01, User02, User06	CI_2018/11_025
	A user is missing information about resistance of cables (and phase resistance)	3	User02: "What about phase resistance? The resistance of cables – is that calculated as well?"	User02	-
Elements	A user is missing information about conductor	3	User03: "I need information about the conductor"	User03	CI_2018/11_046
	Users ca not easily identify the power station	3	User01: "I do not know where the station is. " User02: "I do not know what this means, but it is probably the transformer – I guess."	User01, User02	CI_2018/11_029
	Users are missing information about performance (profiles) of photovoltaics	3	User01: "I cannot see the size of the solar panel."	User01, User02, User06	CI_2018/11_045
	A user misses' information about the EV	3	User02: "I do not know what characteristics there is in this EV. [...] How much do they expect could this EV consume in amperes or	User02	CI_2018/11_045

			kilowatts – what profile is on this EV"		
	A user misses' information about the battery	3	User01: "Some Information about the battery […]. The size of the battery. The effect it can delivery and take from the network"	User01	CI_2018/11_041, CI_2018/11_042, CI_2018/11_045
	Users are missing information about customers/houses (load profiles)	3	User03: "The power of the home […] or when it is an active or passive client." User02: "How much kilowatts do they actually use?"	User01, User02, User03, User06	CI_2018/11_045, CI_2018/11_049
	Users find the identification of a particular node (when they want to find a specific number) cumbersome (However, this could stem from the defined task 4. It is necessary to verify whether the need exists.)	-	User04: "It does not give sense, that you have to press every house or node to find the number"	User03, User04, User05,	CI_2018/11_038
Insert elements	A user wants to install new transformers	-	-	User02	-
	A user wants to set elements where they really should be and not just to exist nodes	-	User02: "I have to use the existing nodes here to install something. But sometimes they build a house here – or here." User02: "What if we have new installation – a big PV installation – 200 meters from this point. How do you could this in the system?"	User02	CI_2018/11_048, CI_2018/11_040
Representation of the grid	A user wants to see the house numbers	3	User03: "Or the street number is interesting"	User03	-
	A user is irritated because of the background graphics (symbols, dotted lines, street names)	3	User02: "Do not know what this is."	User02	CI_2018/11_048
	A user wants to connect the grid to another transformer (neighbour grid) and want to able to open it	-	User02: "You could perhaps solve the problems on the neighbour grid by moving some load from this grid here. […] So, it has to be a	User02	CI_2018/11_040

			little bit more flexible concerning connecting grids from other transformers."		
	Users are missing information about cable characteristics (material, size/thickness, distance)	3	User01: "It will be nice to know the size of the cable, so I have an idea if this one is thick and this one is thin. Or is a thick the whole way around." User02: "How do you calculate [...] that is based on the type of cables and the distance to the transformer and size of whatever you are installing. So of course, I have to know the distance and the cable type we are going to use."	User01, User02, User03 User06	-
Settings, Login, Save	Users find the resolution for their used screen in the test session too small	-	User03: "It is not a good resolution. It is too small"	User02, User03, User06	-
Basic interaction options	Users are not directly aware of the usual interaction options (move map, zoom)	-	User03: "I cannot zoom. I am sorry. "	User03, User04,	CI_2018/11_072

Task 4: Insert a storage model

Table 21. Positive findings - Task 4: Place a storage in the grid.

Category	Positive findings	Task	User comments	Affected users	Reference to expert finding
Insert Elements	Users find it easy to insert things	4.3	User03: "The process is good. I think there are more options to insert [...] I think it is easy."	User03, User05	-
Tools, Insert Elements, Simulations window	After a first exploration, the users find the interaction good.	4.3	User03: "It is a good menu and very easy. Intuitive." User02: "I think it is pretty easy to use." User05: "I like that it seems to be simple to add a storage or to run a simulation"	User01, User02, User03, User05	-

Table 22. Problematic situations - Task 4: Place a storage in the grid.

Category	Problematic situations		User comments	Affected users	Reference to expert finding
Search	Users are irritated that it is not possible to search for a node via the search field.	4.1	User03: "No, this is not a good solution [...] I cannot find it with the search tool"	User01, User03, User05	CI_2018/11_057,
Tools	User cannot directly identify the battery in the interaction bar	4.2	User04 "Are this the storages?"	User04	CI_2018/11_050, CI_2018/11_052
	User thinks at the beginning that the house icon means "Home" (Start)	4.2		User03	CI_2018/11_050
Insert Elements	A user cannot clearly identify if he added an item successfully	4.3	User04 "We not sure – but we think we put a storage in there. It is not very easy to see"	User04	CI_2018/11_034
	User is irritated that he cannot abort the "add dialog" successfully	4.3	User04 "I put another storage in, but I do not know how to cancel it."	User04, User05	CI_2018/11_035
	User is irritated that he cannot delete any added items	4.3	User01 "I do not know how I remove the battery again."	User01, User02, User04, User05	CI_2018/11_030
Representation of the grid	User has problems getting the right node highlighted	4.3	User05: "But no, I connect to the wrong place ". User02: "It is difficult to click on a specific place without getting the entire thing"	User02, User05	CI_2018/11_038, CI_2018/11_039

Appendix D GESSCon data packet example


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}
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Appendix E End-user survey with residential end-users (German)

This project is funded by the European Union

End-User Fragebogen zur statistischen Erhebung

Die in diesem Fragebogen erhobenen Daten werden anonymisiert verarbeitet und lediglich im Projektkontext verwendet. Ein Rückschluss von den Antworten auf Ihre Person ist nicht möglich. Bitte wenden Sie sich jeder Zeit an mich, sollten Sie Fragen haben. Der Fokus des Fragebogens liegt auf dem Verhalten von Energiemanagementsystemen in künftigen Smart-Grids.

Versuchen Sie, alle Antworten so spontan und schnell wie möglich zu beantworten.

Setup:

☐ PV ☐ EV ☐ Storage

User_ID: ___________________

Generelle Fragen

1. Für statistische Erhebungen, würden Sie uns Ihr Alter nennen?

____

2. Bitte kreuzen Sie nur eine Option pro Gerät an. Wie oft benutzen Sie folgende Geräte:

	Mehrmals täglich	Einmal täglich	Mehrmals pro Woche	Einmal pro Woche	Niemals
Smart Phone	◯	◯	◯	◯	◯
Tablet	◯	◯	◯	◯	◯
Desktop PC	◯	◯	◯	◯	◯

3. Wie wichtig ist Ihnen Datensicherheit im Kontext der Energieversorgung? Bitte kreuzen Sie nur eine Antwort an:

Sehr wichtig	Mehr oder weniger wichtig	Überhaupt nicht wichtig
◯	◯	◯

4. Wie wichtig sind Ihnen Ziele des Umweltschutzes im Kontext von Energieproduktion und –verbrauch? Bitte kreuzen Sie nur eine Antwort an:

Sehr wichtig	Mehr oder weniger wichtig	Überhaupt nicht wichtig
◯	◯	◯

Photovoltaik System relevante Fragen

5. Sie besitzen neben dem Photovoltaik System auch ein lokales Speichersystem. Wenn Ihr Photovoltaik System überschüssige Energie produziert und Ihr lokales Speichersystem voll geladen ist, welche Strategie würden Sie bezüglich der überschüssigen Energie verfolgen?
Bitte kreuzen Sie an:

	Sehr überzeugend		Überhaupt nicht Überzeugend
Überschüssige Energie an den Netzbetreiber verkaufen (und Geld verdienen)	◯	◯	◯
Überschüssige Energie anonymisiert der Nachbarschaft zur Verfügung stellen	◯	◯	◯
Überschüssige Energie nicht verwenden (Curtailment)	◯	◯	◯

Spezifische Fragen für Elektroautos (EVs)

6. Wie groß ist die Kapazität Ihres Elektroautos in kWh?

7. Bitte kreuzen Sie pro Option nur eine Antwort an. Wenn Sie den Ladezustands Ihres Autos abfragen, wie Hilfreich ist die folgende Information für Sie:

	Sehr hilfreich				Überhaupt nicht hilfreich
Ladezustand in %	○	○	○	○	○
Restreichweite in km	○	○	○	○	○

8. Wo laden Sie Ihr Auto **für gewöhnlich**? Bitte **nur eine Antwort** wählen

- ○ Zuhause
- ○ Auf der Arbeit
- ○ An öffentlichen Ladesäulen
- ○ Sonstiges:

8.1 Wann laden Sie Ihr Auto **für gewöhnlich**? Bitte **nur eine Antwort** wählen

- ○ Tagsüber
- ○ Nachts
- ○ Sonstiges:

9. Wann starten Sie für gewöhnlich den Ladevorgang Ihres Elektroautos? Bitte wählen Sie **pro Option nur eine Antwort**.

	Stimme voll zu		Stimme nicht zu
Wenn die Restreichweite unter einem bestimmten Wert liegt	◯	◯	◯
Wenn der Ladezustand unter einem bestimmten Wert liegt	◯	◯	◯
Wenn ich eine lange Autofahrt plane	◯	◯	◯
Jeden Tag, tagsüber	◯	◯	◯
Jeden Tag, nachts	◯	◯	◯
Wenn der Wetterbericht für den nächsten Tag einen sonnigen Tag vorher sagt (Viel „grüne" Energie)	◯	◯	◯

10. Wie oft laden Sie Ihr Auto im Laufe eines Monats durchschnittlich zu Hause? Bitte kreuzen Sie **nur eine Antwort** an:

Einmal im Monat	Einmal die Woche	2 -3 mal pro Woche	Öfter als dreimal die Woche	Niemals
◯	◯	◯	◯	◯

11. Falls Sie einen flexiblen Tarif haben, überprüfen Sie den aktuellen Preis bevor Sie Ihr Elektroauto laden? Bitte kreuzen Sie **nur eine Antwort** an:

◯	Ja
◯	Nein
◯	Kein flexibler Tarif

Optimierung des Ladevorgangs Ihres Elektroautos

12. Sind Sie daran interessiert, den Ladevorgang Ihres Elektroautos durch die manuelle Eingabe des momentanen Ladezustandes, z.B. mit Hilfe einer App, zu optimieren? Bitte kreuzen Sie **nur eine Antwort** an:

○	Ja
○	Nein

13. Wie würden Sie diese Information am ehesten bereitstellen? Bitte wählen Sie **pro Option nur eine Antwort**.

	Stimme voll zu		Stimme nicht zu
Mit einer App auf einem mobilen Endgerät (z.B. Smartphone)	○	○	○
Mit einem Interface, das an der Ladestation installiert ist	○	○	○
Durch das Versenden einer Nachricht vom Smartphone/Handy aus	○	○	○
Das System soll diesen Wert automatisch direkt vom Auto beziehen	○	○	○

14. Wie überzeugend sind die folgenden Optimierungsstrategien des Ladevorgangs für Ihr Elektroauto für Sie? Bitte wählen Sie **pro Option nur eine Antwort**.

	Sehr überzeugend		Überhaupt nicht überzeugend
Laden, wenn der Energiepreis niedrig ist	○	○	○
Innerhalb eines kooperativen Szenarios mit Ihren Nachbarn	○	○	○
Erhöhung der Lebensdauer der Autobatterie	○	○	○
Optimierung des Eigenkonsums von selbst produzierter Energie	○	○	○

Spezifische Fragen bezüglich Demand-Side Management

Demand-Side Management (DSM) ist die aktive Teilnahme der Energiekunden bei der Unterstützung des Energienetzes. DSM basiert auf der Anpassung der Verhaltensmuster von Endkunden in Bezug auf deren Stromkonsum. Das wird über zahlreiche Methoden erreicht, zum Beispiel finanzielle Anreize. Das Ziel ist hierbei die Vermeidung von Lastspitzen, die auch durch erneuerbare Energien verursacht werden.

15. Stellen Sie sich vor, Sie möchten an einem DSM Programm teilnehmen. Wie könnte sich dieses Programm auf **Ihre Gewohnheiten auswirken**? Bitte wählen Sie **pro Option nur eine Antwort**.

	Stimme voll zu		Stimme nicht zu
Ohne irgendeine Einschränkung	○	○	○
Mit minimalen Einschränkungen (z.B. Reduktion der Raumtemperatur um 1° C, oder das Verschieben des Ladevorgangs des Elektroautos um einige Stunden)	○	○	○
Mit hohen, aber akzeptablen Einschränkungen (z.B. wird das Auto nicht vollständig, aber ausreichend geladen)	○	○	○

16. Wie wichtig ist es Ihnen, dass das DSM-Programm unabhängig von Drittanbietern ist (z.B. Ihr Energielieferant oder der Netzbetreiber)? Bitte wählen Sie **pro Option nur eine Antwort**.

Sehr wichtig	Mehr oder weniger wichtig	Überhaupt nicht wichtig
○	○	○

17. Sind Sie generell an gemeinschaftlicher Erzeugung und Verteilung von Energie in kleinen Bereichen des Netzes (z.B. in Ihrer Nachbarschaft) interessiert? Das ist z.B. der gemeinschaftliche Verbrauch von gemeinschaftlich erzeugter Energie. Bitte kreuzen Sie **nur eine Antwort** an:

○	Ja
○	Nein

18. Verglichen mit dem momentanen Ansätzen: Für wie überzeugend halten Sie ein DSM Programm*, in dem Sie gemeinsam mit Ihren Nachbarn den Verbrauch und die Erzeugung von Energie als Einheit optimieren? Bitte kreuzen Sie **nur eine Antwort** an:

**Dieses Programm beinhaltet eine faire, anonyme Planung von Heizzyklen, Ladeperioden für Elektroautos, (elektrische) Speichernutzung, Verkauf von überschüssiger Energie aus erneuerbaren Energiequellen).*

Sehr überzeugend	Mehr oder weniger überzeugend	Überhaupt nicht überzeugend
○	○	○

19. Bitte bewerten Sie Ihre Bereitschaft, an einem DSM Programm teilzunehmen, das sich durch folgende Eigenschaften auszeichnet:
Bitte wählen Sie **pro Option nur eine Antwort**.

	Hohe Bereitschaft		Keine Bereitschaft
Ein konventionelles DSM Programm (günstigere Energiepreise für bestimmte Zeiträume)	○	○	○
Eine *Energieflatrate*, bei der der monatliche Preis auf der Flexibilität beruht, die man bereit ist zur Verfügung zu stellen (Heizperioden, Ladeperioden für Elektroautos, …)	○	○	○
Ein kooperativer Ansatz, bei dem die Energie automatisiert verteilt wird (mit fairer Verteilung der finanziellen Begünstigungen und fairer Berücksichtigung der Bereitschaft zur Flexibilität)	○	○	○

Appendix F Tasks for evaluating the paper prototype with end-users in Italy (German)

Interview mit Papierprototypentest

Szenario
Vor einiger Zeit haben Sie sich aus zwei Gründen eine Photovoltaik-Anlage zugelegt: Zum einen wollten Sie Ihre Stromrechnung reduzieren, zum anderen empfanden Sie den Umweltschutzgedanken als sehr reizvoll. Deshalb haben Sie neben sowohl in ein Elektroauto, als auch in ein zusätzliches Speichersystem investiert, in dem Sie überschüssige Energie aus Ihrer Photovoltaikanlage speichern und später verwenden können. Zur Überprüfung Ihres Set-ups (Photovoltaikanlage und Stromspeicher) können Sie eine Website verwenden, über die Sie aktuelle Informationen zum Verbrauch Ihres Haushalts und zur Produktion Ihrer Photovoltaikanlage beziehen können.

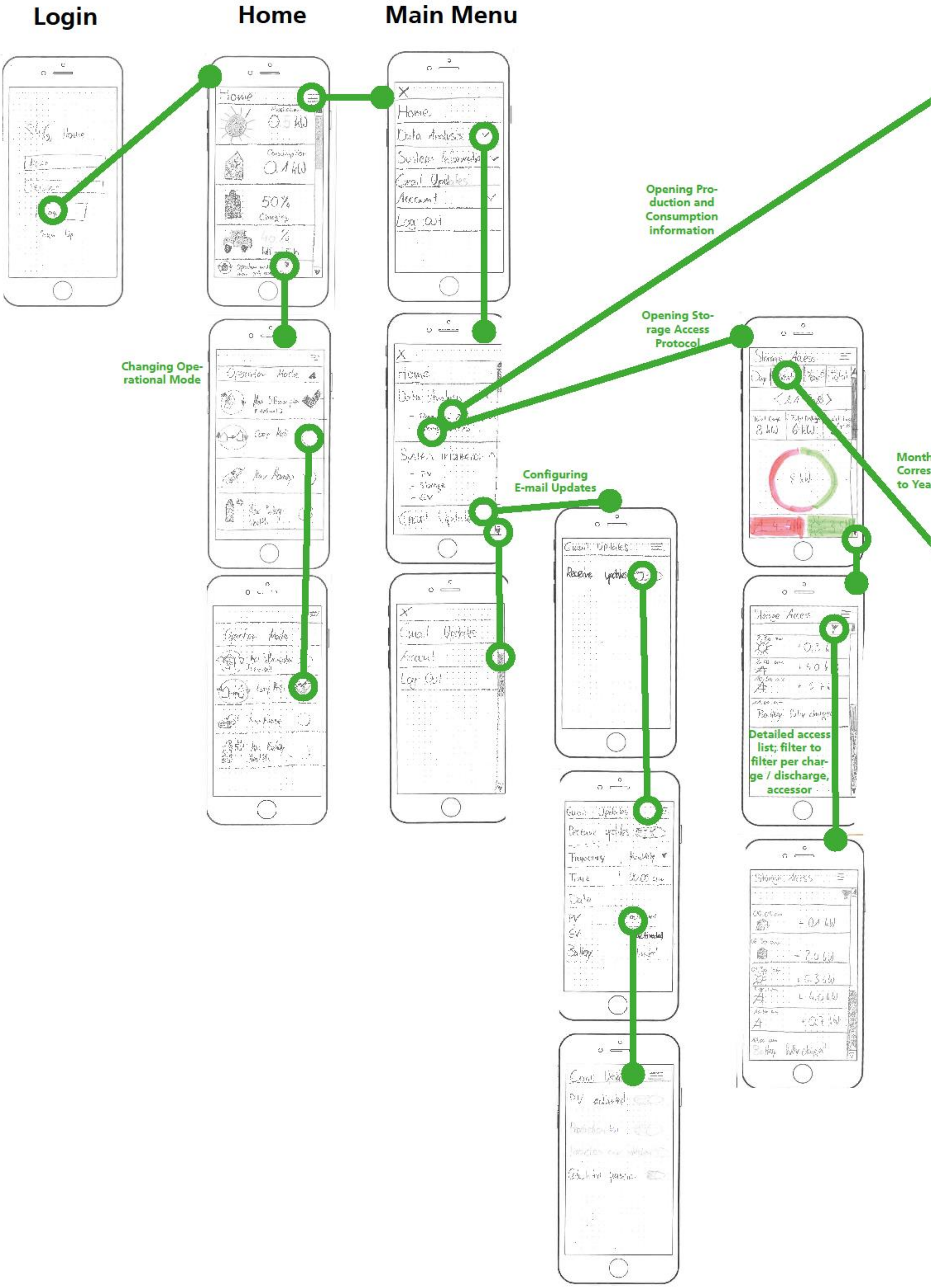
1. **Beschreiben Sie kurz, welche Werte für Sie von großem Interesse sind. Warum gerade diese Werte?**

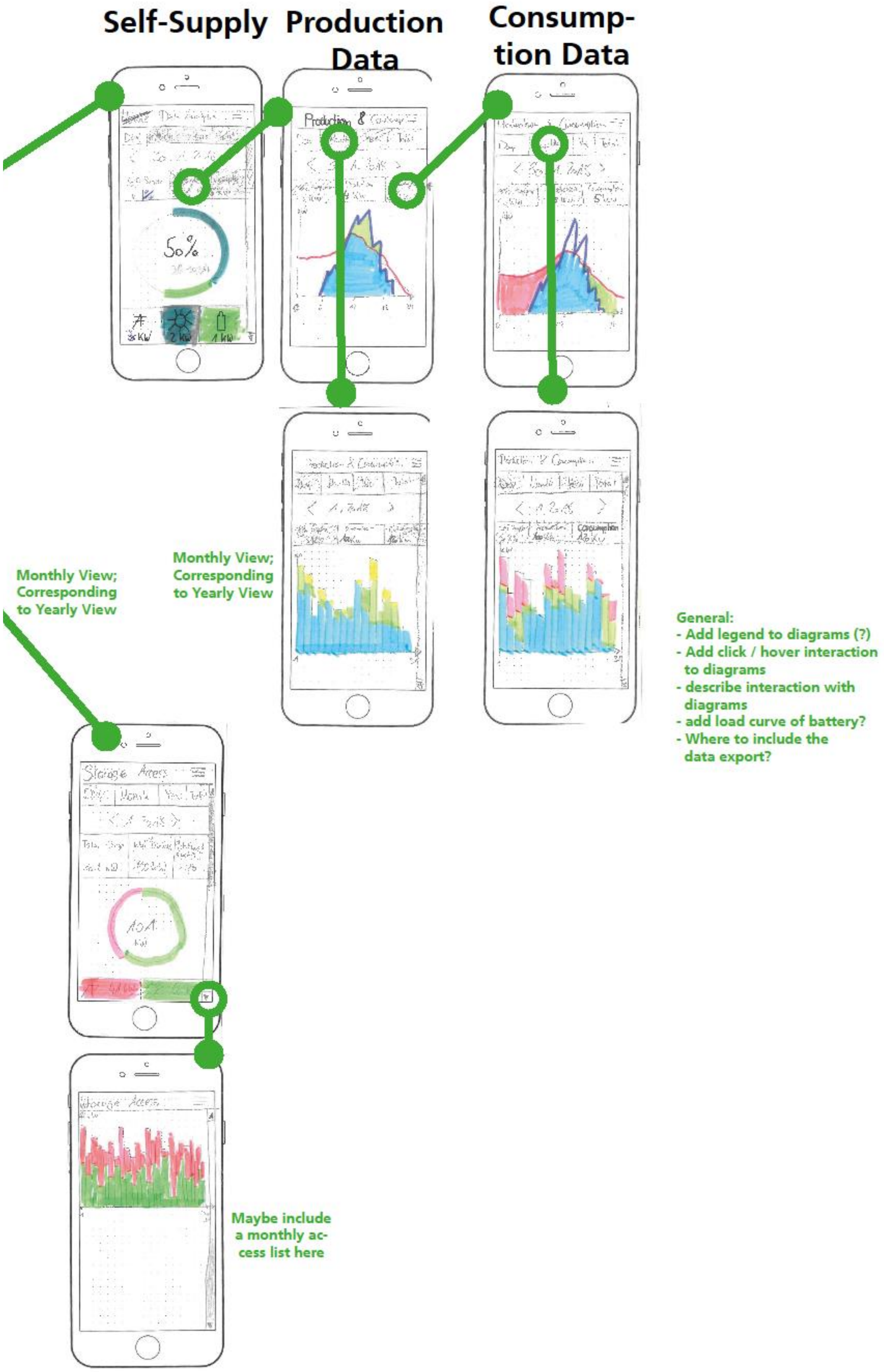
2. **Wie häufig überprüfen Sie diese Werte im Laufe einer Woche?**

3. **Sie möchten nun mithilfe der Applikation überprüfen, ob Ihr System ordnungsgemäß arbeitet. Hierfür öffnen Sie die Website.**
    a. Loggen Sie sich mit Ihren Daten auf der Website ein.
    b. Welche Informationen lesen Sie aus dem Interface?
    c. Vergleichen Sie nun das alternative Dashboard.

4. **Sie möchten die Produktion Ihrer Photovoltaikanlage etwas genauer analysieren.**
    a. Heute ist der 21. Februar 2018. Rufen Sie die Verlaufsdaten des heutigen Tagesproduktion Ihrer Photovoltaikanlage auf. Wie hoch ist die heutige Gesamtproduktion bis jetzt?

Appendix G Interaction flow of the evaluated paper prototype




Self-Supply
Production Data
Consump-tion Data
Monthly View; Corresponding to Yearly View
Monthly View; Corresponding to Yearly View
General:
- Add legend to diagrams (?)
- Add click / hover interaction to diagrams
- describe interaction with diagrams
- add load curve of battery?
- Where to include the data export?
Maybe include a monthly ac-cess list here

s