D6.2 - Phase 2 Test Site Plans

Deliverable ID	**D6.2**
Deliverable Title	**Phase 2 Test Site Plans**
Work Package	**WP6**

Dissemination Level	**PUBLIC**

Version	**1.0**
Date	**28/12/2018**
Status	**Final**
Type	**Report**

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Published by the Storage4Grid Consortium

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731155.

Document History

Version	Date	Author(s)	Description
0.1	2018-06-05	EDYNA	First draft
0.2	2018-07-10	ENIIG	Contributions to chapter 1.1. and chapter 3
0.3	2018-07-23	EDYNA	Contributions to chapter 1.1. and chapter 2
0.4	2018-07-24	UPB	UPB contribution
0.41	2018-08-10	UPB	Additional UPB contribution
0.42	2018-08-13	LiBal	Update grid storage case
0.43	2018-08-16	EDYNA	Little corrections and answers to UPB notes
0.5	2018-08-23	FIT	Contributions to introduction and conclusions
0.6	2018-08-27	ISMB	ISMB contributions
0.7	2018-08-28	EDYNA	Revision of all comments and references correction
0.71	2018-08-29	ENIIG LiBal	Minor contributions to chapter 4 Edit on chapter 3
0.72	2018-08-29	EDYNA	Acceptance of the last comments
0.80	2018-10-08	UNINOVA	Description of phase 2 components plans for integration, deployment and evaluation (Phase 2 S4G components)
0.90	2018-10-10	UPB	Chapter 0 contribution
0.91	2018-10-10	UNINOVA	Addressed partners comments
0.92	2018-10-12	EDYNA	Revision of chapter 1, 2, 3 based on the comments
0.93	2018-10-15	ENIIG	Revision on chapter 4
0.94	2018-10-22	UNINOVA	Addressed partners comments
0.95	2018-10-22	LiBal	Comments Changes in grid-side storage case description Please insert caption for all figures. The numbering may go wrong if some captions are missing.
0.96	2018-11-07	UPB	Addresses evaluation methodology and data collection aspects.
0.97	2018-11-07	UNINOVA	Formatting and use-case mapping
0.98	2018-11-12	UNINOVA	Address new text and minor chapter formatting changes
0.99	2018-11-20	EDYNA	Updated the Executive Summary and checked chapter 0
0.100	2018-11-21	UNINOVA	Evaluation methodology and final formatting. Ready for review
0.101	2018-12-05	UNINOVA	Addressed some reviewer comments
0.102	2018-12-10	ENIIG	Addressed reviewer comments
0.103	2018-12-12	EDYNA	Updated "Executive Summary" and "Conclusions"
0.104	2018-12-12	UPB	Addressed some reviewer comments
0.105	2018-12-14	UNINOVA	Version ready for revision

0.106	2018-12-19	UNINOVA	Addressed some reviewer comments
0.107	2018-12-21	UPB	Addressed reviewer comments
1.0	2018-12-28	UNINOVA	Final version, ready for submission to the EC

Internal Review History

Review Date	Reviewer	Summary of Comments
2018-08-30 (v0.72)	Vasco Delgado-Gomes (UNINOVA)	Not accepted • Not clear which S4G components will be deployed and evaluated in each pilot site. • Most of the S4G components to be deployed in phase 2 do not have their KPIs defined. • Some of the HLUCs planned for phase 2 will not have all their S4G components ready for evaluation until the end of phase 2.
2018-09-06 (v0.72)	Yini Xu (LIBAL)	Reviewed: • Comments on several use-cases, since the descriptions are not clear/wrong • Some figures are incorrect
2018-11-27 (v0.100)	Orlando Tovar (ISMB)	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 evaluation of few pilots is not presented because the components are not ready. The evaluation plans should be adapted to the development phases in order to evaluate progressively each pilot. • Section 2 should be revised • The structure of sections 0,0 and 0 need to be harmonized • Further comments are present in the document
2018-11-21 (v0.100)	Gustavo Aragón (FRAUNHOFER FIT)	Not approved: • Comments in general • Important questions by data collection
2018-12-14 (v0.105)	Gustavo Aragón (FRAUNHOFER FIT)	Not approved: • Text in section 2.5 should be rewritten • Important questions by data collection
2018-12-14 (v0.105)	Orlando Tovar (ISMB)	Approved with minor comments. Comments should be addressed.

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Executive Summary

This deliverable summarizes the **Phase 2 Test Site Plans** in all the three S4G test sites based on D2.2 [S4G-D2.2]. It describes each test site in terms of an architectural view of the two layers relevant for S4G: (i) the electrical layer (PV, loads, storage, inverters, energy meters), and (ii) a combined information layer (real-time measurements, infrastructure descriptors, set-points, local restrictions etc.) with data communication (including data secure transfer between the different S4G components).

This deliverable is an update of the implementation plan described in D6.1 [S4G-D6.1] and will be used for the second phase of the project. The implementation will be further refined during the phase 3, which corresponds to the last one. D6.2 is also based on the outcomes of the D3.2 [S4G-D3.2], which addresses the system architecture.

The main scope of this deliverable is to define appropriate KPIs for the evaluation of each test site, based on the state of implementation in phase 2 and on the use-cases described in D2.2 [S4G-D2.2]. These KPIs are very important to evaluate the correct progress of the S4G project towards its objectives.

D6.3 "Phase 3 Test Site Plans" will describe the final test site plans of the project, with the KPIs for the evaluation of the complete and functioning test sites.

1 Introduction

This deliverable summarizes the **Phase 2 Test Site Plans** in all the three S4G test sites, resulting from the analysis activities performed by task T6.1 - "Test Sites and Cases Planning" and it is an update of D6.1 [S4G-D6.1].

WP6 integrates project outcomes in the test sites in Bucharest, Bolzano and Fur/Skive. Evaluation activities were planned to leverage the test sites taking into account scenarios, use-cases and business models designed in WP2 and documented in D2.2 [S4G-D2.2] as well as the key functional requirements identified by the project and documented in deliverable D2.6 [S4G-D2.6]. The work in T6.1 also builds upon the Architecture and Components specifications developed in WP3 which had the latest results included in deliverable D3.2 [S4G-D3.2].

Starting from scenarios, use-cases, business models and requirements defined in WP2, concrete test and evaluation cases to be deployed in each test site have been designed and deployment activities have already been pursued as described in D6.1 [S4G-D6.1]. For each case, appropriate boundary conditions to be monitored are proposed. To ensure relevance of tests and demonstrations, each test case is mapped to at least one reference business case.

Based on the work reported in D2.2 [S4G-D2.2], description of scenarios and use-cases, and following the requirements derived from JIRA, the expected role and performance of the most important components associated with the specific test site have been considered.

An updated S4G architecture and components was provided in D3.2 [S4G-D3.2] and will evolve and improve during the project implementation (to be reported in D3.3). The demonstrators will focus on testing the communication between main components, as part of the use-cases associated with each of the three test sites. To recall the use-cases associated with each test site please address D2.2 [S4G-D2.2].

After a short introduction, chapter 2 details the overall test and evaluation framework. This framework was applied in three test sites of the project. Chapter 0 presents the list of components developed in the S4G project, their description and in which test site they are planned to be deployed, integrated, and evaluated during phase 2. Chapters 0, 0, and 0 describe the three project test sites: Bolzano, Fur/Skive and Bucharest, respectively. For each test, it is detailed the S4G components planned to be deployed during phase 2. The specific test and evaluation framework (described in chapter 2) is applied to each test site. Lastly, the KPIs for each test site are identified using the business cases approach, described in D2.3 [S4G-D2.3], and the state of the implementation of the use-case, described in D2.2 [S4G-D2.2].

1.1 Scope

This deliverable documents the results generated by Work Package 6 "Integration, Test Sites and Evaluation", and more specifically by task T6.1 "Test Sites and Cases Planning". This document describes technical steps for evaluation of phase 2 demonstrators, included in general plans of the test sites analysed until M20 of the project (July 2018). This document is an update of the D6.1 (ended in M8, July 2017). A future version is expected to update and replace the information documented in this deliverable, namely D6.3 "Phase 3 Test Site Plans" (due in M32, July 2019).

A general view of all the uses cases is presented in D2.2 [S4G-D2.2], where the use-cases are structured according to the scenarios and high-level use-case to be demonstrated in the three test sites. The complete description of the uses case is presented in D2.2 [S4G-D2.2].

1.2 Related Documents

ID	Title	Reference	Version	Date
D2.2	Final Storage Scenarios and Use Cases	[S4G-D2.2]	V1.0	2018-07-31
D2.3	Initial S4G Business Models	[S4G-D2.3]	V1.0	2018-03-20
D2.6	Updated Lessons Learned and Requirements Report	[S4G-D2.6]	V1.0	2018-06-07
D3.2	Updated S4G Component Interfaces and Architecture Specification	[S4G-D3.2]	V1.0	2018-08-31
D6.1	Phase 1 Test Site Plans	[S4G-D6.1]	V1.0	2017-08-16
D6.7	Initial Interfaces for Professional and Residential users	[S4G-D6.7]	V1.0	2017-08-31
D6.8	Updated Interfaces for Professional and Residential users	[S4G-D6.8]	V1.0	2018-08-23
D6.10	Phase 1 Evaluation Report	[S4G-D6.10]	V1.0	2018-05-02

2 Overall test and evaluation framework

The overall test and evaluation framework planned to each S4G test sites is composed by four steps, as follows:

1. S4G components KPIs definition and evaluation procedure
2. Use-case mapping for the corresponding business case
3. Test site use-case KPI definition and evaluation procedure
4. Analysis of evaluation results

The evaluation framework is described in the follow subsections. Moreover, the data collection requirements in the test sites is also addressed.

2.1 S4G components KPIs definition and evaluation procedure

In this step, the KPIs for each S4G component will be defined together with the evaluation procedure that can be different in each test site. The KPIs can be related with the components' communication, the completeness of measurements, and the requirements for data synchronization.

2.2 Use-case mapping for the corresponding business case

One of the aims of S4G is the development of a viable and sustainable business framework for controllable storage solutions that align with global business conditions, and in particular, to develop realistic business models and cases for deploying the S4G outcomes. While a number of technical capabilities and features of S4G control solutions can be operated by single business entities (e.g. private prosumers), the real value of such solutions lies in the use of S4G solutions as an enabler of complex business and market configurations. Therefore, services by different stakeholders and partnerships are dynamically involved and integrated with the energy market in a specific regulatory environment.

An initial analysis of already established models for deployment and operation of storage systems was performed in D2.3 - "Initial S4G Business Models" (M16), initially focusing on simpler business cases with a shorter time perspective of realization. D2.3 [S4G-D2.3] will be updated in M30 as D2.4 - "Final S4G Business Models".

The developed business cases build on knowledge gathered and reported in D2.2 - "Final Storage Scenarios and Use cases" which describes different actors or stakeholders in all use-cases considered for S4G. The stakeholders' business cases are being explored in business conditions, investments and cost, marked perspective and regulation issues.

In order to evaluate the use-cases in each test site, an initial assessment of the possible use-cases to be evaluated will be identified, and mapped to the corresponding business case.

2.3 Test site use-case KPI definition and evaluation procedure

According to the identified use-cases in the previous steps, specific KPIs for each test site will be defined and the evaluation procedure will be described.

2.4 Analysis of evaluation results

The evaluation results in each test site will be analysed and compared with the expect KPIs. In specific test sites the results might be evaluated with numerical simulation.

2.5 Data collection

In phase 2, an important aspect for the test site evaluation is the data collection. A specific and continuous task is to monitor the data collection, as part of the evaluation methodology. Data collection is achieved in the local premises through the SMX software package and links several components and layers of the S4G architecture, starting from the physical layer (composed of hardware such as smart meters and inverters), up to the service layer (with components such as the DSF-DWH) [S4G-D3.2]. Consequently, it allows the development of local and global energy management, which can be related to dedicated business models. The descriptions of this section apply as guidelines for basic data collection and processing over phase 2 and phase 3 period.

S4G is a research project which requires for continuous development of different components, including the local SMX system, which is not envisaged to be developed until an industrial/commercial implementation level but to be used to demonstrate the project concepts. In this context, data collection refers to measurement data from SMM and transferred to the SMX and related components, then to high-level components. For example, one of those components is envisaging using load power data for the forecast of the local consumption (load). The very low spatial granularity of low voltage system selected as demo sites in S4G is correlated with high level of unpredictability of load conditions, unless external information is tuned to the estimation algorithm. Thus, a complete set of measurement data from continuous monitoring is still biased against user behaviour.

For the local data collection, it is considered to be recorded (collected) a number of complete (continuous) daily records and complete (continuous) weekly records which are made available for testing the algorithms designed for specific applications (like building data sets for training). Those sets will be considered representative for the specific measurement process when data is retrieved with good credibility, i.e. at least 95% of all possible samples during the considered time interval (e.g. for one day with reporting rate granularity 5 seconds, out of the maximum 17280 samples, at least 17280 x 0.95 = 16416 credible data records should be available). Similarly, for a time window of one week, and reporting rate granularity of 5s, at least the 95% from the maximum data frame of 17280 x 7 samples, i.e. 120960 x 0.95 = 114912 samples should be "credible"). The specific credibility factor for a day and for a week are labelled as C_{CFD} and C_{CFW} respectively and is represented as percentage [%] of credible data compared with the maximum possible records in the considered period for that metering point and selected reporting rate (data granularity in time). A complete week is considered a set of seven complete and consecutive days where the data from a metering point (SMM + SMX) has been collected (using local data recording within daily files) with the required percentage of credibility (C_{CFD} > 95%). The whole data collection will be based on complete days and complete weeks, as previous defined. The criterion for labelling a measurement data as "credible data record" is following the analysis of the timestamp of the measurement device (ZMG/ZMD meter), which has to change its value in a time period of up to 10 seconds, based on locally recorded or remotely received data samples.

The measurement data set from the ZMG/ZMD metering points relevant for different applications within the project is built as a matrix with the following characteristics. Metering data collection will be available for a cumulated period of at least M=4 months, with a collection of cumulated days of at least one month in each season (winter, spring, summer, autumn), in order to acquire also seasonal behaviour information. In each season collection of cumulated days of one month or more, a number of at least two complete weeks will be present, and a remaining number of complete days will be needed to cover the seasonal collection, each day or complete week being recorded with C_{CFD} > 95%. For clarification, a season collection of cumulated one month will have at least 2 weeks + 31-(2x7) = 2 weeks + 17 days spread over the corresponding season.

To be noted that data availability has several components (i) measurement device (SMM); (ii) local communication to-from (SMX) and (iii) remote communication to/from application. Therefore, data availability may degrade for specific time intervals and metering points. The data collection of cumulated days of at least one month in each season (as previous described), will be assessed at SMX level, based on daily files records.

Data collection monitoring will be performed monthly by UPB for all meaningful ZMG/ZMD metering points deployed in the S4G test sites.

Remote access to corresponding USM/SMX will be supported by the test site owners in real-time mode (to allow real-time remote data collection and interaction with the remote apps), or, in partial-mode (for limited number of metering points and for limited time, which shall be at least one working day per week, when additional actions such as applications improvements and tests are necessary).
Access to data collection will be possible remotely through the S4G project VPN or locally, by the local users which can access local area networks (LANs).

Metering data collection process will be evaluated based on the local daily records in SMX, stored by SMXcore. Considering that, there are other applications as well running on the same Raspberry Pi which may have also their own local logs, and in order to avoid the SD space issues or negative impact on the overall Raspberry Pi 3 performance, close collaboration among all S4G project partners is needed. Data collection monitoring of the ZMG/ZMD meters data will be assisted by an off-line application named Metering Data AnalysiS (MEDAS) developed in the project by UPB. It will evaluate data collection KPIs such as C_{CFD} and C_{CFW} based on daily files recorded in SMX.

MEDAS is able to compute, for daily and weekly time intervals, if the credibility factors of data are achieved (C_{CFD} > 95% for one day and C_{CFW} >95% for one week). Based on daily files processing, MEDAS will generate energy quantities "reported" on one-hour intervals, in order to produce hourly-based energy profiles for each complete day, as standard reporting profiles. It means that, for the selected days and weeks, MEDAS will generate the daily and weekly profiles (as series of consecutive values) i.e. vectors with 24 values per day, corresponding to one hour reporting rates, acting as daily (and weekly when necessary) profiles for the monitored quantities. The output data format is not yet established, to be chosen from CSV or JSON syntax.

Data collection from other devices or systems (e.g. Fronius inverters or EV charging points) and data received remotely from USM/SMX in DSF-DWH may be used as well as data sources for completing the data collection.

For project applications which need a continuous data availability over longer time, e.g. one to three months, UPB is also developing a daily energy profiles generator based on similarity. The application named PROfiles SImilarity Tool (PROSIT) will use the collection of existing real data to produce (for days with missing or incomplete data), profiles of energy based on different criteria, which consider that energy processes have particular repetitions - daily, weekly and yearly based, and which includes Artificial Neural Networks (ANN) trained with the collected daily data previous described. PROSIT will be particularly used to generate similar daily energy profiles for consumption metering points. As basic technology for the ANN based profiling, it is envisioned to be used the Kohonen Self-Organizing Maps (K-SOM) technology, which is a robust technology to cope with partial data and similarity detection.

Data collection will also be used, where needed, for the purpose of various simulations which will assess or demonstrate the specific use-case for each test site. If needed, data collection evaluation may be adapted / improved for the phase 3 of the S4G project test site planning, to be reported in D6.3.

3 Phase 2 S4G components

This chapter presents the S4G components under development during phase 2. Moreover, it describes the KPIs that will be evaluated during phase 2. For more information regarding the S4G functional architecture, see Figure 7 of D3.2 [S4G-D3.2]. The PV and ESS integrated in phase 2 are commercial products (not having specific KPIs), which need S4G components to be integrated, e.g. the three-phase ER described in section 3.25.

3.1 Control broker

This component is located in the **communication layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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 mechanisms are applied for access control.

3.2 Data broker

This component is located in the **communication layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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 mechanisms are applied for access control.

3.3 OGC Sensor Things Server

This component is located in the **communication layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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.

3.4 Professional GUI

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Fur/Skive** test site, and evaluated in 3 tracks as follows.

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

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

- 50% of specified requirements (= 100% of the requirements for year 2 (listed on Confluence)) are implemented (see 1).
- Using an 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 with end-users, the outcome of the overall system usability will be at least 68 or higher (SUS score, 68 classifies a software system as "good").

3.5 DSF-SE

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Fur/Skive (residential)** test site, and evaluated 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.

3.6 GESSCon

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be deployed in **the Bolzano** test site, and evaluated the following KPIs:

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

3.7 DSF-DWH

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, supporting the **Bucharest, Bolzano, and Fur/Skive** test sites in data collection, and evaluated the following KPIs:

- 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.

3.8 GridDB connector

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, providing grid related information of the **Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

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

3.9 Energy Price connector

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, providing energy prices related information of the **Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

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

3.10 Fronius cloud connector

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, providing hybrid Fronius system related information of the **Bolzano, and Fur/Skive** test sites devices, and evaluated the following KPIs:

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

3.11 Weather forecast for PV production connector

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, PV forecast production of the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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.

3.12 DSF-DWH connector

This component is located in the **service layer** of the S4G functional architecture. During phase 2, it will be available in the cloud, providing collected data in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

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

3.13 Solar radiation connector for PROFESS or PROFEV

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in the Bolzano and **Fur/Skive (residential)** test sites, and evaluated 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).

3.14 Residential GUI

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in **Bolzano (residential)** test site, and evaluated the following KPIs:

- Shows in real-time house production and consumption, and battery and car status (sample rate 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 state of charge of the system.
- It is usable on different devices and screen sizes.

3.15 Aggregator broker

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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.

3.16 OGC wrapper

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- 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.

3.17 PROFESS

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bolzano, Fur/Skive (residential)** test sites, and evaluated 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.

3.18 Aggregator DWH

This component is located in the **edge layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bolzano (residential), and Fur/Skive (residential)** test sites**,** and evaluated the following KPIs:

- 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.

3.19 Technical GUI

This component is located in the **device layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

- Shows in real-time selected information acquired from the main meter (especially the measurements of U, I, P, Q on each phase).
- Runs locally on SMX and receives MQTT data from the SMXcore.
- Reporting rate depending on MQTT messages of SMXcore sent on localhost, between 5 and 10 seconds, or slower rates based on various reasons such as communication availability
- Used for quick information during the commissioning and for monitoring operation.

3.20 Dispatcher

This component is located in the **device layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

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

3.21 SMX broker

This component is located in the **device layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated the following KPIs:

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

3.22 SMX core

This component is located in the **device layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated 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 Raspberry Pi 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.

3.23 Energy Router South-bound SMX connector

This component is located in the **device layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Fur/Skive (residential)** test site, and evaluated 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 is publishing on the SMX broker.

3.24 SMM

This component is located in the **physical layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Bucharest, Bolzano, and Fur/Skive** test sites, and evaluated 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.

3.25 Three-phase Energy Router

This component is located in the **physical layer** of the S4G functional architecture. During phase 2, it will be deployed in the **Fur/Skive (residential)** test site, and evaluated the Load Balancing Support KPI:

- The KPI for the ER evaluation is related with the load balancing support defining a three-phase system, the ER capability to compensate the unbalance present in the load.
- The EN50160 establishes that, under normal operating conditions, if the load is unbalanced [95 % of the 10 min mean r.m.s. values of the negative phase sequence component (fundamental) of the load current are outside the range 0 % to 2 % of the positive phase sequence component (fundamental)].
- Load unbalance factor can also be computed dividing the positive phase sequence component by the negative phase sequence component or (with some degree of approximation) dividing the difference between the largest current and their average value by the three-phase average current. The compensation factor (a) will compute the energy router capability to reduce the load unbalanced on the grid side, dividing the load unbalance factor (computed on the grid side - after the energy router point of connection) by the load unbalance factor (computed on the load side - before the energy router point of connection). This quotient (a) changes between 0 (total unbalance compensation) and 1 (no compensation). The goal (KPI) is to keep the compensation factor 0.05 during 95% of the time, requiring that there is enough PV power to perform compensation.

3.26 EV charger

This component is located in the **physical layer** of the S4G functional architecture. During phase 2, it will be deployed in **Bolzano (commercial)** test site, and evaluated the following KPIs:

- Connection with the electric converters used to charge plug-in EVs.

3.27 Planning

Table 1 summarizes were the S4G components that are planned to be deployed, integrated, and evaluated during the phase 2 of the project.

Table 1. Planned S4G components for phase 2.

	Architectural Layer	Bolzano (IT)	Fur/Skive (DK)	Bucharest (RO)
Control broker	Communication layer	✓	✓	✓
Data broker	Communication layer	✓	✓	✓
OGC Sensor Things	Communication layer	✓	✓	✓
Professional GUI	Service layer	-	✓	-
DSF-SE	Service layer	-	✓	-
GESSCon	Service layer	✓	-	-
DSF-DWH	Service layer	✓	✓	✓
GridDB connector	Service layer	✓	✓	-
Energy price connector	Service layer	✓	✓	-
Fronius cloud connector	Service layer	✓	✓	-
Weather forecast for PV production connector	Service layer	✓	✓	✓
DSF-DWH connector	Service layer	✓	✓	✓
Solar radiation connector for PROFESS or PROFEV	Edge layer	✓	✓	-
Residential GUI	Edge layer	✓	-	-
Aggregator broker	Edge layer	✓	✓	✓
OGC wrapper	Edge layer	✓	✓	✓
PROFESS	Edge layer	✓	✓	-
Aggregator DWH	Edge layer	✓	✓	-
Technical GUI	Device layer	✓	✓	✓
Dispatcher	Device layer	✓	✓	✓
SMX broker	Device layer	✓	✓	✓
SMX core	Device layer	✓	✓	✓
ER SMX SB connector	Device layer	-	✓	-
SMM	Physical layer	✓	✓	✓
Three-phase ER	Physical layer	-	✓	-
EV charger	Physical layer	✓	-	-

4 Test site Bolzano: Cooperation EV Charging Scenario

The "Cooperative EV charging" scenario is set up in Bolzano and operated by partners Edyna, Alperia Smart Mobility (ASM), and Alperia. Bolzano is the capital of Alto Adige – Sudtirol , an alpine region in northern Italy characterized by the presence of two medium cities (Merano and Bolzano), with strong seasonal changes in electricity demand and use of electric vehicles (EVs) due to the touristic nature of the site. As of July 2018, approx. 400 EVs are already active in the area, using a charging network of 55 Quick charging stations (maximum power absorbed during charging: 22 kW) and 15 fast charging stations (maximum power absorbed during charging: 45 kW). The diffusion of EVs is currently growing significantly in this area; therefore, Alperia Smart Mobility, as e-mobility provider, has already scheduled investments to activate more than 100 overall charging stations (80 Quick and 20 fast) in the area, before the end of 2018. The current EV charging infrastructure is monitored and controlled in real-time by Alperia Smart Mobility through a dedicated SIEMENS backend management system. The number of charging stations is possible to raise during the project lifetime, considering the high interest for e-mobility in this area. This test site features **two scenarios**: a **residential** case and a **commercial** case.

4.1 Residential case

For the **residential case** Edyna uses as test site a single-family house in a rural village close to Bolzano that is already equipped/fitted with a PV installation on the roof (10 kW) and with an EV private charging station. In the first phase of the test Alperia has equipped the house with an ESS, to fulfil the requirements of the test site. The ESS is a Fronius system, three-phase, with 12 kWh capacity and 5 kW of power. During the first phase, Alperia has installed 4 USM (SMM + SMX) in the house: at the Point of Common Coupling (PCC) between the DSO and the prosumer internal network, at the PV plant, at the ESS, and at the EV charger. The smart meters used here are three-phase ZMG310 meter form Landis+Gyr. Other types of meters have been analysed for the scope, such as MT831 from Iskraemeko, but the Landis+Gyr showed better characteristics in terms of USM flexibility and access to the instrumentation values. In fact, this smart meter shows the better compatibility with the SMX, which is a fundamental characteristic for the project.

During phase 1 ASM has provided a new smart EV charger, to correctly monitor the charge of the electric vehicle and to develop the possibility to command the EV charge in the optimal moment. Before the owner of the house used a charger directly connected to the normal electrical socket for his EV.

In the house, EDYNA has installed a separate internet connection to receive the data of measure from the 4 USMs. The VPN is already active, so all the partners of the S4G consortium are able to read the real-time measurements and to communicate with the SMX. Furthermore, the SMXs were configured to enable the house owner to read the measurements from the 4 SMMs in its own domestic internet.

All physical components have been installed during phase 1. In phase 2 the S4G components listed in Table 1 will be deployed (Figure 1). Legend for the annotations can be found in Table 2.

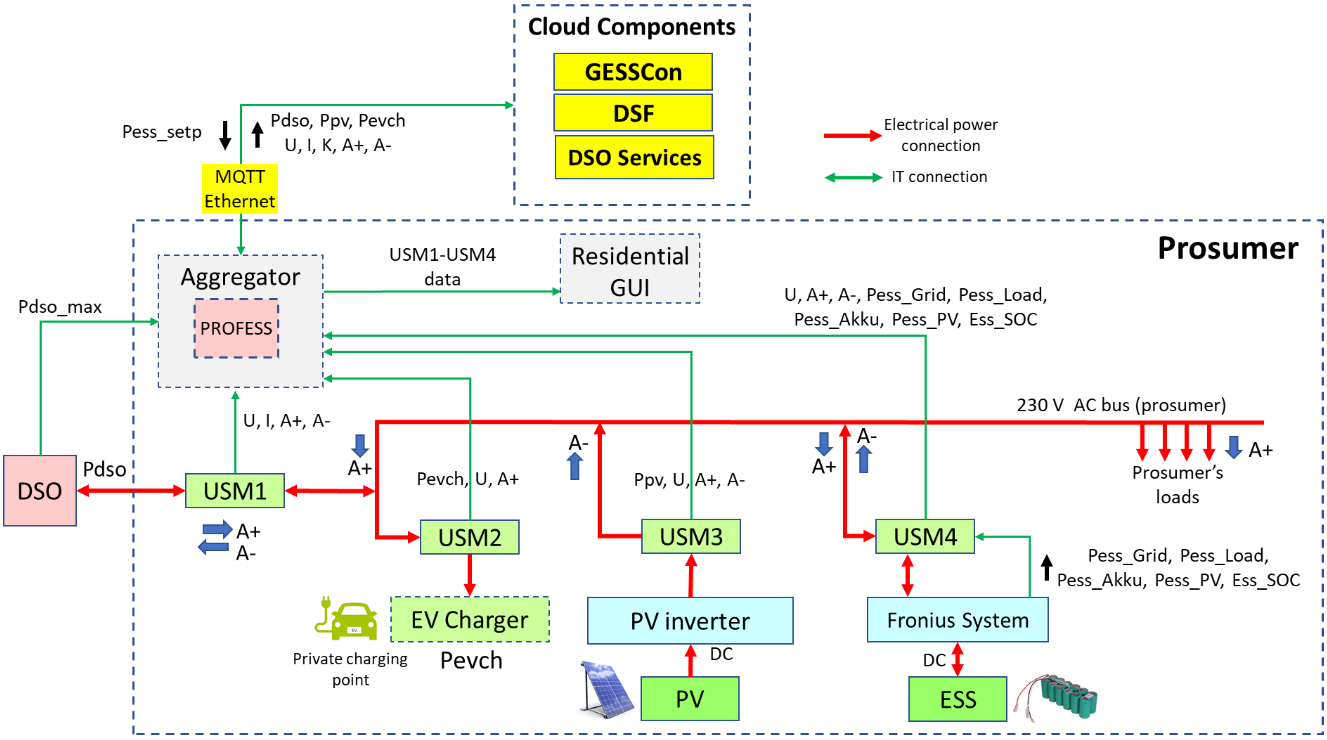

Figure 1. Planned architecture for phase 2 in the Bolzano Residential test site.

Table 2. Legend of Figure 1 (Bolzano Residential test site).

Name	Description
Ess_SOC	State of Charge of the local Energy Storage System of prosumer (information given by the Fronius System to the SMX)
Pess_Grid	Active Power of the Fronius System (positive = power from grid; negative = power to grid)
Pess_Load	Load Power of the Fronius System (positive = generator; negative = consumer)
Pess_Akku	ESS Power of the Fronius System (positive = discharging; negative = charging)
Pess_PV	PV Power production of the Fronius System (positive by default). Due to currently electrical connection, the PV production is zero because the PV system is not connected to the Fronius System but to a separate inverter as show in Figure 1.
Pdso	Active power received from or injected to the DSO, measured by USM1 (main USM)
Pdso_max	Maximum active power required from the DSO, sent to the local components
Ppv	Active power provided by the PV, measured by USM3; this power has usually negative value, as it is mainly generating power; USM3 is also providing the energy consumed (A+) and produced (A-)
Pevch	Active power consumed by the Electrical Vehicle Charging point through the Wall Box (WB)

Pessp_setp	The power schedule provided to the local Energy Storage System of the prosumer (consumption or generation), decided to be sent to PROFESS from GESSCon, as a schedule.
U	Root Mean Square phase voltages delivered with a reporting rate (Tu)
I	Root Mean Square phase currents delivered with a reporting rate (Ti)
A+	Energy consumed by the prosumer
A-	Energy produced by the prosumer

To be noted that Tu will have a value between 2 and 10 seconds, to be decided based on implementation details, such as SMM, WB and Fronius inverter characteristics. As an example, in Figure 1 are presented two layers (networks) corresponding to:

- Power / energy flow (lines depicted in red colour), related to the power network:
  - From the prosumers 230 V AC bus to the charging point; the real-time active power Pevch and active energy A+ are measured with an individual USM2. Based on the metrology meter (SMM) characteristics, the real-time active power will be available with the reporting rate Tu = 2 .. 10 seconds
  - From PV to the prosumer's 230 V AC bus (via Fronius system or USM3), the real-time active power Ppv as well as the active energy A+ are measured and exchanged with an individual USM3. Based on the metrology meter (SMM) characteristics, real-time active power will be available with the reporting rate Tu = 2 .. 10 seconds
  - Between the prosumer's 230 V (AC) bus and the available storage ESSp, the active power Pessp is measured and exchanged by using an individual USM4; Power Pessp, exchanged between the AC bus and the storage unit ESSp, has negative values in battery charging mode (acting as energy consumption) and positive values in battery discharging mode (acting as energy production). Moreover, energies A+ and A- will be available, corresponding to charging and discharging mode of the battery.
  - Power and energy exchanged by the prosumer with DSO are metered by an individual USM1, acting as main USM. Active power Pdso exchanged between DSO and prosumer will have positive values when the prosumer is equivalent to a load and negative values when the prosumer injects energy in the DSO grid, acting as a generator. Based on the meter characteristics, real-time active power will be available with the reporting rate Tu = 2 .. 10 seconds. Moreover, energies A+ and A- will be available, corresponding to load and generator mode of the battery.
  - On the prosumers premises there are other AC loads with active power consumption P_loads or P_Σload. There is no individual meter associated with them. Information on power delivered to these loads will be calculated from power balance P_Σload =Pdso-Pessp-Pevch-Ppv.
  - As a general rule, USM is delivering the A+ as energy consumed by the prosumer and A- as energy sent to the grid by prosumer.
- Information flow (lines depicted in green colour), related to the information network:
  - Measurements from local devices:
    - Delivered by USM: Pdso, Pevch, Ppv, Pessp, Pevch, U (rms phase voltages delivered with a reporting rate Tu), I (rms phase currents delivered with a reporting rate Ti), A+,

A- (A+ is measured energy in the consumption mode and A- is measured energy in the production / inject back to the system mode)
    - Delivered by Fronius system: Pess_Grid, Pess_Load, Pess_Akku, Pess_PV, Ess_SOC (updated at the highest rate of reporting, e.g. each 2 to 10 seconds)
- Setpoints from the cloud applications: Pessp_setp
- DSO restrictions: Pdso_max
- Aggregator: receives and aggregates USM data and make it available for the residential GUI, PROFESS and cloud components

The red lines correspond to the power bus (power wiring in the prosumer's premises, for energy transfer between different components at 230 V AC) and the green lines are IT information exchanged between the different parts (physical media for information transmission will be decided in the next stage).

The cloud components are Grid ESS Control (GESSCon) and Decision Support Framework (DSF). A detailed description of information exchange and of software modules is provided in D3.2 [S4G-D3.2].

4.2 Commercial case

The **commercial case** is in the parking place of Edyna in the Bolzano area. The parking place has several charging points (CP) for EVs. Alperia Smart Mobility has installed 5 SMART charging stations to enable fine-grained monitoring and control of the charging process. Furthermore, some dummy charging stations were installed (initially 3 during phase 1, but the number will increase until the end of the project). In the same site of the parking there are 2 PV plants: one of 50 kW and the other of 100 kW. The first plant is directly connected in the EDYNA LV grid (only production), the second is connected with the load of the EDYNA warehouse (production + load). For the measurements of the energy parameters in all these plants (EV chargers, PV plants, loads) 10 SMMs (Landys+Gyr like in the residential test site) were installed: 5 for the smart EV chargers, 1 for the dummy EV chargers, 1 for the 100 kW PV, 1 for the 50 kW PV, 1 for the PCC of Edyna warehouse (this includes the 100 kW PV) and 1 for the PCC of ASM (total of the EV charger + future ESS), as show in Figure 2. Legend for the annotations can be found in Table 3.

The test site will be completed during phase 3 with the installation of a substation level ESS compliant with S4G interfaces and models.

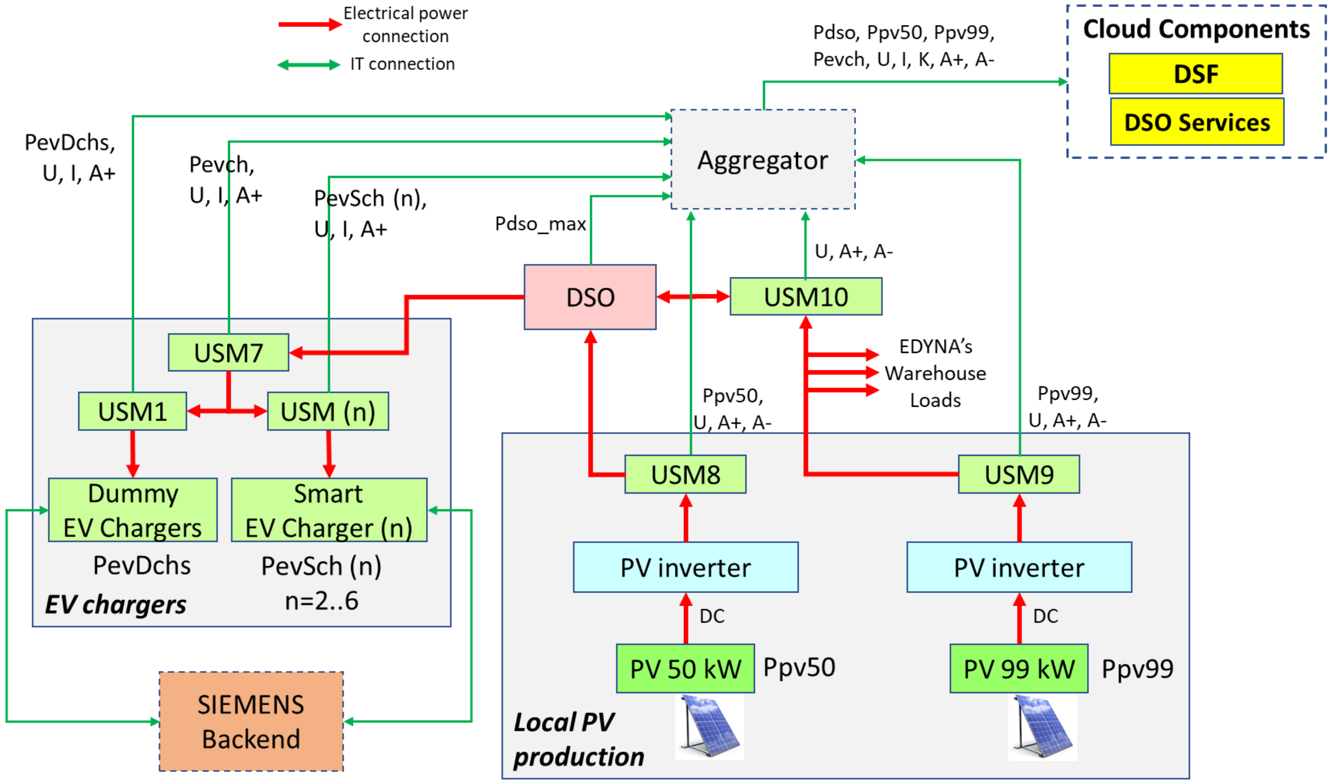

Figure 2. Planned architecture for phase 2 in the Bolzano Commercial test site.

Table 3. Legend of Figure 2 (Bolzano Commercial test site).

Name	Description
Pdso_max	Maximum active power required from the DSO, sent to the local components
Ppv50	Power provided by the PV 50 kW and measured by USM8
Ppv90	Power provided by the PV 99 kW and measured by USM9
PevDchs	Power provided by the Dummy Electrical Vehicle Charging points (7 dummy charging points are connected in phase 2) and measured by USM1
PevSch	Power provided by the Smart Electrical Vehicle Charging points (5 smart charging points are connected in phase 2) and measured by USM2… USM6
Pevch	Active power consumed by all Electrical Vehicle Charging points (PevSch(n) + PevDch)
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the different components: charging stations, and PV inverter when energy production is not possible.
A-	Energy sent to the grid by the different components

In Figure 2 are represented two layers corresponding to:

- Power / energy flow
  - From the DSO to all charging points Pevch = PevSch(n) + PevDchs; the power is measured by USM7.
  - From the DSO to the Dummy charging points PevDchs , the power is measured by USM1.
  - From the DSO to all Smart charging points PevSch (n); the power is measured by USM2 to USM6
  - From the PV to the DSO Ppv; the Ppv power and energy in both directions A+ and A- are measured with individual USM8 (Ppv50) and by USM9 (Ppv99).
- Information flow:
  - Measurements delivered by USMs: Ppv50, Ppv99, PevDchs, PevSch (n), U, I, A+, A-.
  - Aggregator: receives and aggregates USM data and make it available for the cloud components

The cloud component is the GESSCon, which has the support of the DSF-DWH. A detailed description of information exchange and of software modules is provided in D3.2 [S4G-D3.2].

4.3 Overall test and evaluation framework: Bolzano test site

In phase 2, ALPERIA and EDYNA have continued to implement the 2 test sites (residential and commercial) with the realization of the steps described below:

- Implementation of DSF connectors
- Installation of gateway for communication
- Introduction to local GUI for residents
- Access to the managing system of the charging points
- Monitoring of available residential components deployed in the test site, using USM and DSF connector implementations.

Moreover, the overall test and evaluation framework defined in chapter 2 will be applied to the Bolzano test site, as described in the following subsections.

4.3.1 S4G components KPIs definition and evaluation procedure

For the development of the Bolzano test site, the conditions of the measurements and communications were tested and evaluated in phase 1. The details about these boundary conditions are reported in D6.1 [S4G-D6.1]. In phase 2, the KPIs and evaluation procedures for each S4G component is defined in chapter 0.

4.3.2 Use-case mapping for the corresponding business case

Table 4 shows the Bolzano test site use-cases assessment, according to the information available in D2.2 [S4G-D2.2].

Table 4. Use-cases assessment of the Bolzano test site.

Use-Case	Business case	Actors	Available in phase 2
HLUC-2-PUC-1: *Residential prosumer with storage and EV*	HLUC-2-PUC-1-BM-1: *Prosumer with ESS "stand-alone" (baseline)* HLUC-2-PUC-1-BM-2: *Prosumer with grid integration*	Prosumer	✓
		ESS (controllable)	x
		PROFEV	x
		DSF-DWH	✓
		Residential GUI	✓
		GESSCon	✓
		EV (controllable)	x
HLUC-2-PUC-2: *Cooperative charging in the parking lot of a commercial test site*	HLUC-2-PUC-2-BM-1: *Prosumer with ESS "stand-alone" (baseline)*	Garage owner	✓
		DSO	✓
		PROFEV	x
		USM	✓
		DSF-DWH	✓
		GESSCon	✓
HLUC-2-PUC-3: *Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging*	N/A	Professional GUI	✓
		DSF-SE	✓
		DSF-GRIDDB	✓
		PROFEV	x
		Grid planner	✓

4.3.3 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 4, it is not possible to evaluate any use-case during phase 2 due to development status of the S4G components. In this specific test site, PROFEV will only be available during phase 3 and it is a key actor in all Bolzano use-cases.

4.3.4 Analysis of the evaluation results

This step will be reported in D6.11, evaluating the S4G components deployed in the Bolzano test case.

5 Test site Fur/Skive: Storage Coordination Scenario

This test site features **two scenarios**: a local residential case and a grid case. The "Storage Coordination" scenario will be addressed in conjunction with the deployment in the Fur test site led by partner ENIIG and a new test site set up in the Municipality of Skive, led by partner LiBal. The Island of Fur is placed in the Municipality of Skive in the Northern Denmark in a fjord. A more detailed description can be found in D2.2 "Final Storage Scenarios and Use Cases"**.**

This test site features **5 residential Fur houses** which are already provided with storage units paired with PV installations of various sizes (ranging from 3 to 6 kW sizes). The batteries already installed are Solar Batteries Li-ion 4.5 from Fronius. The new test site will be equipped with **one grid-side battery** near by a transformer station in the Municipality of Skive, where a sport facility has a huge PV system size 42 kWp. The grid site battery will be installed in phase 3.

In phase 1 one house has been provided with an USM, integrated with the residential ESS and a dedicated local technical GUI. The project has investigated in phase 1 how to prioritize and control this set-up (preliminary); the project has struggled with the meter specifications and communication to the SMX in phase 1; but the scenario and the use-cases have been developed and updated and are fully documented in D2.2 [S4G-D3.2] as HLUC-3-PUC-2; "Autonomous control of storage installed at user premises and distributed in the grid" / *Monitoring* and HLUC-3-PUC-4; "Coordinated Distributed storage in the grid" / *Simulation*. During phase 2, the communication issues with the SMX were solved.

In phase 3 the S4G project will investigate whether it is feasible to install batteries at substation-level; the corresponding use-cases are HLUC-3-PUC-3; "Voltage and energy transfer control at grid side storage", it will be investigated whether it is feasible to install batteries at sub-station level, how to control the storage and compare the business case with ordinary grid strengthening costs (baseline).

5.1 Local case

The best option from the end user point of view is to store surplus local energy production and to use it themselves in order to secure self-sufficiency (depending on feed-in tariff scheme). Due to the poor feed-in tariffs or even no feed-in tariff, the business-case from the end-user point of view is to consume as much produced as possible. From the DSO point of view the important factor is to secure voltage levels in the local feeder lines and avoid unnecessary grid losses. To secure voltage levels and avoid grid strengthening the local storages can be active for the DSO. HLUC-3-PUC-2: "Autonomous control of storage installed at user premises and distributed in the grid" was developed and will be deployed in phase 2, where voltage set-points are set and controlled by the DSO, the set-points can be different depending on the actual situation in the local grid. The developed S4G residential GUI features the option of including information about an EV. However, this information is not needed for the users in the Fur/Skive test site. Besides this, the residential users in Denmark are very confident in using the competitor software SolarWeb[i], which offers the majority of basic features revealed in the user studies documented in D6.7 [S4G-D6.7] and D6.10 [S4G-D6.10]. This is why the S4G residential GUI will only be rolled-out in Bolzano, where EVs are present. However, it will be possible for the Fur/Skive residential users to use the S4G residential GUI, if they change their opinion. Using the residential GUI, the residential user can get relevant system information, and explore reasons for deviations from the optimal voltage (rms) level (from the rated values ensured by local standards and regulations). In phase 3, the

HLUC-3-PUC-2 use-case will be extended further, by simulating HLUC-3-PUC-4: "Coordinated Distributed storage in the grid", and learnings from this use-case will be carried into the grid case.

In phase 1 the DSO has made contracts with the first house owners about

- Installation of the USM (with two components: smart meter and associated SMX)
- Getting access to the local BMS, i.e. the existing Battery Management System
- Integrating the ESS system

It is considered the process of getting permission to control the local voltage level, which may mean the export of PV-production when the battery is not fully loaded, caused by the demand of electricity in other parts of the local grid which will help to decrease the voltage level. In fact, there are optimal control options that allow to manage the energy from renewables, ESS, Loads, etc., which allow a better use of the energy in the households.

Figure 3 shows the planned architecture for phase 2. Legend for the annotations can be found in Table 5.

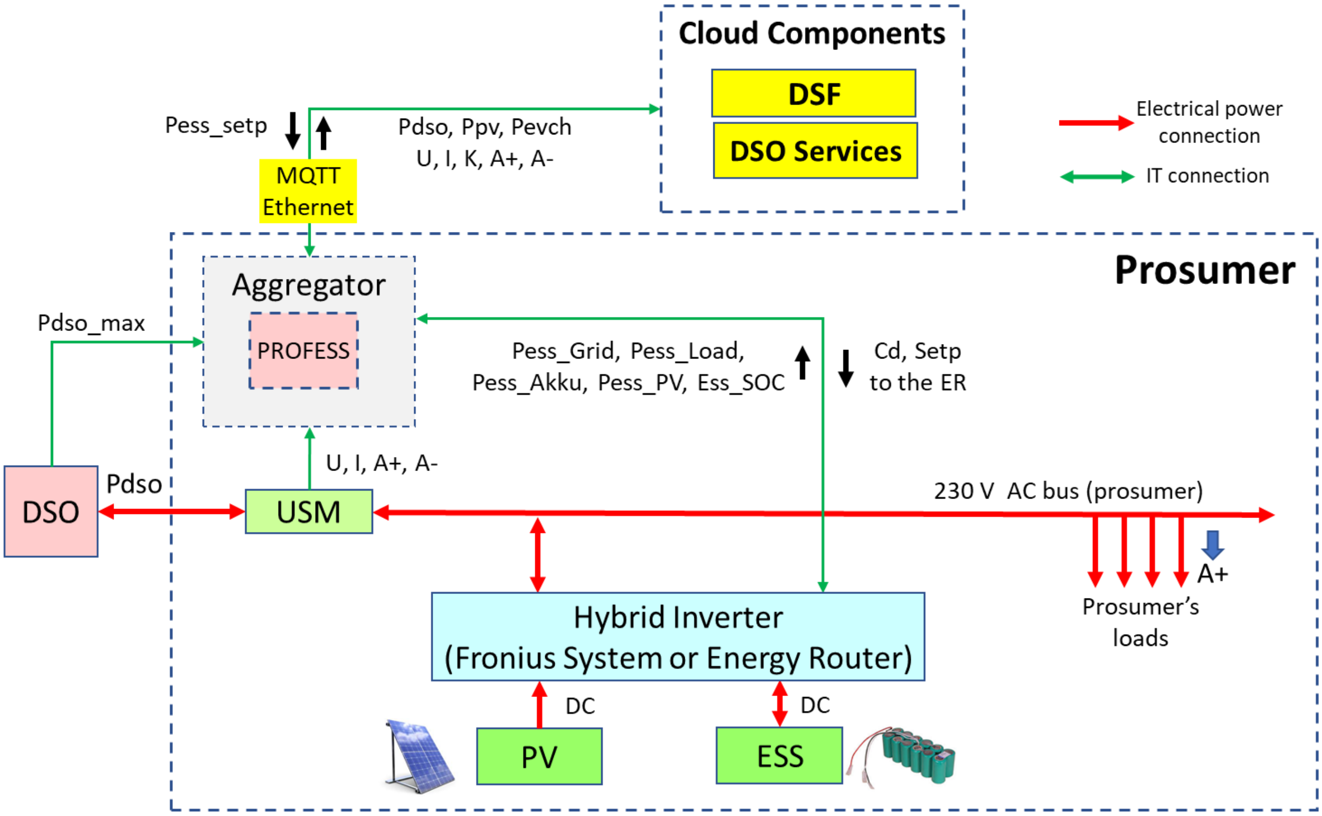

Figure 3. Planned architecture for phase 2 in the Fur/Skive Residential test site.

Table 5. Legend of Figure 3 (Fur/Skive Residential test site).

Name	Description
Ess_SOC	State of Charge of the local Energy Storage System of prosumer (information given by the Hybrid Inverter to the SMX)
Pess_Grid	Active Power of the Hybrid Inverter (positive = power from grid; negative = power to grid)
Pess_Load	Load Power of the Hybrid Inverter (positive = generator; negative = consumer)
Pess_Akku	ESS Power of the Hybrid Inverter (positive = discharging; negative = charging)
Pess_PV	PV Power production of the Hybrid Inverter (positive by default).
Pdso	Power received from or injected to the DSO
Pdso_max	Maximum active power required from the DSO, sent to the local components
Pessp_setp	The power schedule provided Energy Storage System of prosumer (consumption or generation) decided to be sent to PROFESS from GESSCon, as a schedule.
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the component
A-	Energy sent to the grid by component
Cd, Setp	Control Actions to the ER.

Figure 3 has two layers corresponding to:

- Power (energy) flow:
  - From DSO to the AC bus the active power Pdso and energy A+ and A- are measured with the USM.
  - From PV and ESS to the AC bus, via the Hybrid Inverter (Fronius System or Energy Router). The power delivered by the PV system is considered to be available directly from Fronius Hybrid Inverter as a metered variable.
  - On the prosumers premises there are also AC loads with active cumulated power P_load There is no individual meter associated with them. Information on the active power delivered to these loads will be calculated from power balance P_load = Pdso - Ppv - Pessp.
  - USM is delivering the A+ as energy consumed by the prosumer and A- as energy sent to the grid by prosumer.
- Information flow:
  - Measurements
    - Delivered by USM: U (rms phase voltages delivered with a reporting rate Tu), I (rms phase currents delivered with aa reporting rate Ti), A+, A-
    - Delivered by Hybrid Inverter: Pess_Grid, Pess_Load, Pess_Akku, Pess_PV, Ess_SOC (updated at the highest rate of reporting, e.g. each 2 to 10 seconds)
  - Setpoints: Pessp_setp.
  - Control actions to the ER (setpoints per phase of the active and reactive power, the required power of the ESS and of the PV panels)

PROFESS is the optimization tool considered to run in the Aggregator. The cloud components are the DSF and the Data warehouse. A detailed description of information exchange and of software modules was provided in D3.2 [S4G-D3.2].

5.2 Overall test and evaluation framework: Fur/Skive test site

In phase 2, ENIIG have continued the implementation of the test sites, consisting on the following steps:

- New contracts with house-owners about controlling voltage level
- Installation of specific meter in connection with USM extension in one house
- Implementation of DSF connectors
- Installation of SMX as gateway for communication
- Recap of the Solar Web to residents
- Introduction to professional GUI for DSO employees
- Set-points for voltage level set by the DSO
- Monitoring voltage level
- Monitoring the combined PV and storage information given by the Fronius System

Moreover, the overall test and evaluation framework defined in chapter 2 will be applied to the Fur/Skive test site, as described in the following subsections.

5.2.1 S4G components KPIs definition and evaluation procedure

In phase 2, it is planned that the system will be up and running in one house for preliminary tests before the installation in other houses. Moreover, the KPIs and evaluation procedures for each S4G component is defined in chapter 0.

5.2.2 Use-case mapping for the corresponding business case

Table 6 shows the Fur/Skive test site use-cases assessment, according to the information available in D2.2 [S4G-D2.2].

Table 6. Use-case assessment of the Fur/Skive test site.

Use-Case	Business case	Actors	Available in phase 2
HLUC-3-PUC-1: *Support for analysing storage dimensioning and positioning in the low-voltage grid*	HLUC-3-PUC-1-BM-1: *Baseline*	DSO Strategic grid planner	✓
		DSF-SE	✓
		Professional GUI	✓
		DSF-GRIDDB	✓
		PROFESS	✓
HLUC-3-PUC-2: *Autonomous control of storage installed at user premises and distributed in the grid*	HLUC-3-PUC-4-BM-1: *"Autonomous" voltage control at household battery*	DSO	✓
		PROFESS	✓
		SMX	✓
		ESS (controllable)	✓ (only using the ER)
		PV	✓
HLUC-3-PUC-3: *Voltage and flux control at grid side storage*	HLUC-3-PUC-3-BM-1: *Voltage control at grid side battery*	DSO	✓
		LiBal Site Controller	x
		USM	✓
		Grid-ESS	x
		PV	✓
HLUC-3-PUC-4: *Coordinated Distributed storage in the grid*	HLUC-3-PUC-4-BM-2: *Voltage control at both household and grid side battery and Energy Flux control at grid side battery* HLUC-3-PUC-4-BM-3: *Flux control and load shaving at households with PV and battery* HLUC-3-PUC-4-BM-4: *Flux control at household battery by introducing network-controlled demand side management* HLUC-3-PUC-4-BM-5: *Privately owned virtual storage plant*	Professional GUI	✓
		DSF-SE	x
		GESSCon	✓
		PROFESS	✓

5.2.3 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 6, it is possible 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".

HLUC-3-PUC-4 test case will demonstrate voltage (U, rms value) control at household level by controlling the charging/discharging mode of the local batteries. The target is to keep the voltage (rms) deviation from the rated value (ΔU) within +/- 10% of 230 V (single phase connection point PCC) due to legislation and regulation demands. Different control bands can also be considered in answer to the operation conditions of the DSO.

The impact of storage availability on the voltage deviation ΔU will vary from day to day and from installation to installation depending on production and consumption locally and in the local feeder lines. It is also a function of the grid conditions (substation voltage level) and therefore set points might vary according to the actual grid operation. In this phase, it is considered a fix set point for ΔU of max +/- 10%.
In general (currently), during sunny days, the storage control will not help the voltage regulation since sun-peak will come after battery is fully charged, when the battery is self-managed. Therefore, PV production is often being injected into the grid on random times and not at optimal times (Figure 4).

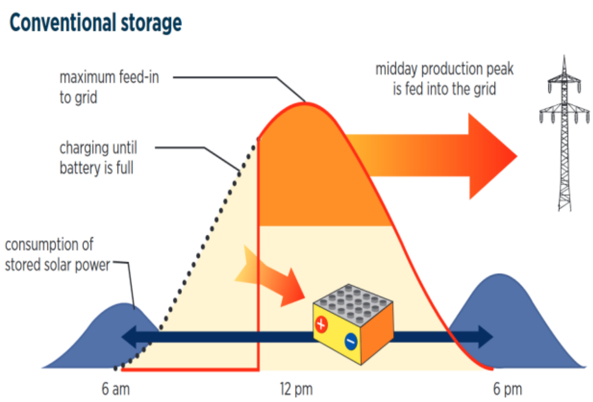

Figure 4. Self-managed battery system.

When introducing voltage-level-control, the [positive] impact will increase on the local feeders (for example, the system will postpone the charging until the sun-peak), see Figure 5. This means that the control algorithm also gets information from weather forecast. The impact is defined as the possibility of installing more energy generation units in local feeders.

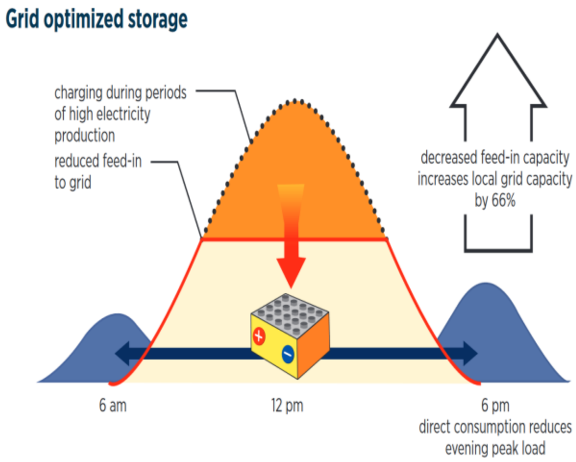

Figure 5. Grid optimized storage.

Distributing electricity around and/or to a higher voltage level causes more grid losses due to higher energy flux. This requires that the battery never will be able to discharge into the grid but only to deliver electricity to local loads. This is being investigated in more details in HLUC-3-PUC-4, during phase 3.

HLUC-3-PUC-2 will be evaluated measuring the voltage levels at user premises. The PROFESS should keep the voltage under the limits established by the DSO, using the three-phase ER for one day, up to one week of continuous control. The voltage levels should be according to the DSO limits for 95% of the evaluation time.

5.2.4 Analysis of the evaluation results

This step will be reported in D6.11, evaluating the S4G components deployed in the Fur/Skive test case. Moreover, HLUC-3-PUC-2 will also be evaluated according to the evaluation procedure described in the previous section.

6 Test site UPB: Cooperative Storage System Scenario

The “Advanced Cooperative Storage Systems” scenario will be addressed in conjunction with the deployment in the Bucharest test site and be led by partner UPB. A detailed description can be found in D2.2 [S4G-D3.2].

This test site is deployed in a laboratory setting and features a **home DC bus** used by the local prosumer able also to interact and support the DSO. The energy exchange in point of common coupling (PCC) is monitored 24/7, with variable time granularity, with a maximum reporting rate of 5 s (1, 2 up to 10 s are also possible, however they may be used for limited periods, in case of separate tests). Equipment to be deployed are the following: **SMX, energy router (to be integrated in phase 3), and data communication devices (for example, local Wi-Fi router)** which may even allow for future black-start support for isolated grids. To ensure that the local DC grid will be able to supply its critical (local) loads also during small AC voltage interruptions or during black-outs (the connection to the grid will be kept open during this period) it needs to be compatible with existing network codes, which is highly simplified by keeping the advanced prosumer as a consumption entity. Additionally, it will also allow to enable new services in the future[ii], e.g. for black-start inside a micro-grid set-up, which works in island mode.

The installed demonstrator components are as follows:

- RES-PV (available in phase 1 and 2, to be integrated in phase 3 based on ER deployment)
- Batteries (available in phase 1, and 2 to be integrated in phase 3 based on ER deployment)
- USM (SMX and SMM) for point of common coupling and for AC submetering (available in phase 1 and upgraded in phase 2, to be finalized in phase 3)
- ER (a set of power converters with accessible and controllable DC bus) (to be deployed in phase 3)
- First DC bus with local loads (directly connected to DC) for ensuring local resilience DC_{bus_remote} (deployed in phase 2 in the laboratory EB105, to be operated in phase 3)
- DC link (2/4 wire cable) between ER DC bus and remote DC bus (partially deployed in phase 2 and to be finalized and operated in phase 3)
- Neighbour DC bus to supply naturally DC loads remotely (at min. 200m distance) (to be deployed and operated in phase 3)
- DC/DC converter for mediating energy transfer towards neighbouring loads (partially designed in phase 2 and to be finalized and operated in phase 3)
- ESS Software (LESSAg for advanced prosumer) (prototype designed in phase 2 in a simulated environment and to be improved and tested in phase 3)

The UPB test site has been built as a first focus on the scenarios **HLUC-1-PUC–1 and 2**, where the Advanced Self Resilient Prosumer (ASRP) is working for performing storage related services (PUC-1) or to be seen as a load (consuming as much as possible from his RES energy production) and will not back-generate surplus energy (PUC-2). This is accomplished based on the optimal management of all components or actors implicated: ER, PV panels, DSO, batteries, DC loads, and AC loads. The energy management is implemented in such a way that the energy exchanged with the DSO will always be controlled over a specific time period. More details about HLUC-1 can be found in D2.2 [S4G-D2.2].

Figure 6 shows the planned architecture for phase 2. Legend for the annotations can be found in Table 7.

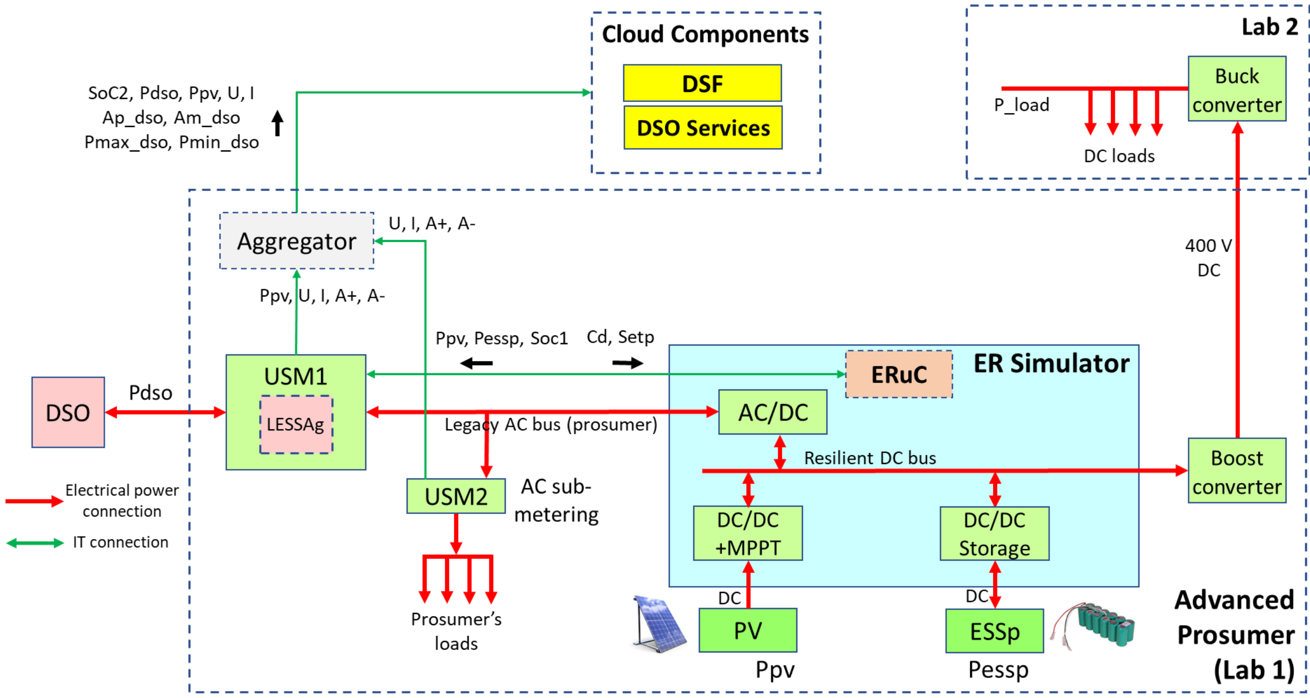

Figure 6. Planned architecture for phase 2 in the Bucharest test site.

Table 7. Legend of Figure 6 (Bucharest test site).

Name	Description
SoC	State of Charge of the Energy Storage System of prosumer (Energy Router)
Pdso	Power received from or injected to the DSO
Pmax_dso	Maximum power required/provided from/by the DSO sent from the cloud components
Pmin_dso	Minimum power required/provided from/by the DSO sent from the cloud components
Ppv	Power provided by the PV
Pessp	Power provided or absorbed by Energy Storage system of prosumer
Pessp_setp	The value of power provided Energy Storage System of prosumer decided to be sent to SMX by the cloud components
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the DSO/prosumer/ER
A-	Energy sent to the grid by DSO/prosumer/ER
Cd, Setp	Control Actions
ERuC	Energy Router's micro controller
USM2	Submeter for measurements on parameters of energy delivery to local (AC) loads

Figure 6 presents two layers (networks) corresponding to:

- Power (energy) flow
  - From the DC bus to the PV; the power is measured via Energy Router;
  - Between the DC bus and the available storage ESSp, the power is exchanged and measured via Energy Router; the power exchanged between the DC bus and storage unit ESSp will have positive values in battery charging mode and negative values in battery discharging mode.
  - Power exchanged by the prosumer with DSO is Pdso and is metered by USM. Active power exchanged between DSO and prosumer Pdso will have positive values when the prosumer is equivalent to a load and negative values if the power is injected in the grid.
  - On the prosumers' premises, there are other (AC, DC, neighbour) loads with active total power P_load or P_∑load. There is no individual meter associated with the DC connected loads ($P\_\sum load_{DC}$), however there is a sub-meter (USM2) to measure the AC legacy loads ($P\_\sum load_{AC}$). Information on the power delivered to these loads will be calculated from power balance:

$$P\_\sum load_{AC} + P\_\sum load_{DC} = Pdso - Pessp - Ppv.$$

- Information flow:
  - Measurements
    - Delivered by USM: Pdso, $P\_\sum load_{AC}$, Ppv, Pessg, Soc1, U (rms phase voltages delivered with a reporting rate TU), I (rms phase currents delivered with a reporting rate TI), A+, A-
    - Other: number of partial charging/discharging cycles of ESSp etc.
    - Calculated: SoC, $P_{\sum load}$ (DC), storage capacity.
  - Set points: SoC2, Pessp_setp, Op.mode.
  - Signals for control actions.

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the USM. The cloud component is the DSF-DWH. As data from the resilience prosumer is sent in the cloud, some data such as the voltage level can be considered as DSO service (DSO can improve grid observability by using the data sent to DSF). Possible grid restrictions will be simulated during all use-cases, as they are laboratory based and not real-grid situations. The data exchange will be based on LESSAg compatible flexible JSON supported by SMXcore application.

6.1 Overall test and evaluation framework: Bucharest test site

In the Bucharest test site, the overall test and evaluation framework specific methodology will be evaluated mainly using simulations for one data set (generation data collected for 15 minutes from the PV and partially for the loads).

Moreover, the overall test and evaluation framework defined in chapter 2 will be applied to the Bucharest test site, as described in the following subsections.

6.1.1 S4G components KPIs definition and evaluation procedure

For the development of the Bolzano test site, the conditions of the measurements and communications were tested and evaluated in phase 1. The details about these boundary conditions are reported in D6.1 [S4G-D6.1]. In phase 2, the KPIs and evaluation procedures for each S4G component is defined in chapter 0.
During phase 2, the performance assessment of the Bucharest test case will be executed using the specific boundary conditions as follows:

- Completeness of measurements: the quantities delivered by the USM (Pdso, Ppv, Pessg, U, I, A+, A-), both aggregated and individual (phase) values, time granularity for all measurements reporting rate being 5 to 10 seconds (1 or 2 seconds granularity may be also used at least on short time, for further analysis). Requirements for data synchronization: measurements with time stamp of minimum 1-minute resolution; requirements for control signals.
- Communication: Requirements for communication medium (wireless/ cable/) and interfaces (Wi-Fi, RS232, RS485, …), security (VPN), provider (public, LAN).

6.1.2 Use-case mapping for the corresponding business case

Table 8 shows the Bucharest test site use-cases assessment, according to the information available in D2.2 [S4G-D2.2].

Table 8. Use-case assessment of the Bucharest test site.

Use-Case	Business case	Actors	Available in phase 2?
HLUC-1-PUC-1-S1a/b: *Avoid curtailment with/without storage capacity*	HLUC-1-PUC-1-BM-1: *Handle over-generation from RES into the grid (avoid curtailment orders from DSO)*	DSO	✓
		AS/ASRP	✓
		Grid	✓
		ER	x
		USM	✓
HLUC-1-PUC-1-S2: *Serving peak demands on DSO level*	N/A	DSO	✓
		AS/ASRP	✓
		ER	x
		USM	✓
		Grid	✓
HLUC-1-PUC-1-S3: *Provide ancillary services (black-start)*	N/A	DSO	✓
		ASRP	✓
		ER	x
		USM	✓
		Micro grid	✓
HLUC-1-PUC-2: *Advanced self-resilient prosumer*	HLUC-1-PUC-2-BM-1: *Prosumer will act always as a consumer from the grid side*	ASRP	✓
		DSO	✓
		USM	✓
		ER	x
HLUC-1-PUC-3: *Resilient hybrid cooperative ecosystem*	HLUC-1-PUC-3-BM-1: *Enabling energy services to connected neighbourhood prosumers and consumers*	ASRP	✓
		Neighbour of ASRP	✓
		DC bus for neighbour connection	✓
		ER	x

6.1.3 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 8, it is not possible to evaluate any use-case during phase 2 due to development status of the S4G components. In this specific test site, the single-phase ER will only be available during phase 3 and it is a key actor in all Bucharest use-cases.

However, some KPIs related with the resilient prosumer will be evaluated during phase 2. The used KPI notation is KPIx.y, where x is the phase (1 or 2) and y is the KPI number. Each KPI type has a different number y, however, if a certain KPI is retested in another phase, it will have the same y, but with different x.
The first set of tests for the Bucharest use-case focused on the communication between components. The KPIs related to successful communication between components were the following:

- KPI1.1 - Smart Meter (USM) and the Smart Meter eXtension (SMX), at rates of 5 to 10 seconds (better time resolution may be tested on short periods)
- KPI1.2 - SMX and cloud applications: MQTT messages between SMX client and simulated remote MQTT client, with messages at rates of 5 to 10 seconds (lower or higher values up to one minute may be also tested on short periods)

These KPIs will be also evaluated in phase 2, according to new software components deployed in the SMX, which should not affect these characteristics. As being communication and performance tests, it is expected to be checked also in phase 3.

During phase 2, the KPIs are related to the HLUC-1 algorithms refinement and on final deployment, namely:

- KPI2.1 - number of AC labelled appliances with demonstrated full functionality when supplied with direct voltage (220 V +-10%) for T0=15 min; KPI2.1 ≥ 3;
- KPI2.2 - (active energy transferred from the prosumer to the DSO network averaged over T=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=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;
- KPI2.3 - RES-based generation curtailment degree KPI2.3; KPI2.3<20% from produced energy for an analysis window T1=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 T2=1day; 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;

The KPI2.2, 2.3 and 2.4 will be tested with a simulation tool developed in an PC-based environment. KPI values higher than previous listed will be possible, for specific situations which show cases when they are not possible due to different constraints or dimensioning (e.g. battery energy is chosen too low, consumption is too low, PV power is too high etc.). The simulation tool will have a specific section containing the LESSAg algorithms, which will be deployed and adapted in final phase on the SMX target, to work together with the energy router, which will be also available in the final stage.

Where it applies, the tools developed by UPB will be published as licensed, free and/or open software and will therefore be accessible for broad communities (both industrial, RTD and academia), using common licensing schemes, with preferred GPL licencing to be used. This enables the usage of the results for realizing commercial products, for teaching purposes and for further research activity.

6.1.4 Analysis of the evaluation results

This step will be reported in D6.11, evaluating the S4G components deployed in the Bucharest test case. Moreover, the HLUC-1 KPIs defined in the previous section will also be evaluated and reported.

7 Conclusions

The version 2 test site plans are developed according to the S4G vision and scenarios considered for the three main high-level use-cases. The components and associated requirements are set in correlation with findings reported in D2.2 [S4G-D2.2] and in D3.2 [S4G-D3.2]. The test sites planning considers simultaneously the energy flow, the real-time and context-based information (need of specific measurement quality with a maximum 5 s reporting rate) and the communication infrastructure (and requirements), thus bringing an overall picture of the entire system. In this context, real-time is defined based on the maximum reporting rate (seconds) of measurements used in the control system.

The complete description of the installations done during phase 2 in three the test sites will be reported is reported in D6.5 “Phase 2 Test Site Platforms and Deployments Report” [S4G-D6.5], while the results achieved will be reported in D6.11 “Phase 2 Evaluation Report” [S4G-D6.11]. This deliverable will be updated according to the findings during the project developments and will be finalized with the update in M32: D6.3 - “Phase 3 Test Site Plans”.

Acronyms

Acronym	Explanation
ANN	Artificial Neural Networks
AP	Advanced Prosumer
ASRP	Advanced self-resilient prosumer
BMS	Battery Management System
BTM	Behind The Meter
C_{CFD}	Daily Collection Credibility Factor
C_{CFM}	Monthly Collection Credibility Factor
CP	Charging Points
DER	Distributed Energy Resource
DSF	Decision Support Framework
DSO	Distribution System Operator
Eexch.bat	Energy exchanged by the batteries
EMS	Energy Management System
ER	Energy Router
ESCO	Energy Service Companies
ESS	Energy Storage System
ESSp	Energy Storage System of the prosumer
EV	Electric Vehicle
GUI	Graphical User Interface
HI	Hybrid Inverter
HLUC	High Level Use-Case
IT	Information Technology
KPI	Key Performance Indicator
K-SOM	Kohonen Self-Organizing Maps
LAN	Local Area Network
LV	Low Voltage
MEDAS	MEtering Data AnalysiS
MQTT	Message Queuing Telemetry Transport
PAC	Power of the AC loads
PCC	Point of Common Coupling

PDC	Power of the DC loads
POD	Point Of Delivery
PPV	PV power
PROFESS	Professional Realtime Optimization Framework for Energy Storage Systems
PROFEV	Professional Realtime Optimization Framework for Electric Vehicles
PROSIT	PROfiles SImilarity Tool
PUC	Primary Use-Case
PV	Photovoltaic
RES	Renewable Energy Sources
RMS	Root Mean Square
S	Scenario
SQL	Structured Query Language.
SMX	Smart Meter eXtensions
SoC	State of Charge
SoCmin	Minimum State of Charge
SoCmax	Maximum State of Charge
SUC	Secondary Use-Case
SUS	System Usability Scale
Ti	RMS phase currents reporting rate
Tu	RMS phase voltages reporting rate
UniRCon	Unidirectional resilient consumer
USM	Unbundled Smart Meter
VPN	Virtual Private Network
WB	Wall Box

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