D6.3 - Phase 3 Test Site Plans

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2019-08-26 (v0.24)	Otilia Werner-Kytölä (FRAUNHOFER FIT)	Approved: • Minor corrections • Comments and suggestions.
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2019-09-16 (v0.28)	Gustavo Aragon (FRAUNHOFER FIT)	Reviewed: • Comments on the KPIs.
2019-10-25 (v0.30)	Gustavo Aragon (FRAUNHOFER FIT)	Approved.

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Executive Summary

This deliverable describes the Phase 3 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 (e.g., PV, loads, storage, inverters, energy meters), and (ii) a combined information layer (e.g., real-time measurements, infrastructure descriptors, set-points, local restrictions) with data communication (including data secure transfer between the different S4G components).

This deliverable is the final version of the implementation plan, described in D6.1 [S4G-D6.1] and D6.2 [S4G-D6.2], and will be used for the phase 3 of the S4G project. This deliverable is also based on the outcomes of D3.3 [S4G-D3.3], which addresses the system architecture.

The main scope of this deliverable is to define the final evaluation framework and the appropriate Key Performance Indicators (KPIs) for the evaluation of each test site, based on the final state of implementation in phase 3. The phase 3 evaluation framework considers both technical and economic aspects of the use-cases (D2.2 [S4G-D2.2]) and business cases (D2.4 [S4G-D2.4]) defined in the project. The phase 3 KPIs are very important to evaluate the correct progress and the results of the S4G project towards its final objectives, with the complete and functioning test sites.

The overall test and evaluation framework composed of three steps is presented in this document, where the use-cases will be evaluated according to the described KPIs. The KPIs were defined for the HLUCs of the three test sites (Bucharest, Bolzano, Fur/Skive), and also for the S4G components and prototypes developed within the S4G project. The test and evaluation framework will be applied during the remaining duration of the project and the results document in D6.12, the phase 3 evaluation report.

1 Introduction

This deliverable summarizes the Phase 3 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] and D6.2 [S4G-D6.2].

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 D2.7 [S4G-D2.7]. The work in T6.1 also builds upon the architecture and components specifications developed in WP3 which had the latest results included in D3.3 [S4G-D3.3].

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] and D6.2 [S4G-D6.2]. For each High-Level Use-Case (HLUC), appropriate 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. 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

After a short introduction, section 2 details the overall test and evaluation framework. This framework was applied in three test sites of the project. Section 3 presents the list of components and prototypes developed in the S4G project and in which test site they are planned to be deployed, integrated, and evaluated during phase 3. The planned architecture of the three project test sites: Bucharest (section 4), Bolzano (section 5), and Fur/Skive (section 6) are presented. Section 2 describes the specific test and evaluation framework that will be applied to each test site. Lastly, the KPIs for each test site are identified using the business cases approach, described in D2.4 [S4G-D2.4], 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 the technical steps for the final evaluation of phase 3 demonstrators. This document is an update of D6.1 [S4G-D6.1] and D6.2 [S4G-D6.2]. No future updates of this deliverable are expected.

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

1.2 Related Documents

ID	Title	Reference	Version	Date
D2.2	Final Storage Scenarios and Use Cases	[S4G-D2.2]	1.0	2018-07-31
D2.4	Final S4G Business Models	[S4G-D2.4]	1.0	2019-08-06
D2.6	Updated Lessons Learned and Requirements Report	[S4G-D2.6]	1.0	2018-06-07
D3.3	Final S4G Component Interfaces and Architecture Specification	[S4G-D3.3]	1.0	2019-10-17
D4.3	Final User-side ESS control system	[S4G-D4.3]	1.0	2019-06-13
D4.5	Final Grid-side ESS control system	[S4G-D4.5]	1.0	2019-09-25
D4.7	Final Cooperative EV charging station control algorithms	[S4G-D4.7]	1.0	2019-09-03
D4.10	Final USM extensions for Storage Systems	[S4G-D4.10]	1.0	2019-10-17
D4.12	Final Energy Router	[S4G-D4.12]	1.0	2019-09-12
D5.2	Final DSF Hybrid Simulation Engine	[S4G-D5.2]	1.0	2019-09-25
D5.5	Final DSF Connectors for external systems and services	[S4G-D5.5]	1.0	2019-09-25
D5.7	Final DSF Predictive Models	[S4G-D5.7]	1.0	2019-09-25
D6.1	Phase 1 Test Site Plans	[S4G-D6.1]	1.0	2017-08-16
D6.2	Phase 2 Test Site Plans	[S4G-D6.2]	1.0	2018-11-28
D6.7	Initial Interfaces for Professional and Residential users	[S4G-D6.7]	1.0	2017-08-31
D6.9	Final Interfaces for Professional and Residential users	[S4G-D6.9]	1.0	2019-09-25
D6.10	Phase 1 Evaluation Report	[S4G-D6.10]	1.0	2018-05-02
D6.11	Phase 2 Evaluation Report	[S4G-D6.10]	1.0	2019-05-02

2 Overall test and evaluation framework

The overall test and evaluation framework planned to each S4G test sites is composed by the following steps:

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

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

2.1 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 [S4G-D2.3], initially focusing on simpler business cases with a shorter time perspective of realization. D2.3 [S4G-D2.3] has been updated in D2.4 [S4G-D2.4] reporting the final S4G Business Models.

The developed business cases build on knowledge gathered and reported in D2.2 [S4G-D2.2] 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, market perspective and regulation issues.

In order to evaluate the use-cases in each test site, it was identified the use-cases that will be evaluated in both technical and economic aspects, as being mapped to the corresponding business case.

2.2 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.

2.3 Analysis of evaluation results

The evaluation results in each test site will be analysed and compared with the expect KPIs. Evaluation will cover both technical and economic aspects, in order to demonstrate potential benefit for stakeholders in terms of cost efficiency and added-value information. Moreover, the evaluation framework documents the results and insights on lessons learned throughout the whole project.

D6.12 – "Phase 3 Evaluation Report" (M39) will include, depending on the HLUC of each test site, recommendation for future test site implementations, suggestions to changes in policies and regulations based on generated results, dedicated "views" on evaluation results and the most interesting business cases for different stakeholders including at least DSOs, energy service companies interested in investing in storage aggregation, storage solutions providers, prosumers and energy communities with storage resources.

2.4 Data collection

In phase 3, an important aspect for the test site evaluation continues to be also 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-D3.3]. 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 cumulated phase 2 and phase 3 periods.

S4G is a research project which requires for continuous development of different components, including the local SMX system, which was not envisaged to be developed up to 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 to use load data for the forecast of the local energy consumption (load).

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 datasets 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 dataset 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.

Data availability as a process of ensuring that data is available to end-users and applications relies on and depends on the following factors:

- Smart Metrology Meter (SMM) features, measurement capabilities and proper functionality.
- Local bidirectional communication between the measurement device (SMM) and the Smart Meter eXtension (SMX).

- Remote bidirectional communication between the applications that asks for data and the device that can deliver it (SMX).

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 for all meaningful ZMG/ZMD metering points deployed in the S4G test sites for the cumulated phase 2 and phase 3 period. The main KPI for this test is to have at least the previously described metering data collection (set). As an exception, the metering data collection for the ESS in the Bolzano Commercial test site, having a later deployment than all other metering points, will cover a set of data to be recorded during phase 3, proportional the same conditions and total number of functional months until the project finalisation.

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. The application evaluates data collection KPIs such as C_{CFD} and C_{CFW} based on daily files recorded in SMX and provides number of days and continuous weeks with successful data collection for a specific metering point.

MEDAS is able to compute hourly based load profiles of produced or consumed energy and average power, 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, MEDAS will generate the daily 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. Weekly profiles can be obtained from seven consecutive complete daily profiles. The output data format is based on a CSV format.

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 developed a daily energy profiles generator based on similarity. The application named PROfiles SImilarity Tool (PROSIT) uses the collection of existing real data generated as hourly based daily load profiles (24 records for a day) 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, by providing hourly based daily load profiles for days with missing data. The basic technology for the ANN based profiling is 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 test site HLUCs. Hardware-in-the-Loop (HIL) and other hybrid simulations will use specific data collection parts, in order to better evaluate different project use-cases.

3 Phase 3 S4G components and prototypes

This section presents the S4G components and prototypes under development during the S4G project. For more information regarding the S4G functional architecture, see D3.3 [S4G-D3.3].
Table 1 details where the final versions of the S4G protypes will be deployed and evaluated during the S4G project phase 3.

Table 1. Phase 3 S4G prototypes.

Phase 3 S4G prototype deliverables	Name	Bucharest (RO)	Bolzano (IT)	Fur/Skive (DK)
D4.3 [S4G-D4.3]	Final User-side ESS control system	✓	✓	✓
D4.5 [S4G-D4.5]	Final Grid-side ESS control system	-	✓	✓ (grid)
D4.7 [S4G-D4.7]	Final Cooperative EV charging station control algorithms	-	✓ (commercial)	-
D4.10 [S4G-D4.10]	Final USM Extensions for Storage Systems	✓	✓	✓
D4.12 [S4G-D4.12]	Final Energy Router	✓	-	-
D5.2 [S4G-D5.2]	Final DSF Hybrid Simulation Engine	✓	✓	✓
D5.5 [S4G-D5.5]	Final DSF Connectors for external systems and services	✓	✓	✓
D5.7 [S4G-D5.7]	Final DSF Predictive Models	✓	✓	✓
D6.9 [S4G-D6.9]	Final Interfaces for Professional and Residential Users	-	✓	✓

Moreover, Table 2 summarizes where the S4G components will be deployed, integrated, tested, and evaluated during the phase 3 of the project. The **Layer** column represents the architectural layer the component belongs to, i.e. communication, service, edge, device or physical layer.

The phase 3 S4G components and prototypes will have an overall testing during the individual HLUC evaluation on each test site. When performing the necessary steps to collect data and obtaining results for the HLUC, the S4G prototypes will be tested covering its software, developed interfaces and their integration.

Table 2. Phase 3 S4G components.

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
Control broker	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
Data broker	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
OGC Sensor Things	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
DSF DSO SCADA System connector	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	-

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
DSO EV connector	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	-
DSF-SE Hybrid Simulation Plug-in	Service	D5.5 [S4G-D5.5]	✓	-	-
Professional GUI	Service	D6.9 [S4G-D6.9]	-	✓	✓ (grid)
DSF-SE	Service	D5.2 [S4G-D5.2]	-	✓	✓ (grid)
DSF Predictive Models (Load)	Service	D5.5 [S4G-D5.5]	-	✓	-
DSF Predictive Models (ESS)	Service	D5.5 [S4G-D5.5]	✓	✓	✓
DSF Predictive Models (PV)	Service	D5.5 [S4G-D5.5]	✓	✓	✓
DSF Economic Engine (DSF-EE)	Service	D5.2 [S4G-D5.2]	-	✓	✓
DSF Electric Vehicle Analytics (DSF-EVA)	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	-
ESS Life-time estimation	Service	D5.5 [S4G-D5.5]	-	✓	✓ (grid)
GESSCon	Service	D4.5 [S4G-D4.5]	-	✓	✓
DSF-DWH	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Grid Models connector	Service	D5.5 [S4G-D5.5]	-	✓	✓
Energy price connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Weather forecast connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Geolocation connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Solar radiation connector for PROFESS or PROFEV	Edge	D5.5 [S4G-D5.5]	-	✓ (residential)	✓ (residential
Residential GUI	Edge	D6.9 [S4G-D6.9]	-	✓ (residential)	-
Residential GUI (back-end)	Edge	D6.9 [S4G-D6.9]	-	✓ (residential)	-

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
Aggregator broker	Edge	D5.5 [S4G-D5.5]	✓	✓	✓
OGC wrapper	Edge	D5.5 [S4G-D5.5]	✓	✓	✓
PROFESS	Edge	D4.3 [S4G-D4.3]	-	-	✓ (residential)
PROFEV	Edge	D4.7 [S4G-D4.7]	-	✓	-
SenML connector (PROFESS/PROFEV)	Edge	D4.3 [S4G-D4.3] D4.7 [S4G-D4.7]	-	✓	✓
Aggregator DWH	Edge	D5.5 [S4G-D5.5]	-	✓	✓
Technical GUI	Device	D4.10 [S4G-D4.10]	✓	✓	✓
Data Dispatcher	Device	D5.5 [S4G-D5.5]	✓	✓	✓
LESSAg	Device	D4.3 [S4G-D4.3]	✓	-	-
SMX broker	Device	D4.10 [S4G-D4.10]	✓	✓	✓
SMX core	Device	D4.10 [S4G-D4.10]	✓	✓	✓
ER SMX SB connector	Device	D4.10 [S4G-D4.10]	✓	-	✓ (residential)
Fronius SMX SB connector	Device	D4.10 [S4G-D4.10]	-	✓ (residential)	✓ (residential)
EV SMX SB connector	Device	D4.10 [S4G-D4.10]	-	✓	-
SMM	Physical	-	✓	✓	✓
Three-phase ER	Physical	D4.12 [S4G-D4.12]	-	-	✓ (residential)
EV charging point	Physical	-	-	✓	-
Hybrid Inverter (Fronius)	Physical	-	-	✓ (residential)	✓ (residential)
LiBal System	Physical	D4.5 [S4G-D4.5]	-	-	✓ (grid)

4 Bucharest Test Site: Advanced 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. This test site is deployed in a laboratory setting and features a home DC bus used by the local prosumer able also to interact with and support the DSO. The PCC energy exchange is monitored 24/7, with different time granularity, with a maximum reporting rate of 5-seconds (1-, 2- up to 10-seconds are also possible. Since the laboratory consumption differs from a real residential user profile, additional daily records of two residential users were used in the S4G project to have realistic residential user consumption data. One of the residential users lives is an apartment in the Romania's capital (Bucharest) with usual loads, e.g., lighting, refrigerator, washing machine, ironing machine, vacuum cleaner. The other user also lives in Bucharest, but in a house. The main difference from the consumption profile is that the first one is inhabited by one person, while the second by a family of three.

As the Bucharest test site distribution grid is over dimensioned and thus underused, it does not have the flexibility to be used for the Bucharest use-cases, a complementary HIL strategy will be used to evaluate the DSO grid impact of the use-cases. Moreover, to evaluate the Bucharest use-cases in a flexible way, a HIL system will be implemented using the ER together with scaled consumption records and with the possibility to scale all other inputs. The ER manages a real PV system, an ESS, and a neighbourhood DC bus.

An Advanced Prosumer (AP) being able to provide storage services for the grid or acting as a consumption entity are main features to be demonstrated. Additionally, it will also allow to enable new services in the future, e.g. for black-start inside a micro-grid setup working in island mode. The deployed equipment is the following: SMX, ER (deployed in phase 3), and data communication devices (e.g. local Wi-Fi router) which may even allow for future black-start support for isolated grids. A more detailed description of the Bucharest test site hardware components available in phase 3 is as follows:

- **USM:** SMX and SMM in the PCC for AC submetering.
- **ER:** a set of power converters with accessible and controllable DC bus.
- **PV system**: integrated in phase 3 using the ER.
- **ESS**: 17 Ah batteries integrated in phase 3 using the ER.
- **Laboratory DC bus with local loads**: directly connected to DC for ensuring local resilience , operational in the EB105 laboratory Lab 1 (Figure 1) in phase 3.
- **DC link**: a cable between ER DC bus and remote DC bus, operational in phase 3.
- **Neighbourhood DC bus**: supplying DC loads in Lab 2 (Figure 1), deployed and operational in phase 3.
- **DC/DC converters:** boost and buck converters (Figure 1) for mediating energy transfer towards neighbourhood loads, operational in phase 3.

The UPB test site has been built as a first focus on the scenarios where the Advanced Self-Resilient Prosumer (ASRP) is working for performing storage related services (HLUC-1-PUC–1) or to be seen as a load (consuming as much as possible from his Renewable Energy Source (RES) energy production) and will not back-generate surplus energy (HLUC-1-PUC–2). Moreover, HLUC-1-PUC-3 will be evaluated by showing the possibility to supply neighbourhood consumers in the second laboratory. This is accomplished based on the optimal management of all components or actors implicated, i.e. ER, PV panels, ESS, DSO, DC loads, and AC loads. The energy management is implemented in such a way that the energy exchanged with the grid will always be controlled over a specific time period. More details about HLUC-1 can be found in D2.2 [S4G-D2.2].

Figure 1 shows the planned architecture for phase 3. Legend for the annotations can be found in Table 3.

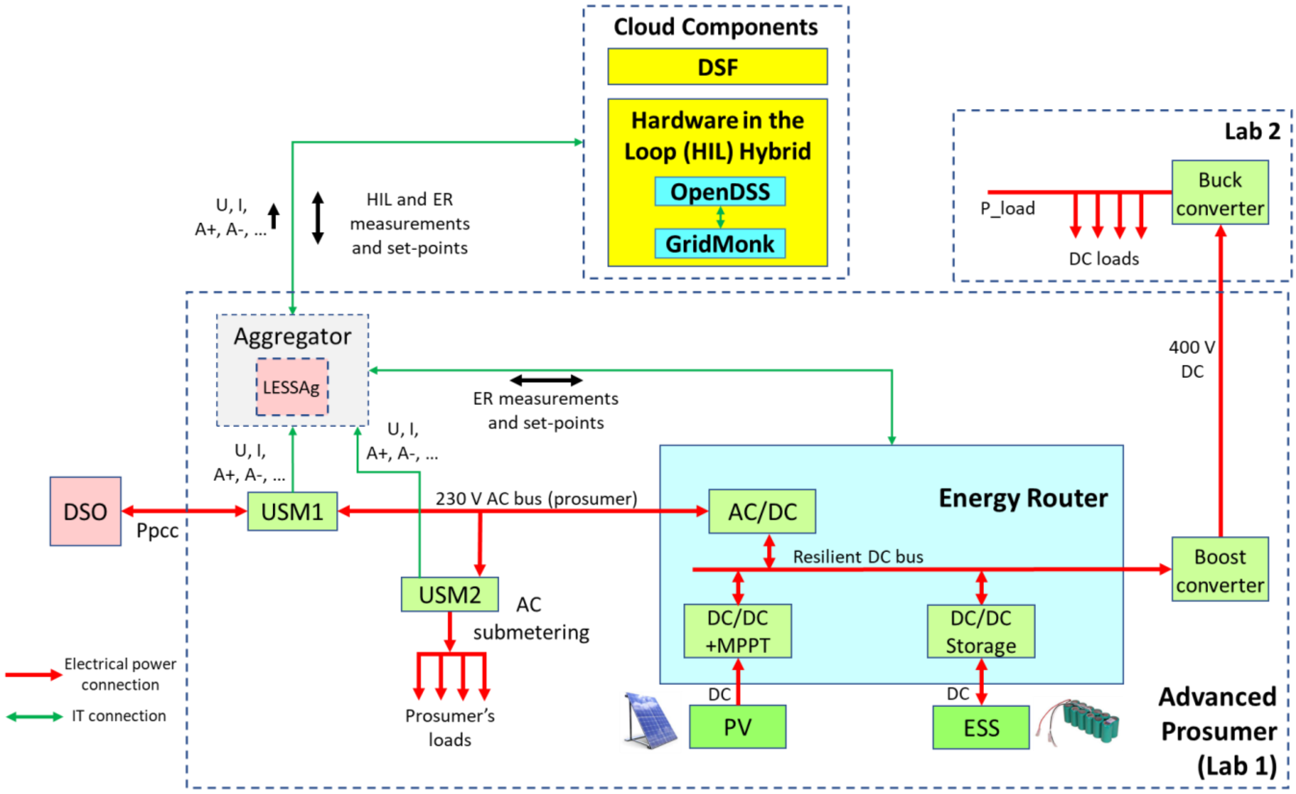

Figure 1. Planned architecture for phase 3 in the Bucharest test site.

Table 3. Legend of Figure 1 (Bucharest test site).

Name	Description
HIL measurements	Several measurements are provided to the HIL system, e.g. Ppcc, PV power, ESS power.
HIL set-points	The HIL system provides different set-points to the LESSAg, e.g. charging or discharging service status (P_{STOR}).
ER measurements	Several measurements are provided by the ER, e.g. ESS SoC, ESS power, PV power, ER power input/output. (Pgrid_er). The complete measurement list is available in D4.10 [S4G-D4.10].
ER set-points	The ER enables the definition of different set-points, e.g. ER power input/output, reactive power control, operation mode definition, ESS (dis)charging power. The complete set-points list is available in D4.10 [S4G-D4.10].
Ppcc	Active power received or injected to the DSO in the prosumer's PCC.
U	RMS phase voltages delivered with a reporting rate (Tu).
I	RMS phase currents delivered with a reporting rate (Ti).
A	Active energy consumed (A+) or produced (A-) by the prosumer.

Figure 1 presents two layers (networks) corresponding to:

- *Power (energy) flow:*
    - **DSO and the prosumer's 230 V AC bus:** power and energy consumed/produced (A+/A-) by the prosumer are measured by USM1.

    - 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 submeter (USM2) to measure the AC legacy loads ($P\_\sum load_{AC}$).
- *Information flow:*
    - Measurements
        - **Delivered by USM:** Ppcc, U (RMS phase voltages delivered with a reporting rate Tu), I (RMS phase currents delivered with a reporting rate Ti), A+ (energy consumed from the grid), A- (energy produced to the grid).
        - **Delivered by ER:** updated at the highest possible reporting rate, e.g. each 10 to 30 seconds.
    - Set-points to operate the ER.
    - Aggregator: receives and aggregates USM data and make it available for the LESSAg and cloud components.

LESSAg runs in the Aggregator. The cloud components are the DSF and the HIL. Possible grid restrictions will be simulated during all HLUC-1, as they are laboratory based and not real-grid situations. The data exchange is based on LESSAg compatible flexible JSON supported by SMXcore application.

The HIL Hybrid is composed of an open-source OpenDSS load-flow simulation tool and an UPB developed Grid Monitoring and Control Knowledge (GridMonK) application, able to connect ER and its components to a simulated DSO grid, in order to test use-cases in a flexible and realistic scenario. The two components will be used such that the grid is simulated by the OpenDSS software, using the AP exchanged power in the PCC as input for the power calculation. In order to perform HIL, measurements and set-points are exchanged between HIL hybrid and LESSAg. More details of the HIL hybrid used for Bucharest use-cases will be given in the D6.12 as part of the evaluation report.

4.1 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 which combine data sets for consumption and generation with data collected each 1-minute and scheduled storage with the ER's ESS. Selected tests will also use HIL simulating the impact of AP behaviour on a low voltage grid.

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

4.1.1 Use-case mapping for the corresponding business case

Table 4 shows the Bucharest test site use-cases assessment in phase 3, according to the information available in D2.2 [S4G-D2.2] and D2.4 [S4G-D2.4].

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

Use-case	Business case	Actors
HLUC-1-PUC-1-S1: *Avoid curtailment with/without storage capacity*	HLUC-1-PUC-1-BM-1:	DSO (person)
		AP/ASRP (person)
		Grid (system)

Use-case	Business case	Actors
	Handle over-generation from RES into the grid (avoid curtailment orders from DSO)	ER (system) USM (system)
HLUC-1-PUC-1-S2: *Serving peak demands on DSO level*	N/A	DSO (person) AP/ASRP (person) ER (system) USM (system) Grid (system)
HLUC-1-PUC-1-S3: *Provide ancillary services (black-start)*	N/A	DSO (person) ASRP (person) ER (system) USM (system) Micro grid (system)
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 (person) DSO (person) USM (system) ER (system)
HLUC-1-PUC-3: *Resilient hybrid cooperative ecosystem*	HLUC-1-PUC-3-BM-1: *Enabling energy services to connected neighbourhood prosumers and consumers*	ASRP (person) Neighbour of ASRP (person) DC bus for neighbour connection (system) ER (system)

4.1.2 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 4, all actors are available in phase 3, so it is possible to evaluate all the use-cases defined for the Bucharest test site, using the evaluation procedure defined in the following subsections.

4.1.2.1 HLUC-1-PUC-1-S1

HLUC-1-PUC-1-S1: "Avoid curtailment with/without storage capacity" related with the business case HLUC-1-PUC-1-BM-1: "Handle over-generation from RES into the grid (avoid curtailment orders from DSO)" will demonstrate that the AP prosumer is able to absorb additional power from PCC, if over-generation from RES is present in the grid. The use-case will be considered as a "storage service" (P_{STOR} order) to be provided to the grid.

The LESSAg is orchestrating resources in order to absorb additional power during a $T_{SERVICE}$ time frame (selected 15- or 60-minutes periods).

In order to make the tests, a complete HIL setup will be used, with LESSAg receiving a P_{STOR} order from HIL during $T_{SERVICE}$. The test is proving the advanced prosumer capability to do the service asked from any entity to need it and translated in a general P_{STOR} order during $T_{SERVICE}$.

HLUC-1-PUC-1-S1 will be evaluated by recording the power calculated in PCC during the P_{STOR} service versus the usual exchanged power. The LESSAg algorithm uses UniRCon strategy with a behaviour with the storage system having a reserve for the maximum used power when the service is offered, in order to be able to provide the service, while the power in PCC is amended by the P_{STOR} obligation. The basic UniRCon storage algorithm is described in D4.3 [S4G-D4.3].

The KPI to be tested is the change of average power in PCC during the P_{STOR} service, compared with the ordered service, thus resulting a deviation factor (deviation of executed service from the ordered service), which is considered to have a maximum percentage value (e.g. 10%) of the average power in PCC.

The evaluation of HLUC-1-PUC-1-BM-1: "Handle over-generation from RES into the grid (avoid curtailment orders from DSO) will cover also common economics aspects of this functionality – projected on different time horizons (e.g. for 2020, 2025 and 2030 for the costs of batteries, inverters and for the energy price), to demonstrate potential benefit for the advanced prosumer in terms of cost efficiency and added-value, by providing Storage as a Service (SaaS) to the grid, either for storing energy or for releasing it when the grid ask for such flexibility. The "break-even" time horizon for being commercially viable will be considered as specific business model KPI for the services covered by this business model.

4.1.2.2 HLUC-1-PUC-1-S2

HLUC-1-PUC-1-S2: "Serving peak demands on DSO level" will demonstrate that the AP is able to produce additional power for PCC, if over-consumption is present in the grid, in order to avoid grid congestions. The use-case will be considered as a "storage service" (P_{STOR} order) to be provided to the grid during peak hours (e.g. in the evening).

The LESSAg is orchestrating resources for producing additional power during a $T_{SERVICE}$ time frame (selected 15- or 60-minutes periods).
In order to make the tests, a complete HIL setup with LESSAg receives a P_{STOR} order from HIL during $T_{SERVICE}$. To be noticed that due to the fact that in this use-case there is an order for energy production, P_{STOR} demand is negative, according to the consumption convention (which states that consumption power is positive and generated power is negative).
HLUC-1-PUC-1-S2 will be evaluated by recording the power in PCC during the negative P_{STOR} service versus the usual exchanged power. The LESSAg algorithm is the modified UniRCon, where the storage system has a reserve towards the minimum used power when the service is offered, in order to be able to provide the service, while the power in PCC is amended by the negative value of P_{STOR} obligation.

The main KPI to be tested is the change of average power in PCC during the P_{STOR} service, compared with the ordered service, thus resulting a deviation factor (deviation of executed service from the ordered service) which is considered to be maximum percentage value (e.g. 10%) of the average power in PCC.

4.1.2.3 HLUC-1-PUC-1-S3

HLUC-1-PUC-1-S3: "Provide ancillary services (black-start)" will demonstrate that in case of grid failure the advanced prosumer is able to provide a certain power towards the islanded grid, while the islanded grid has a total load lower than the black-start power.

The test will be made by considering the grid load as having maximum a selected value between 100 W and 500 W.

HLUC-1-PUC-1-S3 will be evaluated by recording during a $T_{SERVICE}$ time frame (between 5- and 15-minutes period). the ER production towards the simulated grid, while the voltage level is kept in a band between ± 10% of the nominal voltage (U_N=230 V).

4.1.2.4 HLUC-1-PUC-2

HLUC-1-PUC-2: “Advanced self-resilient prosumer” related with the business case HLUC-1-PUC-2-BM-1: “Prosumer will act always as a consumer from the grid side” will demonstrate the UniRCon functionality, which demonstrates a prosumer setup where there is a very small power injection to the grid, such that the grid is not stressed by local production and can accommodate therefore additional distributed RES production.

HLUC-1-PUC-2 will be evaluated using KPI2.2 to 2.4, already introduced in D6.2 [S4G-D6.2] and presented in Table 5. In phase 3 these tests are performed using a combination of scaled real and simulated data, using also the storage resource in ER and a simulated grid through HIL technology. In the final phase, KPI2.2 relates the active energy transferred from the prosumer to the grid averaged over T period (one hour or more) to nominal load of the prosumer (contractual power).

KPI2.2 (presented in Table 5) will be tested for different simulation scenarios. It is intended to obtain situations with KPI2.2 < 10% of the contractual power considered for consumer, for an analysis on selected T time windows during a day, demonstration through refined simulation and UniRCon algorithm. Simulations will be based on real and rescaled daily data records from selected project metering points and on selected prosumer’s resource dimensioning.

KPI2.3 (presented in Table 5) is looking for RES-based generation curtailment degree. This KPI should have values lower than 20% from produced energy for an analysis on selected time windows during a day. Demonstration will be made through refined simulation and UniRCon algorithm, based on real and rescaled daily data records from selected project metering points.

KPI2.4 (presented in Table 5) 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. A value below 70% is expected for the analysis window during a day.

Different combinations of consumption and production evolution will be considered during the tests. The evaluation of KPI2.2 to 2.4 will be performed using HIL technology. The KPIs will be presented in each of these cases, with additional comments and interpretations on special status.

A KPI for showing the Advanced Self-Resilient Prosumer (ASRP) self-resilient behaviour during DSO interruptions will be also calculated. This KPI2.5 will show resilience behaviour on the DC bus during an AC outage, as capability to keep a certain load (e.g. 100 W) supplied on the DC bus, for a period of time, e.g., 30- to 60-minutes. The KPI will be the successful result during the test of keeping the DC connected load the chosen period at a voltage level within a ± 10% of the nominal DC voltage of the ER.

The evaluation of HLUC-1-PUC-2-BM-1: “Prosumer will act always as a consumer from the grid side” will cover also economic aspects of this functionality – projected on different time horizons (e.g. for 2020, 2025 and 2030 for the costs of PVs, batteries, inverters and for the energy price), to demonstrate potential benefit for the advanced prosumer acting always as a consumer from the grid side. The “break-even” time horizon for being commercially viable will be considered as specific business model KPI for the advanced prosumer acting always as a consumer from the grid side.

4.1.2.5 HLUC-1-PUC-3

HLUC-1-PUC-3: "Resilient hybrid cooperative ecosystem" related with the business case HLUC-1-PUC-3-BM-1: "Enabling energy services to connected neighbourhood prosumers and consumers" will demonstrate the technical solution and its economics.

HLUC-1-PUC-3 will be evaluated by showing the possibility to supply consumers in the second laboratory through the 400 V DC line. The supplied consumers will be tested on selected time periods (e.g. 15-minutes schedules) and the power absorbed through the 400 V DC bus will be up to 500 W.

The evaluation will consider measurements on the 400 V DC bus which show consumption in laboratory 2 up to 500 W during an interval of 15-minutes timeframe.
The KPI will be calculated as voltage level on the 400 V DC connection which should remain, during 95% of the period, in the ± 10% of the 400 V (using 2- to 5-seconds measurements), using thus a statistical level similar with the one used in AC networks.

The evaluation of HLUC-1-PUC-3-BM-1: "Enabling energy services to connected neighbourhood prosumers and consumers" will cover also common economics aspects of this functionality – projected on different time horizons (e.g., for 2020, 2025 and 2030 for the costs of batteries, inverters and for the energy price), to demonstrate potential benefits of the energy exchange within the cooperative ecosystem. The "break-even" time horizon for being commercially viable will be considered as specific business model KPI for the services covered by this business model.

4.1.3 Analysis of the evaluation results

This evaluation step will be reported in D6.12, evaluating the use-cases HLUC-1-PUC-1-S1, HLUC-1-PUC-1-S2, HLUC-1-PUC-1-S3, HLUC-1-PUC-2, and HLUC-1-PUC-3 according to the evaluation procedures described in the previous section and summarized in Table 5.

Table 5. Phase 3 KPIs of the HLUC-1.

Case	KPIs
HLUC-1-PUC-1-S1: *Avoid curtailment with/without storage capacity*	Considering: • $T_{SERVICE}$ =15 min, 60 min • $P_{STOR} > 0$ The average power in the PCC during $T_{SERVICE}$ must be $P_{PCC} = P_{PCC\_NO\_STOR} + P_{STOR} \pm 10\% \, P_{PCC\_NOM}$ This evaluation will use HIL technology.
HLUC-1-PUC-1-BM-1: *Handle over-generation from RES into the grid (avoid curtailment orders from DSO)*	Economic aspects of this functionality will be analysed in different time horizons, to show the "break-even" moments for being commercially viable.

Case	KPIs
HLUC-1-PUC-1-S2: *Serving peak demands on DSO level*	Considering: • $T_{SERVICE}$ =15 min, 60 min • $P_{STOR} < 0$ The average power in the PCC during $T_{SERVICE}$ must be $P_{PCC} = P_{PCC\_NO\_STOR} + P_{STOR} \pm 10\%\ P_{PCC\_NOM}$ This evaluation will use HIL technology.
HLUC-1-PUC-1-S3: *Provide ancillary services (black-start)*	Considering: • 5 min ≤ $T_{SERVICE}$ ≤ 15 min • 100 W ≤ $P_{GridLoad}$ ≤ 500 W The nominal voltage in the PCC during $T_{SERVICE}$ must be $U_{PCC} = 230\ V \pm 10\%$ The black-start evaluation will use a simulated grid with $P_{GridLoad}$
HLUC-1-PUC-2: *Advanced self-resilient prosumer*	Considering: • T = 1 hour, 1 day • $P_{DCLoad} \approx 100$ W • 30 min < T_{ASRP} < 60 min KPI2.2 to 2.4 will be evaluated during T using HIL technology $KPI2.2 = K_{USER\_E\_BACK} = \frac{E_{PCC-}}{E_{CONS}} < 10\%$ $KPI2.3 = K_{PV\_LIM} = \frac{E_{PV\_LIM}}{E_{PV\_METEO}} < 20\%$ $KPI2.4 = K_{USER\_E\_DSO} = \frac{E_{PCC+}}{E_{CONS}} < 70\%$ Regarding KPI2.5, a resiliency service during T_{ASRP}, using P_{DCLoad} connected to the ER DC bus, its DC bus voltage must be $V_{DCBus\_ER} = 220\ V \pm 10\%$
HLUC-1-PUC-2-BM-1: *Prosumer will act always as a consumer from the grid side*	Economic aspects of this functionality will be analysed in different time horizons, to show the "break-even" moments for being commercially viable.
HLUC-1-PUC-3: *Resilient hybrid cooperative ecosystem*	Considering: • T = 15 min • $P_{Lab2Load}$ ≤ 500 W While feeding the $P_{Lab2Load}$ during 95% of T, the 400 V DC bus voltage must be $V_{DCBus} = 400\ V \pm 10\%$
HLUC-1-PUC-3-BM-1: *Enabling energy services to connected neighbourhood prosumers and consumers*	Economic aspects of this functionality will be analysed in different time horizons, to show the "break-even" moments for being commercially viable.

The analysis of HLUC-PUC-1-S1, HLUC-PUC-1-S2 and of HLUC- PUC2 will cover also economic aspects of this functionality – projected on the chosen time horizons in order to show "break-even" time for being commercially viable, thus giving our contribution guidelines related to pathways towards carbon-neutral energy domain, according to EC latest policies related to climate change challenges. The time horizon for being commercially viable will be considered as specific business model KPI for the services covered by HLUC-1-PUC-1, HLUC-1-PUC-2 and HLUC-1-PUC-3.

Additionally, the analysis will provide considerations regarding the approach of “microgrids by design” which uses inverter-only generation and solid-state transformer with associated storage, as a connection solution between the medium voltage main grid and the resilient microgrid. The analysis will be based on simulations. The architecture of this microgrid resilient solution, studied as possible future developments on low voltage grids, are described in D3.3 [S4G-D3.3], describing the S4G architecture. This will be an additional low TRL contribution for the S4G project, associated with the Bucharest HLUCs.

5 Bolzano Test Site: 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 – Südtirol, 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.

5.1 Residential case

For the **residential case** Edyna, 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 is used as test site. 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 PV plant, at the ESS, at the EV charger and the fourth for the other loads of the house. The smart meters used here are three-phase ZMG310 meter from 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 in the house to receive data measurements 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 3 the S4G prototypes and components listed in Table 1 and Table 2 respectively, will be deployed as shown in Figure 2. Legend for the annotations can be found in Table 6.

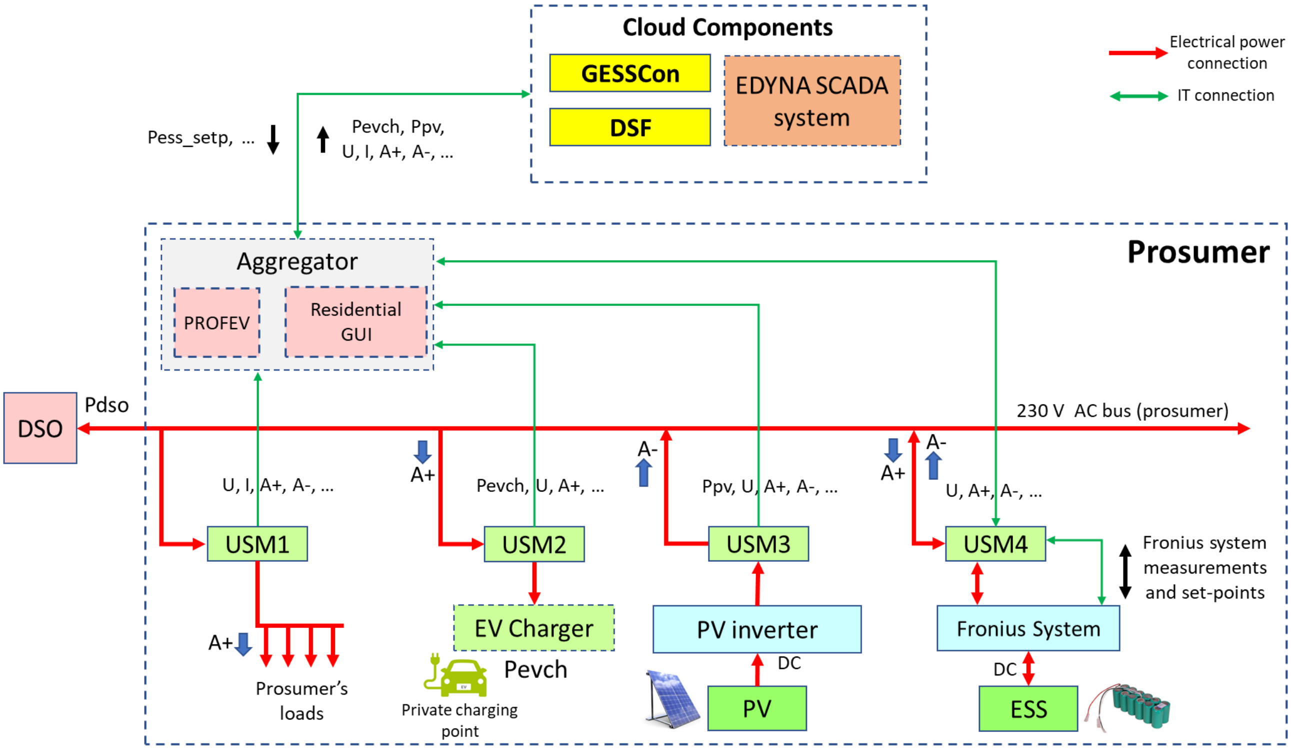

Figure 2. Planned architecture for phase 3 in the Bolzano Residential test site.

Table 6. Legend of Figure 2 (Bolzano Residential test site).

Name	Description
Fronius system measurements	Several measurements are provided by the Fronius system, e.g., ESS SoC, ESS power, PV power, inverter power input/output. The complete measurement list is available in D4.10 [S4G-D4.10].
Fronius system set-points	The Fronius system enables the definition of different set-points, e.g., Fronius power input/output, reactive power control, connection or disconnection from grid. The complete set-points list is available in D4.10 [S4G-D4.10].
Pdso	Active power received or injected to the DSO.
Ppv	Active power provided by the PV.
Pevch	Active power consumed by the EV charging point through the Wall Box (WB).
Pess_setp	The power schedule provided by the GESSCon to the PROFEV, to operate the prosumer's ESS (consumption or generation).
U	RMS phase voltages delivered with a reporting rate (Tu).
I	RMS phase currents delivered with a reporting rate (Ti).
A	Active energy consumed (A+) or produced (A-) by the prosumer.

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

- *Power / energy flow (lines depicted in red colour), related to the power network:*
    - **Prosumer's 230 V AC bus and the prosumer's loads:** power and energy consumed by the prosumer's load are measured by USM1. The real-time measurements are available with a reporting rate Tu = 2 .. 10 seconds.
    - **Prosumer's 230 V AC bus and the EV charging point:** the real-time active power Pevch and active energy A+ are measured with an individual USM2. The real-time measurements are available with a reporting rate Tu = 2 .. 10 seconds.
    - **PV to the prosumer's 230 V AC bus:** the real-time active power Ppv as well as the active energy A+ are measured by USM3. The real-time measurements are available with a reporting rate Tu = 2 .. 10 seconds.
    - **Prosumer's 230 V AC bus and the prosumer's ESS:** the active energy A+ and A- are measured by USM4 in real-time, with a reporting Tu = 2 .. 10 seconds. The Fronius measurements are available in the USM4, and are forwarded to Aggregator and then to the DSF.
    - The energy and power exchanged between the prosumer and the DSO is not measured by any USM. These values will be calculated from power balance Pdso =Pess+Pevch+Ppv+P_Σload.
- *Information flow (lines depicted in green colour), related to the information network:*
    - Measurements from local devices:
        - **Delivered by USM:** P_Σload , Pevch, Ppv, U (RMS phase voltages delivered with a reporting rate Tu), I (RMS phase currents delivered with a reporting rate Ti), A+ (energy consumed from the grid), A- (energy produced to the grid).
        - **Delivered by Fronius system:** updated at the highest possible reporting rate, e.g., each 2 to 10 seconds.
    - Set-points:
        - From the cloud applications: Pess_setp.
        - To operate the Fronius system.
    - Set-points from the cloud applications: Pess_setp.
    - Aggregator: receives and aggregates USM data and make it available for the residential GUI, PROFEV, 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 ICT information exchanged between the different parts (physical media for information transmission will be decided in the next stage).

PROFEV is an optimization tool running in the Aggregator. The cloud components are Grid ESS Control (GESSCon), Decision Support Framework (DSF), and the EDYNA SCADA system. The EDYNA SCADA system was not developed within the project, but is used to retrieve real-time information regarding substation measurements. A detailed description of information exchange and software modules is available on D3.3 [S4G-D3.3].

5.2 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 parking site, there are 2 PV plants: one of 50 kW and the other of 99 kW. The first plant is directly connected in the Edyna low voltage grid (only production), the second PV is connected with Edyna warehouse loads (production + load). For the energy parameters measurements in all these points (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 3 dummy EV chargers, 1 for the 99 kW PV, 1 for the 50 kW PV, 1 for the Edyna warehouse Point of Common Coupling (PCC) (including the 99 kW PV) and 1 for the ASM PCC (total of the EV charger + ESS), as show in Figure 3. Legend for the annotations can be found in Table 7.

During phase 3 the test site will be completed with the installation of an ESS in the ASM grid. The ESS has a power of 30 kW in charge and discharge, with an energy capacity of 80 kWh. It is purchased by LiBal, and the connection with the AC grid is performed by a 33 kW inverter of Socomec. For the measurements of the energy parameters in the ESS another USM11 will be installed. Due to the expected increase of EVs in Edyna fleet, ASM is installing more EV chargers. They will be not monitored by a dedicated USM, but their measurements are available in USM installed at ASM PCC.

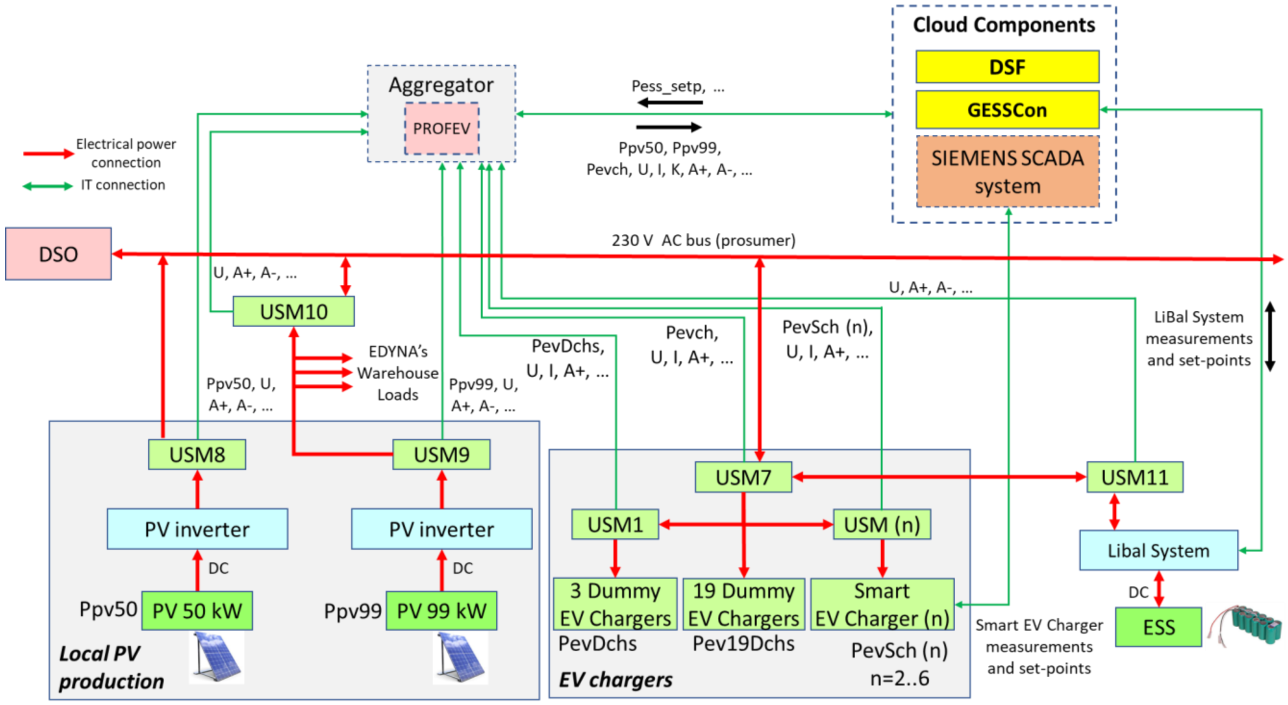

Figure 3. Planned architecture for phase 3 in the Bolzano Commercial test site.

Table 7. Legend of Figure 3 (Bolzano Commercial test site).

Name	Description
LiBal System measurements	The LiBal System provides ESS SoC to the Cloud Components.
LiBal System set-points	The LiBal System is able to receive the ESS active power set-point.
Smart EV Charger measurements	Several measurements are provided by the Smart EV charger system for each Charger Unit (CU) active plug, e.g., active power, energy, current, voltage. The complete measurement list is available in D4.10 [S4G-D4.10].

Name	Description
Smart EV Charger set-points	The Smart EV charger enables the definition of different set-points on the CU plugs, e.g., active power, energy, current. The complete set-points list is available in D4.10 [S4G-D4.10].
Pess_setp	The power schedule provided by the GESSCon to the PROFEV, for prosumer's ESS operation (consumption or generation).
Pdso	Active power received or injected to the DSO.
Ppv50	Power provided by the 50 kW PV.
Ppv90	Power provided by the 99 kW PV.
PevDchs	Power consumed by 3 Dummy EV CP.
PevSch	Power consumed by the Smart EV CP.
Pev19Dchs	Power consumed by 19 Dummy EV CP.
Pevch	Active power consumed by all EV CP (PevSch(n) + PevDch + Pev19Dchs).
U	RMS phase voltages delivered with a reporting rate (Tu).
I	RMS phase currents delivered with a reporting rate (Ti).
A	Active energy consumed (A+) or produced (A-) by the prosumer.

In Figure 3 are represented two layers corresponding to:

- *Power / energy flow*
  - **Prosumer's 230 V AC bus and all CP:** Pevch is measured by USM7. The real-time measurements are available with a reporting rate Tu = 2 .. 10 seconds.
    - PevDchs: The dummy EV chargers' power is measured by USM1.
    - PevSch(n): The smart EV chargers' power is measured by USM2 … USM6..
    - Pev19ch: The 19 EV chargers' power is not measured by a single USM, but it can be obtained in USM7, using Pev19Dchs = Pevch - PevDchs - PevSch(n).
  - **From the PV:** The PV power and energy are measured with individual USM8 (Ppv50) and by USM9 (Ppv99).
  - **Prosumer's 230 V AC bus and the prosumer's ESS:** the active energy A+ and A- are measured by USM11 in real-time, with a reporting Tu = 2 .. 10 seconds.
- *Information flow:*
  - **Delivered by USM**: Ppv50, Ppv99, PevDchs, PevSch(n), Pevch, U (RMS phase voltages delivered with a reporting rate Tu), I (RMS phase currents delivered with a reporting rate Ti), A+ (energy consumed from the grid), A- (energy produced to the grid).
  - **Delivered by the LiBal System:** updated at the highest possible reporting rate, e.g., each 10 seconds.
  - **Delivered by the Smart EV Chargers:** updated at the highest possible reporting rate, e.g., each 60 seconds.
  - Set-points:
    - From the cloud applications: Pess_setp.
    - To operate the LiBal System.
    - To operate the EV Chargers.
  - Aggregator: receives and aggregates USM data and make it available for the residential GUI, PROFEV, and cloud components.

PROFEV is an optimization tool running in the Aggregator. The cloud components are the GESSCon, DSF, and the SIEMENS SCADA system. The SIEMENS SCADA system was not developed within the project, but is used to retrieve real-time information regarding EV CP measurements, enabling also their control. A detailed description of information exchange and software modules is available on D3.3 [S4G-D3.3].

5.3 Overall test and evaluation framework: Bolzano test site

In phase 3, Alperia and Edyna will continue the implementation of the 2 test sites (residential and commercial) with the realization of the following steps:

- 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 section 2 will be applied to the Bolzano test site, as described in the following subsections.

5.3.1 Use-case mapping for the corresponding business case

Table 8 shows the Bolzano test site use-cases assessment in phase 3, according to the information available in D2.2 [S4G-D2.2] and D2.4 [S4G-D2.4].

Table 8. Use-cases assessment of the Bolzano test site.

Use-case	Business case	Actors
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 (person)
		ESS (only controllable system)
		PROFEV (system)
		DSF-DWH (system)
		Residential GUI (system)
		GESSCon (system)
		EV (system)
HLUC-2-PUC-2: *Cooperative charging in the parking lot of a commercial test site*	HLUC-2-PUC-2-BM-1: *Cooperative Charging at Commercial or Fleet level*	Garage owner (person)
		DSO (person)
		PROFEV (system)
		USM (system)
		DSF-DWH (system)
		GESSCon (system)
HLUC-2-PUC-3: *Simulation of high penetration of EV*	N/A	Professional GUI (system)
		DSF-SE (system)

Use-case	Business case	Actors
chargers and of prosumers with storage and residential EV charging		DSF-GridDB (system)
		PROFEV (system)
		Grid planner (person)

5.3.2 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 8, all actors are available in phase 3, so it is possible to evaluate all the use-cases defined for the Bolzano test site, using the evaluation procedure defined in the following subsections.

5.3.2.1 HLUC-2-PUC-1

HLUC-2-PUC-1: "Residential prosumer with storage and EV" related with the business cases HLUC-2-PUC-1-BM-1: "Prosumer with ESS "stand-alone" (baseline)" and HLUC-2-PUC-1-BM-2 "Prosumer with grid integration". HLUC-2-PUC-1 will demonstrate the possibility to decrease the exchange of power between the prosumer and the DSO (HLUC-2-PUC-1-BM-1) and the possibility for the DSO to exploit an ESS

HLUC-2-PUC-1 will be evaluated by monitoring the power exchange between the prosumer and the DSO grid. At the moment, the house owner has an electric contract for 10 kW, both consuming and feeding in. If he can optimize the self-consumption, he could decrease the contracted power, saving money.
In cases where the ESS is discharged, no sun is shining and loads are high, the prosumer obtains up to 8-10 kW of electrical power from the grid. On the other hand, the prosumer produces up to 7-9 kW surplus (PV plant) in the afternoon with high solar radiation and full charged ESS.

The goal of this HLUC is the coordination of EV charging with the PV production and the consumption is in such a way that the maximum power at Point Of Distribution (POD) is within the contractual limit (10 kW), not needing an upgrade or needing a smaller upgrade than without storage and coordination. To verify the achievement of this goal, the power exchanged with the grid will be monitored for three months.

HLUC-2-PUC-1-BM-1 is the baseline for other business models concerning the residential prosumer in the Italian context and in the Bolzano test site, and it will evaluate if it is profitable for a residential prosumer with an EV charging station to invest money in a residential ESS.

HLUC-2-PUC-1-BM-2 will evaluate the prosumers possibility of making business by providing ancillary services to the DSO by installing batteries in addition to the benefits obtained by the HLUC-2-PUC-1-BM-1. This way, the prosumer can offer a sustainable solution to the DSO, whereby the prosumer gets as much out of his investment and increase his private business case and the DSO avoids or postpones grid strengthening.

5.3.2.2 HLUC-2-PUC-2

HLUC-2-PUC-2: "Cooperative charging in the parking lot of a commercial test site" related with the business case HLUC-2-PUC-2-BM-1: "Cooperative Charging at Commercial or Fleet level" will demonstrate the possibility to increase the self-consumption and to decrease power consumption from the grid.

HLUC-2-PUC-2 will be evaluated with the monitoring of the total energy consumed from the grid. At this moment, ASM has a 90 kW contract, due to a 90 kW consumption in the evening, when all the EVs are charging in the garage. The PV plants power (50 kW + 99 kW) should be enough to cover the needs of the EV chargers, with the help of a 30 kW (80 kWh) ESS.

The goal of this HLUC is that the grid is not stressed in terms of voltage band violation (basic power quality is kept) due to storage and EV charging coordination. To verify the achievement of this goal the voltage at PCC will be monitored for three months. Currently, there are 22 EVs.

The Return of Investment (ROI) time will be evaluated. The money saved with the use of the storage will be compared with the cost of the installation of the ESS. The ROI time needs to be less than 20 years to accomplish the HLUC-PUC-2-BM-1 KPI.

5.3.2.3 HLUC-2-PUC-3

HLUC-2-PUC-3: "Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging" will calculate the maximum value of EV chargers that can be installed in the Edyna grid without the grid strengthening need. It will be done evaluating the difference between using or not ESS.

HLUC-2-PUC-3 will be evaluated comparing the result obtained with or without the use of ESS. The findings will be compared, and a feasibility study will be carried out to determine whether the additional storage represents an economic solution for the DSO. The results will be given by the Professional GUI together with the DSF-SE, and they will also be verified by the OpenDSS software.

5.3.3 Analysis of the evaluation results

This evaluation step will be reported in D6.12, evaluating the use-cases HLUC-2-PUC-1, HLUC-2-PUC-2, and HLUC-2-PUC-3 according to the evaluation procedures described in the previous section and summarized in Table 9.

Table 9. Phase 3 KPIs of the HLUC-2.

Use-case	KPIs
HLUC-2-PUC-1: *Residential prosumer with storage and EV*	The maximum power consumed from the grid (P_{DSO}) will be monitored for 3 months and it must be $P_{DSO\_consumed\_S4G} \leq P_{DSO\_consumed\_noS4G}$, *and* $P_{DSO\_consumed\_S4G} \leq 10$ *kW (contractual limit)*
HLUC-2-PUC-1-BM-1: *Prosumer with ESS "stand-alone" (baseline)*	Baseline. Analyse if it is profitable for a residential prosumer with an EV charging station to invest money in a residential ESS.
HLUC-2-PUC-1-BM-2: *Prosumer with grid integration*	Analyse the possibility for prosumers to make business by providing ancillary services to DSO by installing batteries in addition to the benefits obtained by the HLUC-2-PUC-1-BM-1.
HLUC-2-PUC-2: *Cooperative charging in the parking lot of a commercial test site*	The three phases voltages will be monitored for 3 months and it must be $V_{PCC} = 230\ V \pm 10\%$ *(EN 50160 standard)*
HLUC-2-PUC-2-BM-1: *Cooperative Charging at Commercial or Fleet level*	Analyse if it is profitable for a commercial site (or a Company Fleet site) with some EV charging stations to invest money in an ESS with or without a PV plant. The ROI time should be less than 20 years.

Use-case	KPIs
	Moreover, the Professional GUI System Usability Scale (SUS) should be classified as "good" and the DSF-SE results should be equal to the OpenDSS results.
HLUC-2-PUC-3: *Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging*	Analyse if it is profitable for a commercial site (or a Company Fleet site) with some EV charging stations to invest money in an ESS with or without a PV plant. The ROI time should be less than 20 years. Moreover, the Professional GUI System Usability Scale (SUS) should be classified as "good".

6 Fur/Skive Test Site: 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 Spøttrup Kulturhal at Skive Municipality, led by partner LiBal. The Island of Fur is placed in a fjord at Skive Municipality in the Northern Denmark.

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). The installed batteries are Solar Batteries lithium-ion 4.5 kWh from Fronius.

The new grid case test site is the Spøttrup Kulturhal, a combined sport and cultural arena, which has taken a lot of energy savings actions. The arena is heated up with ground heating and has a large PV plant at the roof. Spøttrup Kulturhal has activities during the entire day, with the majority in the late afternoon and evening.
This test site will be equipped with **one grid-side battery** near by a transformer station in Spøttrup Kulturhal, where this sport arena has a huge PV system size 75 kWp. The grid-side 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, updated and are fully documented in D2.2 [S4G-D2.2].. During phase 2, the communication issues with the SMX were solved. In phase 2, a stable SMX communication was accomplished and therefore, the remaining Fur houses have been equipped with the USM and data collection and communication are running smoothly. It will be investigated whether it is feasible to install batteries at household level, and if local storage can decrease voltage levels and compare the business case with ordinary grid strengthening costs (baseline).

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 flux control at grid side storage", it will be investigated whether it is feasible to install batteries at substation level, how to control the storage and compare the business case with ordinary grid strengthening costs (baseline).

6.1 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 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 and the local storage placement 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 SolarWeb[i] commercial software, 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 2 the DSO has made contracts with the five house owners regarding:

- Installation of the USM (with two components: smart meter and associated SMX).
- Getting access to the local existing Battery Management System (BMS).
- 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 4 shows the planned architecture for phase 3. Legend for the annotations can be found in Table 10.

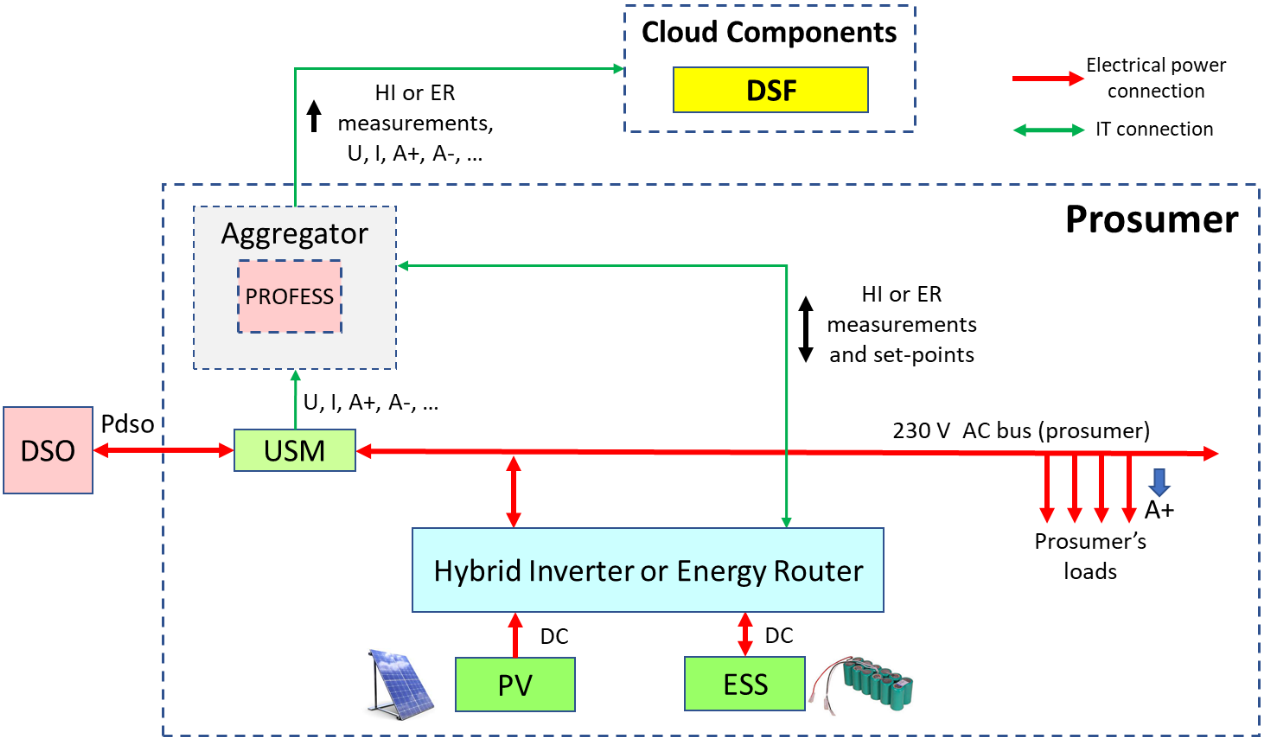

Figure 4. Planned architecture for phase 3 in the Fur/Skive Local test site.

Table 10. Legend of Figure 4 (Fur/Skive Local test site).

Name	Description
HI or ER measurements	Several measurements are provided by the HI or the ER, e.g., ESS SoC, ESS power, PV power, inverter power input/output. The complete measurement list is available in D4.10 [S4G-D4.10].
HI or ER set-points	The HI or the ER enables the definition of different set-points, e.g., Fronius power input/output, reactive power control, connection or disconnection from grid. The complete set-points list is available in D4.10 [S4G-D4.10].

Name	Description
Pdso	Active power received or injected to the DSO.
U	RMS phase voltages delivered with a reporting rate (Tu).
I	RMS phase currents delivered with a reporting rate (Ti).
A	Active energy consumed (A+) or produced (A-) by the prosumer.

Figure 4 has two layers corresponding to:

- *Power (energy) flow:*
  - **DSO and the prosumer's 230 V AC bus:** power and energy consumed/produced (A+/A-) by the prosumer are measured by USM.
  - **Hybrid and the prosumer's 230 V AC bus:** The power produced/consumed by the Hybrid Inverter are directly provided by the Fronius system or the ER.
  - On the prosumers premises there are also AC loads with active cumulated power P_load, which is not measured by any USM. Information on the active power delivered to these loads will be calculated from power balance P_load = Pdso – P_inverter.
- *Information flow:*
  - Measurements
    - **Delivered by USM:** P_Σload , Pevch, Ppv, U (RMS phase voltages delivered with a reporting rate Tu), I (RMS phase currents delivered with a reporting rate Ti), A+ (energy consumed from the grid), A- (energy produced to the grid).
    - **Delivered by the HI or ER:** updated at the highest possible reporting rate, e.g., each 2 to 10 seconds.
  - Set-points to operate the HI or the ER.
  - Aggregator: receives and aggregates USM data and make it available for the PROFESS and cloud components.

PROFESS is an optimization tool running in the Aggregator. The cloud component is the DSF. A detailed description of information exchange and software modules is available on D3.3 [S4G-D3.3].

6.2 Grid case

Figure 5 shows the planned architecture for phase 3. Legend for the annotations can be found in Table 11.

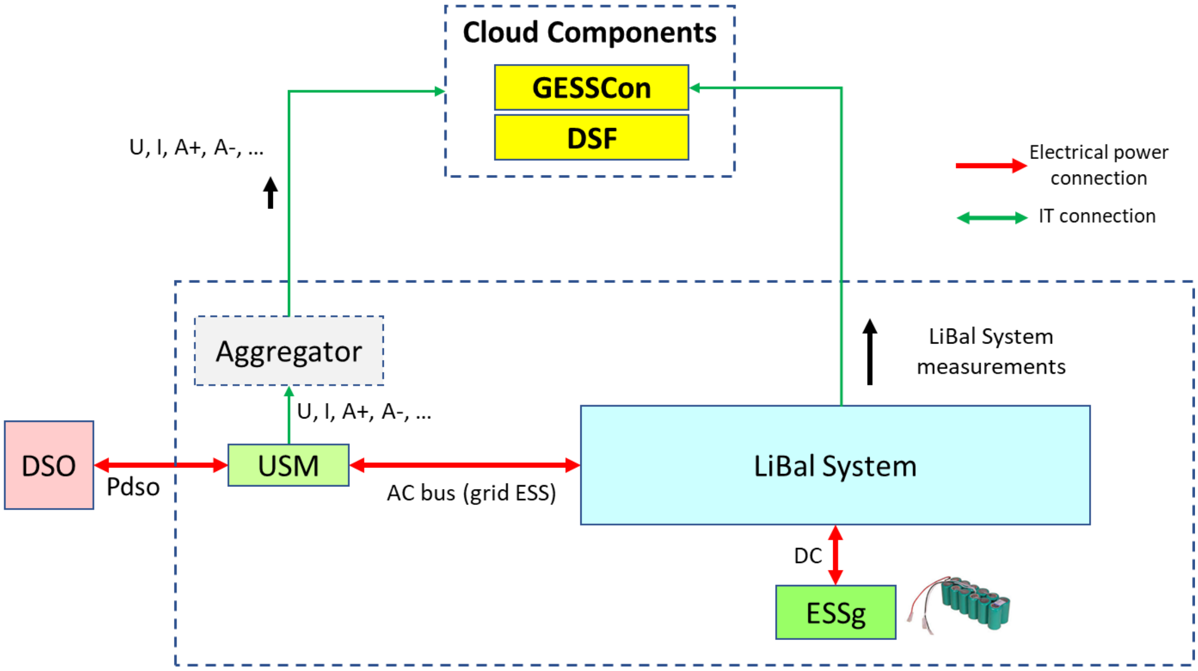

Figure 5. Planned architecture for phase 3 in the Fur/Skive Grid test site.

Table 11. Legend of Figure 5 (Fur/Skive Grid test site).

Name	Description
LiBal System measurements	Some measurements are provided by the LiBal System, e.g., ESSg SoC, inverter power input/output.
Pdso	Active power received or injected to the DSO.
U	RMS phase voltages delivered with a reporting rate (Tu).
I	RMS phase currents delivered with a reporting rate (Ti).
A	Active energy consumed (A+) or produced (A-) by the prosumer.

Figure 5 has two layers corresponding to:

- *Power (energy) flow*
  - **DSO and LiBal System:** power and energy consumed/produced (A+/A-) by the prosumer are measured by USM.
- *Information flow:*
  - Measurements
    - **Delivered by USM:** P_Σload , Pevch, Ppv, U (RMS phase voltages delivered with a reporting rate Tu), I (RMS phase currents delivered with a reporting rate Ti), A+ (energy consumed from the grid), A- (energy produced to the grid).
    - **Delivered by LiBal System:** updated at the highest possible reporting rate, e.g., each 10 seconds.
  - Aggregator: receives and aggregates USM data and make it available for the cloud components.

The LiBal System will be installed together with its grid-side ESS. The cloud components are the GESSCon and the DSF. A detailed description of information exchange and software modules is provided on D3.3 [S4G-D3.3].

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

In phase 3 the test will continue in the local case, and LiBal will complete the implementation of the grid case test site, consisting on the following steps:

- Install ESS in Fur/Skive grid test site.
- Setup communication between LiBal System and the ESS.
- Monitor PV production and load consumption in relation to voltage level on-site

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

6.3.1 Use-case mapping for the corresponding business case

Table 12 shows the Fur/Skive test site use-cases assessment, according to the information available in D2.2 [S4G-D2.2].

Table 12. Use-cases assessment of the Fur/Skive test site.

Use-case	Business case	Actors
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 (person)
		DSF-SE (system)
		Professional GUI (system)
		DSF-GridDB (system)
		PROFESS (system)
HLUC-3-PUC-2: *Autonomous control of storage installed at user premises and distributed in the grid*	HLUC-3-PUC-2-BM-1: *"Autonomous" voltage control at household battery*	DSO (person)
		PROFESS (system)
		USM (system)
		ESS (system)
		PV (system)
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 (person)
		LiBal System (system)
		USM (system)
		ESS (system)
		PV (system)
		South-bound connector (system)
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*	Professional GUI (system)
		DSF-SE (system)
		GESSCon (system
		PROFESS (system)

	HLUC-3-PUC-4-BM-3: *Flux control and load shaving at households with PV and battery*	

6.3.2 Test site use-case KPI definition and evaluation procedure

As it can be observed in Table 12, all actors are available in phase 3, so it is possible to evaluate all the use-cases defined for the Fur/Skive test site, using the evaluation procedure defined in the following subsections.

6.3.2.1 HLUC-3-PUC-1

HLUC-3-PUC-1: "Support for analysing storage dimensioning and positioning in the low-voltage grid" related with the business case HLUC-3-PUC-1-BM-1: "Baseline" will demonstrate the state-of-the-art cost for traditional grid strengthening.

HLUC-3-PUC-1 will be the baseline for the other business cases, to make it possible to compare cost of installation (CaPex) of storage with traditional grid strengthening. The results of this comparison will decide if storage is a feasible solution to solve voltage issues in the selected topology.

6.3.2.2 HLUC-3-PUC-2

HLUC-3-PUC-2: "Autonomous control of storage installed at user premises and distributed in the grid" related with the business case HLUC-3-PUC-2-BM-1: ""Autonomous" voltage control at household battery" 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%.

HLUC-3-PUC-2 will be evaluated measuring the voltage levels at user premises, while the PROFESS keeps the voltage under the limits established by the DSO, using the Hybrid Inverter for one day, up to one week of continuous control. A good result is if the voltage levels are according to the DSO limits 230 ± 10%. If not, the voltage levels can be compliant, then the DSO may consider grid strengthening or another solution with storage. The KPI for the DSO is to maintain and operate the grid with the lowest possible cost. This counts for the overall grid and for each feeder line.

6.3.2.3 HLUC-3-PUC-3

HLUC-3-PUC-3: "Voltage and flux control at grid side storage" related with the business case HLUC-3-PUC-3-BM-1: "Voltage control at grid side battery" will demonstrate voltage control at substation level by controlling the battery charge/discharge active/reactive power to stabilize the voltage level at the feeder line while flux fluctuates. The target is to keep the feeder line voltage at 230V ± 10% for operational safety.

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 the battery will react on voltage deviation ΔU within max ± 10%.

HLUC-3-PUC-3 will be evaluated by measuring if the voltage level at the site PCC is within 230V ± 10%. The KPI for the DSO is to maintain and operate the grid with the lowest possible cost. This counts for the overall grid and for each part of the grid.

6.3.2.4 HLUC-3-PUC-4

HLUC-3-PUC-4: "Coordinated distributed storage in the grid" related with the business cases HLUC-3-PUC-4-BM-2: "Voltage control at both household and grid side battery and Energy Flux control at grid side battery", and HLUC-3-PUC-4-BM-3: "Flux control and load shaving at households with PV and battery" 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 (three phase PCC) due to legislation and regulation demands. Different control bands can also be considered to answer to the DSO's operation conditions.

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 6).

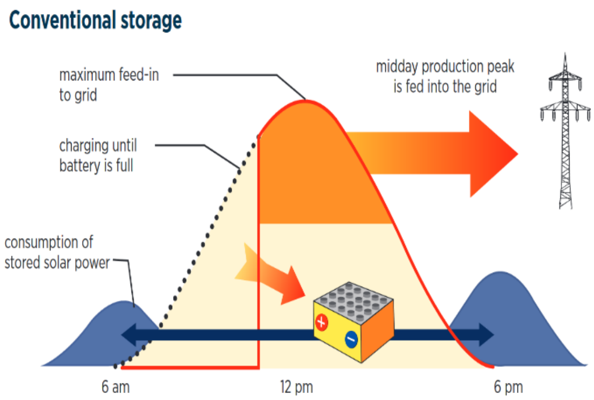

Figure 6. Self-managed battery system.

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 7. 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.

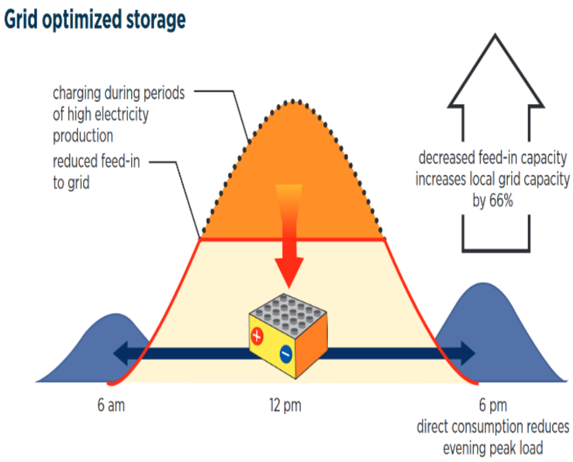

Figure 7. Grid optimized storage.

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.

HLUC-3-PUC-4 will be evaluated using the Professional GUI, the DSF-SE and the DSF-EE to simulate if the voltage grid issues can be solved by using an ESS global control approach. The results will be displayed by the Professional GUI linking the load flow simulations conducted by DSF-SE.

6.3.3 Analysis of the evaluation results

This evaluation step will be reported in D6.12, evaluating the use-cases HLUC-3-PUC-1, HLUC-3-PUC-2, HLUC-3-PUC-3, and HLUC-3-PUC-4 according to the evaluation procedures described in the previous section and summarized in Table 13.

Table 13. Phase 3 KPIs of the HLUC-3.

Case	KPIs
HLUC-3-PUC-1: *Support for analysing storage dimensioning and positioning in the low-voltage grid*	Calculation of the traditional grid strengthening cost. Moreover, the Professional GUI System Usability Scale (SUS) should be classified as "good".
HLUC-3-PUC-1-BM-1: *Baseline*	Calculation of the traditional grid strengthening cost.
HLUC-3-PUC-2: *Autonomous control of storage installed at user premises and distributed in the grid*	The RMS voltage in the PCC during household ESS (dis)charging must be $V_{PCC} = 230\ V \pm 10\%$ *(EN 50160 standard)*.
HLUC-3-PUC-2-BM-1: *"Autonomous" voltage control at household battery*	CapEx and OpEx evaluation, and comparison with HLUC-3-PUC-1-BM-1 (baseline) to verify if the ESS household installation can be a better economical solution for the DSO.

Case	KPIs
HLUC-3-PUC-3: *Voltage and flux control at grid side storage*	The simulation results of the RMS voltage in the PCC during grid ESS (dis)charging must be $V_{PCC} = 230\ V \pm 10\%$ *(EN 50160 standard)*.
HLUC-3-PUC-3-BM-1: *Voltage control at grid side battery*	CapEx and OpEx evaluation, and comparison with HLUC-3-PUC-1-BM-1 (baseline) to verify if the ESS installation can be a better economical solution for the DSO.
HLUC-3-PUC-4: *Coordinated Distributed storage in the grid*	The simulation results of an ESS global control approach will be used for the analysis of grid constraints comparing with a grid without ESS (and the voltage levels must also comply with the EN 50160 standard). Moreover, the Professional GUI System Usability Scale (SUS) should be classified as "good".
HLUC-3-PUC-4-BM-2: *Voltage control at both household and grid side battery and Energy Flux control at grid side battery*	CapEx and OpEx evaluation, and comparison with HLUC-3-PUC-1-BM-1 (baseline) to verify if the ESS household installation can be a better economical solution for the DSO.
HLUC-3-PUC-4-BM-3: *Flux control and load shaving at households with PV and battery*	CapEx and OpEx evaluation, and comparison with HLUC-3-PUC-1-BM-1 (baseline) to verify if the ESS household installation can be a better economical solution for the DSO.

7 Conclusions

The phase 3 evaluation framework was defined, and it considers both technical and economic aspects of the use-cases (D2.2 [S4G-D2.2]) and business cases (D2.4 [S4G-D2.4]) defined in the project of the three test sites. The S4G phase 3 test site plans were developed according to the S4G vision and evaluation scenarios. The KPIs for each HLUC are presented in each section related to the test sites.

The complete description of the phase 3 deployments in the three test sites will be reported in D6.6 - "Phase 3 Test Site Platforms and Deployments Report" (December 2019), while the final results achieved during phase 3 will be reported in D6.12 - "Phase 3 Evaluation Report" (February 2020). D6.3 is the final S4G test site plans deliverable.

Acronyms

Acronym	Explanation
ANN	Artificial Neural Networks
AP	Advanced Prosumer
ASRP	Advanced Self-Resilient Prosumer
BM	Business Model
BMS	Battery Management System
CaPex	Capital Expenditure
C_{CFD}	Daily Collection Credibility Factor
C_{CFW}	Weekly Collection Credibility Factor
CP	Charging Points
CU	Charging Unit
DSF	Decision Support Framework
DSO	Distribution System Operator
ER	Energy Router
ESS	Energy Storage System
EV	Electric Vehicle
GESSCon	Grid Energy Storage System Control
GridMonK	Grid Monitoring and Control Knowledge
GUI	Graphical User Interface
HI	Hybrid Inverter
HIL	Hardware-in-the-Loop
HLUC	High-Level Use-Case
ICT	Information and Communication Technology
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
K-SOM	Kohonen Self-Organizing Maps
LESSAg	Local Energy Storage System Agent
MEDAS	MEtering Data AnalysiS
OpEx	Operating Cost
PCC	Point of Common Coupling
POD	Point Of Distribution

Acronym	Explanation
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
ROI	Return of Investment
S	Scenario
SaaS	Storage as a Service
SMX	Smart Meter eXtensions
SoC	State of Charge
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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References

[i] SolarWeb, Fronius Solar.Web, https://www.solarweb.com/, accessed 10 July 2019.