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Assessment of the scalability and replicability of EUSysFlex solutions

D10.4

EU-SysFlex

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EXECUTIVE SUMMARY

The full roll-out to industrial scale and througout Europe of the solutions tested in the EU-SysFlex demonstrations require a suitable degree of scalability and replicability (S&R). The main objective of this report is to analyse the main barriers to scalability and replicability of the flexibility solutions in the demonstrations carried out during the EU-SysFlex project.

The first step of the analysis consisted in carrying out an in-depth literature review (See §14) on past projects, available reports and publications which helped better understand the variety of approaches and define the conceptual and methodological framework used to carry out this analysis. The resources allocated to WP10 made it necessary to follow a simplified qualitative approach based on a data collection from the EU-SysFlex demonstrations by means of a questionnaire to assess and evaluate to what extent the demonstrations'results and solutions can actually be scaled-up and replicated, what the hindrances are, what evolutions are foreseen and/or needed to facilitate a widespread dissemination (see Annex 1). This approach allows an assessment per demonstration and also a cross-analysis between them highlighting the drivers and barriers to scalability and replicability and providing a feedback on key dimensions for improvement.

Scalability can be defined as the ability of a system to change its scale in order to meet growing volumes of demand. A system is understood as a set of interacting elements with similar boundary conditions. By contrast, replicability denotes the property of a system that allows it to be duplicated at another location or time. The SRA in this report will be a solution-based SRA in which the technical solutions must be analyzed to assess whether they can cope with an increased volume of information, elements, or a larger radius of action. A scalable concept will thus be understood as a demonstration which size can successfully be increased to industrial scale under the same boundary conditions (e.g. more distributed VRES in a specific area or a higher volume of data to be transfered), whereas a replicable concept will refer to a demonstration that could perform successfully under different boundary conditions (e.g. market designs of different countries).

The methodology which has been used for carrying out the SRA follows the recommendations of the BRIDGE Task Force on Replicability & Scalability Analysis. It also uses results from the Grid+ EU project. In this approach, the structure of the Smart energy Grid Architecture Model SGAM (see Figure 3) is used as the backbone for the definition of the Scalability and Replicability Analysis (SRA) guidelines. The questionnaire addresses these topics by means of a structured assessment aiming at identifying potentially critical aspects to scaling up the concepts, actions that were performed to mitigate risks, future actions that may, in the future, remove the barriers.

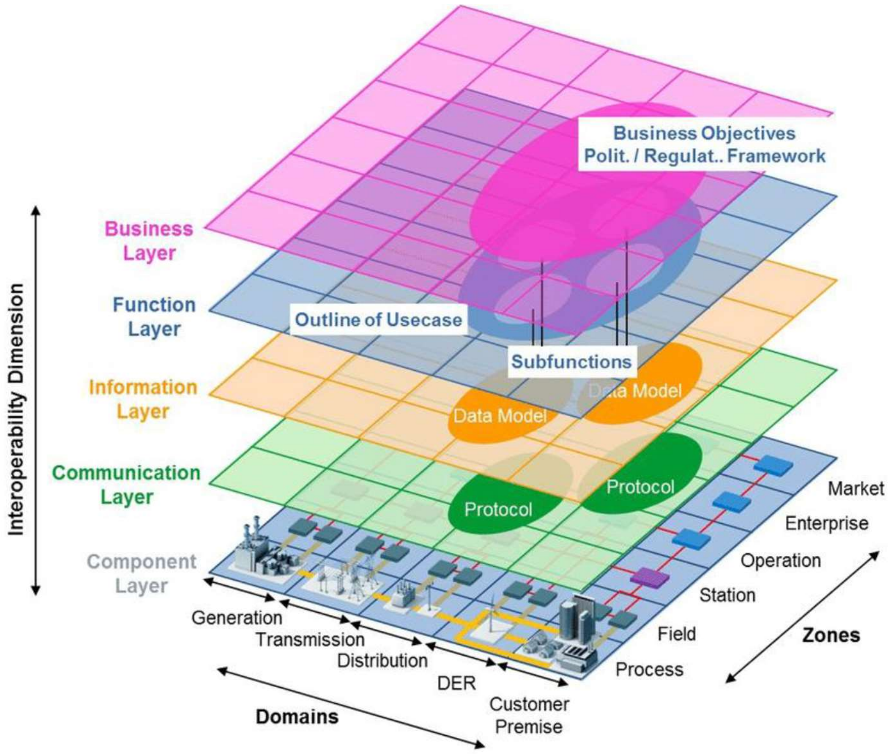


FIGURE 1: SGAM FRAMEWORK

The selected approach comprises several steps:

1. Select SGAM layers
2. Select SRA dimensions
3. Define a methodology for each SRA dimension selected
4. Perform the SRA for each dimension
5. Draw conclusions and deliver the SRA rules/roadmap

SRA dimensions that influence and condition a demo's scalability and replicability have been identified by means of an in-depth literature review (See §14). Since EU-SysFlex demonstrations cover a wide range of applications, these dimensions needed to be sufficiently generic and could not be too application-specific. Therefore, the dimensions considered here have been classified into five main categories. They involve i) business related aspects such as regulation, economics and stakeholder acceptance, ii) functions and services related aspects such as SUCs variability to boundary conditions, iii) Data-models attributes, iv) communication protocols, and finally v) technical components related aspects such as hardware, softwares and ICT architecture.

The evaluation of the answers to the questionnaires has been carried out according to the SGAM layers and their associated dimensions. It is important to mention that the answers to the questions reflect the experts'view and results. The advantage of this bottom-up approach is that the experts involved in the demonstrations are the one having the better understanding of the context and the results. A drawback resides in the fact that sometimes the same experts have mainly a technical background and additional support was needed to answer questions related to non-technical questions such as the ones on regulation or economics.

The sections 5 to 11 detail the Scalability and Replicability Analysis of each demonstration and highlight specific limitations and challenges that could hamper the scalability and replicability dimensions of the EU-SysFlex demonstrations. The main conclusions are recapped here:

- The Finnish demonstration is technically scalable and replicable. The potential hurdles are mainly related to the regulation and economic dimensions of the SRA. Among the services proposed by the demonstration, FCR-N, FCR-D and mFRR markets apply only in Finland. At national level, some adaptations of frequency regulation rules would be beneficial to facilitate aggregation of a large number of assets (lower bid limits and a larger fast response time required for FCR-D). In other countries, frequency control services rely on similar principles and therefore only minor adaptations would be needed to adapt them to another setting. In contrast, there is currently no DSO reactive power market in Finland and elsewhere and thus no rules. This is a hurdle to the related BUC (FI-RP: Manage reactive power flexibility to support voltage control at the TSO/DSO connection points) that could be long-lasting as compared to the limitations previously mentioned for frequency regulation services. Regarding economic viability, no definite conclusion can be drawn. In the short to medium term, prices of Battery Energy Storage Systems (BESS) are expected to decrease sharply due to the development of electric mobility. This is a favourable factor. Moreover, economies of scale are foreseen in a scaled-up concept and could slightly contribute to improve the economics.
- The German demonstration is already at industrial-scale and therefore the main focus was replication of the concept in a different host environment and not the increase in size. The dependance on the grid topology would imply some modifications to adapt the software to a new setting.
- The technical solution implemented in the Italian demo can be considered as scalable and replicable from a technical point of view. There is however a strong and long-lasting impediment from the regulation standpoint related to the current prohibition for the DSO to own and manage storage and the absence of remuneration mechanism of network and market services provided by DER that affects the economic viability of the concept.
- The Portuguese Flexhub demonstration is scalable and replicable with respect to technical aspects (SUCs, Data, communication and components). However, potential regulatory barriers to scalability and replicability have been identified.
- the Portuguese VPP concept appears to be scalable and replicable over Europe with respect to all other dimensions of the SRA apart from regulation. Current regulation in several countries (including Portugal) do not allow the implementation of a multi-technology VPP and this is a hindrance to S&R. However, the barrier is likely to wane in the near future and the impediment should therefore only be temporary.
- The SRA of the French VPP shows that there are no hurdle to scalability and replicability with respect to technical dimensions. There are some concerns however on the economic viability related to low remunerations.
- Data exchange relies on the concept of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process. These elements are not available yet in all EU countries which is a temporary impediment to replicability that should be solved on the short to medium term. There are currently some hurdles with respect to regulation but there is no lasting impediment: i)

current regulation as such in Estonia does not hinder scaling up the solution, ii) regarding cross-border data exchange, critical aspects are related to authentication of data users and data access permissions (consents) given to data users of other countries. However, future EU regulation (eIDAS, Data Governance Act, Data Interoperability Implementing Act) is expected to address these points.

A Cross-Analysis of the results highlight that:

- The various demonstrations have a strong focus on the technical level of their solution/application,
- Their upscaling could however encounter issues, in particular regarding the massive amounts of data to manage,
- The main possible problems pointed out in the analyses may arise from the regulation or market design dimension either because rules may not allow the envisaged services or because the remuneration is currently low or nil,
- The economic barriers were difficult to address properly since no Cost Benefit Analysis (CBA) was carried out at the demonstration level. Therefore, the economic viability was rather assessed through experts'opinions and foreseen economies of scale and changes in market rules that could be favourable to S&R,
- Some limitations regarding the component-related dimensions have been identified and are likely to arise upon up-scaling some of the demonstrations. However, the demonstrations are rather to be considered as prototypes and components and architecture will change in industrial-scale versions thereby solving the potential problems.

Table 1 summarizes these limitations and challenges and indicates whether these impediments are temporary or long-lasting :

(green)	Short-Term impediment
(pink)	Long-Term impediment
(yellow)	Intermediate

TABLE 1: LIMITATIONS AND CHALLENGES IN THE EU-SYSFLEX DEMONSTRATIONS

Barriers		Scalability		Replicability
Component-related	Software	PT-FlexHub: software limitations due to grid size (in terms of computation time)	Software	DE: slight dependance of software on the grid topology
	Communication	PT-FlexHub: communication architecture might meet limitations with an increase in data volumetry		
Economics	Profitability	All: Viability difficult to assess (no cost-benefit analysis at demo level in the EU-SysFlex project)	Business-Model	FI: Market not fully ready (EVs infrastructure, no DSO Q-market)

		FI: price of components (BESS) still expensive and so far low electricity prices		
		IT: Absence of remuneration mechanism		
		FR: Low market prices for frequency regulation services		
Regulation and market rules	**Regional / National**	FI, PT-FlexHub: no DSO reactive power market at the moment in Finland and elsewhere	**National / Intl.**	FI, PT-FlexHub: no DSO reactive power market at the moment in EU countries
		FI: adaptations of frequency regulation rules would be beneficial (lower bid limits and larger fast response time required for FCR-D)		FI: Frequency regulation services are different in other EU countries but rely on similar principles
		IT: current prohibition for the Italian DSO to own and manage storage		IT: current prohibition for DSOs to own and manage storage in EU countries
		IT: absence of remunation mechanism in Italy.		FR, PT-FlexHub: only few countries allow distributed resources to provide flexibility
		PT-VPP: implementation of a multi-technology VPP not allowed yet in Portugal		PT-VPP: implementation of a multi-technology VPP not allowed yet in most EU countries
		FR: Low market prices for frequency regulation services		Data exchange: the concepts of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process, are not available yet in all EU countries.
				Data Exchange (cross-border): current EU regulation do not address authentication of data users and data access permissions (consents) given to data users of other countries

Most of the difficulties arise from the fact that overcoming the barriers often depends on exogenous factors which are not part of the demonstrations and with limited influence of the latter to make things evolve.

The regulation and market design dimensions are the most important factors in this analysis since the main barriers and challenges stem from them. Actual impediments arise from i) the absence of appropriate regulation framework at national level as regards scalability or in other member states with respect to replicability and ii) lack of remuneration rules or low market prices. The latter could put at risk the economic viability of the concepts whereas the former could hamper the roll-out to an industrial-scale version of the concept and its deployment in other EU member states. These limitations have causes which stand outside of the project boundaries. They stress the need for evolutions in terms of regulation and market-design at the EU level and in some cases these changes are already expected which makes the hurdle only temporary. These changes are rather to be expected in the medium to long term.

The financial dimension is also of high importance. Possible business-models have been studied within WP11 (See D11.29). As mentioned earlier, there was no Cost-Benefit Analysis at the demonstration level and thus the economic viability of the concepts has not been studied per se in the EU-SysFlex project. The demonstrations had a strong focus on the technical feasibility so the economic aspects were not the priority. The analysis carried out has thus relied on experts'opinions and on factors that could be either favourable or detrimental such as the foreseen economies of scale or foreseen changes in remuneration schemes. The main barriers that have been identified come from i) components which are still expensive (e.g. Battery Energy Storage Systems) and whose expected decrease in cost could ease the potential economic constraint, ii) low remuneration or no remuneration at all which ties the economic dimension to the market design and iii) the insufficient readiness of the market. The SRA showed that the demonstrations sometimes use proprietary standards or other types of standards (mandatory, open). Use of non-proprietary standards has a positive impact on cost since multiple vendors can provide offers. The recommendation from the analysis of the economic dimension of the concepts developed in EU-SysFlex is to complete the studies carried out during the project by a cost-benefit analysis of a larger scale solution and especially in a different setting.

Limitations can also arise from components (hardware, software, ITC architecture). Some limitations have been detected related to i) the computation time of softwares when dealing with larger grids, ii) the dependence of software on the grid topology, and iii) the increase in data volumetry when up-scaling. None of these potential limitations are considered as real impediments mainly because the EU-SysFlex demonstrations are to be considered as prototypes and medium to major changes to the solution/application are to be expected for most of them with the roll-out to an industrial-scale or within different boundary conditions. Therefore technologies and design are likely to change and be adapted.

1. INTRODUCTION

The EU-SysFlex project seeks to enable the European power system to utilise efficient, coordinated flexibilities in order to integrate at least 50% of electricity coming from renewable energy sources (RES-E). Transitioning from power systems which have traditionally been dominated by large synchronous generating units to systems with high levels of variable non-synchronous renewable technologies results in challenging the safe and reliable operation of power systems.

The Work Package 10 of the EU-SysFlex European project has several main objectives, the main one being the elaboration of a roadmap of flexibility for Europe (D10.5). The roadmap is fed by all results of the project and in particular by other studies carried out in WP10 such as the definition of Key Performance Indicators (D10.1) for the demonstrations, a Technical Energy Analysis analysing the KPI results (D10.2), a Technical Reliability Analysis (T10.3), and finally a Scalability and Replicability Analysis (SRA) of the results from the demonstrations which is the aim of this very report (D10.4).

The full roll-out to industrial scale and througout Europe of the solutions tested in the EU-SysFlex demonstrations require a suitable degree of scalability and replicability (S&R). The main objective of this report is to analyse the main barriers to scalability and replicability of the flexibility solutions in the demonstrations carried out during the EU-SysFlex project. The report will provide as well the conceptual and methodological framework used to carry out this analysis.

The first step of the analysis consisted in carrying out an in-depth literature review (See §14) on past projects, available reports and publications which helped better understand the variety of approaches and define the conceptual and methodological framework used to carry out this analysis. The resources allocated to WP10 made it necessary to follow a simplified qualitative approach based on a data collection from the EU-SysFlex demonstrations by means of a questionnaire to assess and evaluate to what extent the demonstrations'results and solutions can actually be scaled-up and replicated, what the hindrances are, what evolutions are foreseen and/or needed to facilitate a widespread dissemination (see Annex 1). This approach allows an assessment per demonstration and also a cross-analysis highlighting the drivers and barriers to scalability and replicability and providing a feedback on key dimensions for improvement.

1.1 SCALABILITY AND REPLICABILITY DEFINITIONS

Scalability can be defined as the ability of a system to change its scale in order to meet growing volumes of demand. A system is understood as a set of interacting elements with similar boundary conditions. By contrast, replicability denotes the property of a system that allows it to be duplicated at another location or time.

Scalability and replicability have different scopes that need to be considered in Scalability and Replicability Analyses (SRA):

- **Scaling-up in size**: the implementation of the demo is assessed for a larger area, including a larger number of network elements and network users.
- **Scaling-up in density**: the scope of the demo is widened in terms of implementation degree of the flexibility solution (e.g.: larger number of consumers involved, higher volume of participating distributed energy resources (DER), higher number of smart grid elements in the system).

- **Intranational replication**: the implementation of the demo is analyzed for different grid areas within a country.
- **International replication**: the implementation of the use case is analyzed for different countries.

Within a country, similar boundary conditions may be expected regarding regulation, perspectives of stakeholders, or technical aspects such as voltage levels. Other technical boundary conditions (host network architecture, reliability levels, etc.) may change for different distribution areas with different types of network users (areas with high PV penetration, etc.). When considering different countries, the boundary conditions may differ more widely, including different regulation schemes, network characteristics, economic conditions or perspectives from stakeholders.

Actually, scaling-up in size implies considering a larger region, where boundary conditions may change. Therefore, intranational replication implies scaling-up in size and international replication can be regarded as a step further in upscaling. Scaling-up in density refers to the ability of the system to cover wider regions (e.g. larger grids), whereas scalability in density would be related to the ability to cover a higher number of elements (e.g. a higher number of PV units receiving setpoints from a control system).

1.2 SOLUTION-BASED SRA VS FUNCTIONALITY-BASED SRA

Scalability and Replicability may be broadly defined as assessing the implementation potential of a given concept / technology / solution / application / business model at a larger scale or in a different context. The analysis may be approached from two different perspectives: i) "solution-based" to assess the scalability and replicability of the flexibility solutions, and ii) "functionality-based" to assess the outcome of scaling-up and replicating the implemented functionalities. According to, solution-based and functionality-based, the diagram in Figure 2 presents these two perspectives for SRA and the aspects involved in the implementation of flexibility solutions.

- **Functionality-based SRA: understanding scaling-up and replication**

  The questions raised in a functionality-based SRA are related to the impact of the scaling-up and replicating use cases. The aim is to assess the effectiveness of flexibility solutions to achieve certain objectives, regardless of the actual technologies implemented, provided that the solution is scalable and replicable. The outcome of scaling-up and replicating is strongly affected by the different boundary conditions of the implementation.

  The main questions to be answered are thus: What could be expected if the use cases (in terms of the enabled functionality) were implemented elsewhere or at a larger scale? How could the technical impacts on the distribution system be determined? Under what conditions would it make more sense to implement it? What would be the factors or boundary conditions that could affect the outcomes?

  Under this approach, the technical impact are generally quantified through KPIs.

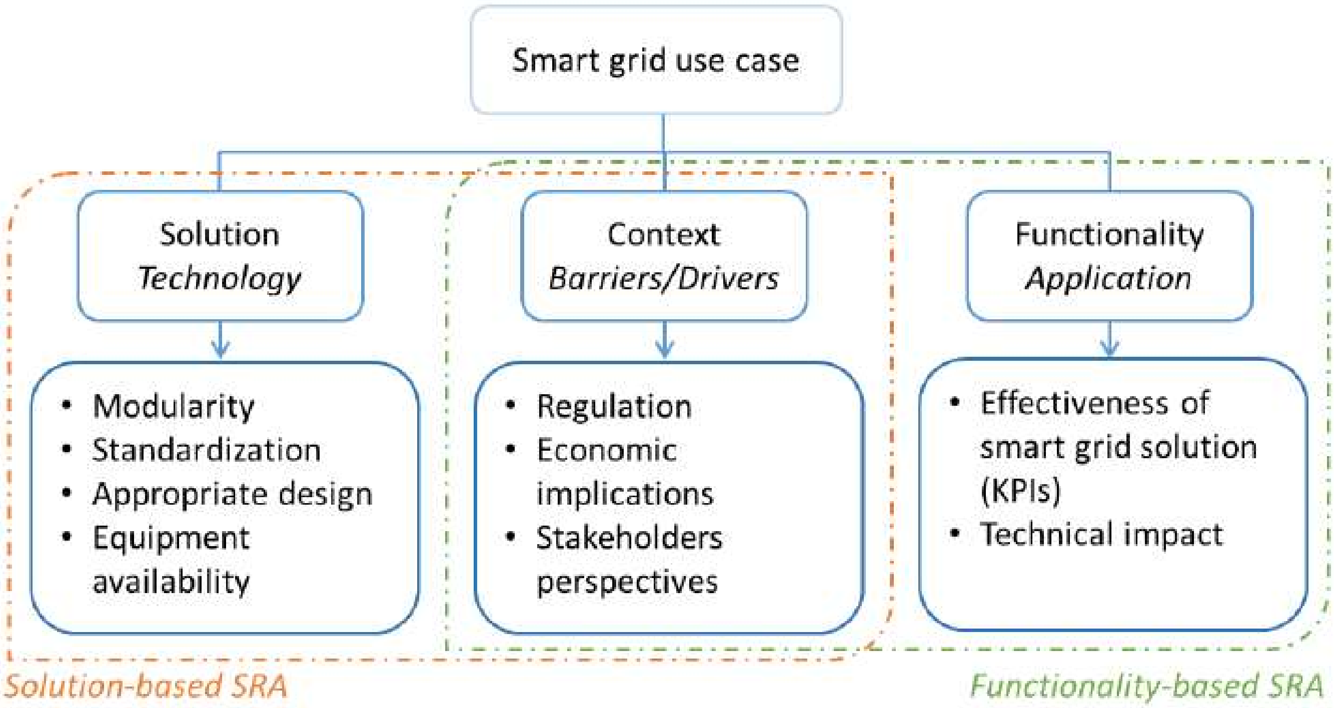


FIGURE 2: REPLICABILITY OF THE FLEXIBILITY SOLUTIONS IN THE DEMONSTRATIONS CARRIED OUT DURING THE EU-SYSFLEX PROJECT [CALVO A R, 2017]

- **Solution-based SRA: assessing scalability and replicability**
  In a solution-based SRA, the technical solutions must be analyzed to assess whether they can cope with an increased volume of information, elements, or a larger radius of action. Furthermore, software and hardware compatibility with existing infrastructure and the evolution of technology must be considered to ensure a correct integration of the smart grid solution in the distribution system. Technical dimensions that affect the scalability and replicability of flexibility solutions include modularity, interface design, standardization, interoperability, and availability of components. From this perspective, SRA is mainly related to the technical and data exchange aspects of the solutions and the context to their implementation. Additionally, the regulatory framework, the business-models and the acceptance of stakeholders must be studied to determine whether scaling up or replication of the considered solution would be viable.
  The main questions to be answered here are the following: Is it possible to actually implement the same flexibility solution elsewhere or at a larger scale? How could that be accomplished? Would the hardware, software, infrastructure, etc. have to be adapted? What would be the barriers?

The SRA in this report will be a solution-based SRA. A scalable concept will thus be understood as a demonstration whose size can successfully be increased to industrial scale under the same boundary conditions (e.g. more distributed VRES in a specific area or a higher volume of data to be transfered), whereas a replicable concept will refer to a demonstration that could perform successfully under different boundary conditions (e.g. market designs of different countries).

2. BRIDGE APPROACH TO SRA

The methodology which has been used for carrying out the SRA follows the recommendations of the BRIDGE Task Force on Replicability & Scalability Analysis and uses the Smart energy Grid Architecture Model (SGAM) as the backbone (see Figure 3). It also uses results and part of the qualitative approach of the Grid+ EU project.

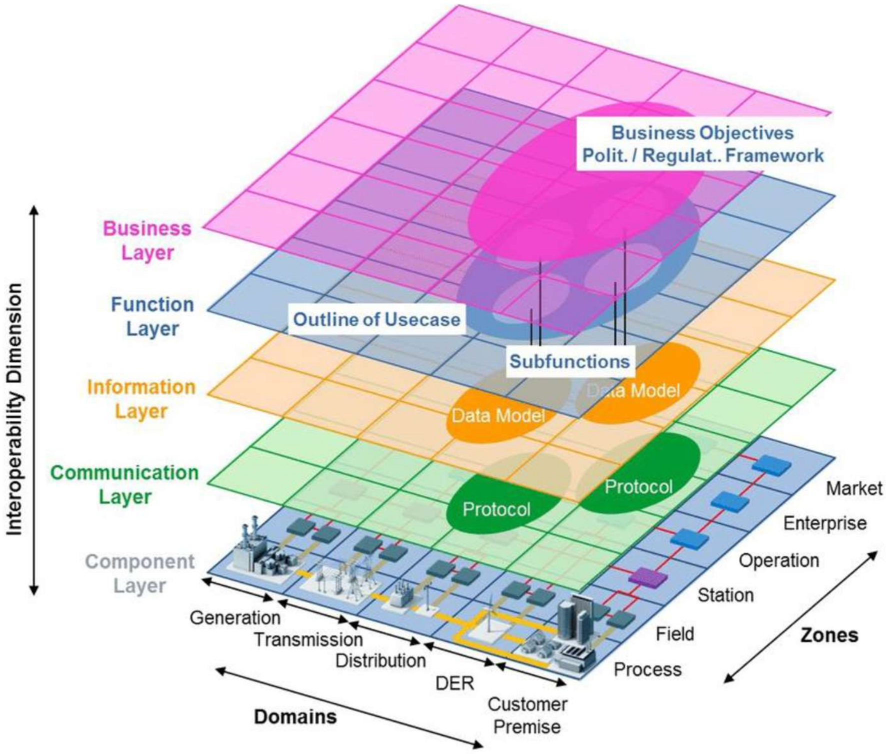


FIGURE 3: SGAM FRAMEWORK

The selected approach is depicted in Figure 4 and comprises several steps:

6. Select SGAM layers
7. Select SRA dimensions
8. Define a methodology for each SRA dimension selected
9. Perform the SRA for each dimension
10. Draw conclusions and deliver the SRA rules/roadmap

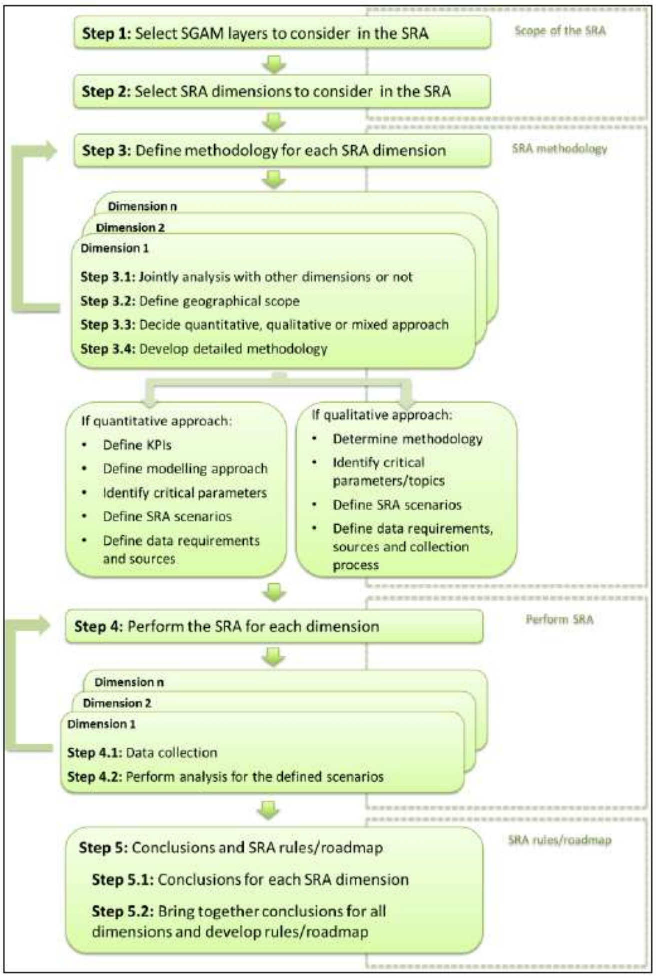


FIGURE 4: SRA GUIDELINES PROPOSED BY THE BRIDGE TASK-FORCE ON SRA

1 - Select SGAM layers: first of all, the SGAM layers relevant to each demonstration have been selected. In order to deploy a solution such as those proposed in the EU-SysFlex project, the scalability and replicability analysis must be guaranteed from the perspectives of five main focus areas, this includes the business (economic, regulatory and stakeholders), functions and services, information, communication and component domains. Each of the analysis areas provides individual SRA analysis based on each of their respective objectives and methodologies:

- Business layer: provides a business view on the information exchange related to smart grids. It is used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer.
- Function and services layer: comprises functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components.
- Information layer: deals with the information that is being used and exchanged between functions, services and components as well as protocols and mechanisms for the interoperable exchange of information between components.

- Communication layer: The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.
- Component layer: includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

The specific scope of the scalability and replicability analysis (SRA) vary significantly depending on the characteristics of the demonstrations. Therefore, the relevant selected layers differ from one demonstration to another (e.g. the hardware layer is out of scope of the German demonstration) and the type of questions that the latter are able answer.

2 - Select SRA dimensions: After that, within each SGAM layer, the SRA dimensions on which the project is likely to have an impact have been identified. As a comprehensive demonstration project, EU-SysFlex addresses to some degree all of the identified dimensions. These dimensions are summarized in Table 2.

TABLE 2: SRA DIMENSIONS IDENTIFIED WITHIN THE LAYERS OF THE SGAM MODEL

SGAM Layer	*SRA Dimension*
Business	Regulatory analysis
	Economic analysis (CBA)
	Business model aspects: market preparedness, market maturity, competition level, ease of doing business
	Stakeholders' perspectives
Functions and services	SUCs scalability
Information	Data-models attributes: compliance to standards
Communication	Communication protocols for data exchange (within an area or point-to-point): which protocols are being used (MQTT, REST, SOAP, …) ?, are they open protocols? are they standard ?
Component	Hardware (modularity, standardization, interoperability)
	Software scalability and replicability (modularity, standardization, interoperability, portability, etc.)
	ICT scalability: foreseen limitations upon scaling-up the solution in terms of communication volumetry, latency, bandwidth, data loss
	ICT replicability: modularity, standards, open protocols, etc.

3 - Define a methodology for each SRA dimension selected: the following stage requires identifying critical parameters and/or topics, defining scenarios, data requirements, sources and collection process. The following steps have been performed:

a) analysis of the above-mentioned dimensions in an individual way but also looking for some possible joint dimensions (such as the joint interaction between the economic viability and the regulation aspects).

b) definition the geographical scope as: the EU-28. This analysis sets the basis for a proper replicability of the project around Europe.
c) qualitative approach through demo-leaders and experts consultation and the use of a questionnaire aiming at identifying the critical parameters for the future wide-scale deployment.

4 - Perform the SRA for each dimension selected: Once the methodology has been defined, a data collection has been organised in order to perform the corresponding qualitative analyses for the scenarios previously defined.

5 - Draw conclusions and deliver the SRA rules/roadmap: the last stage consists in analysing the results obtained in the SRA, for each dimension individually and subsequently trying to relate among them the results for the different dimensions when relevant. This analysis focused on the drivers and barriers that may be encountered.

3. SCALABILITY AND REPLICABILITY DIMENSIONS

The SRA dimensions that influence and condition a demo's scalability and replicability have been identified by means of an in-depth literature review (See §14). The literature review showed that feasibility of scaling up mainly depends on technical dimensions, whereas feasibility of replication is strongly affected by both regulatory and technical dimensions. Viability of scaling-up and replication mainly depends on the economic dimensions but also on regulatory and acceptance-related dimensions.

Since the EU-SysFlex demonstrations cover a wide range of applications, these dimensions needed to be sufficiently generic and could not be too application-specific. Therefore, the dimensions considered here have been classified into six main categories. They involve i) business related aspects such as regulation, economics and stakeholder acceptance, ii) functions and services related aspects such as SUCs variability to boundary conditions, iii) Data-models attributes, iv) communication protocols, and finally v) technical components related aspects such as hardware, softwares and ICT architecture. These concepts are explained below:

1) **Regulation dimension** reflects the extent to which the current regulatory framework allows the deployment of a scaled-up version of a demonstration or whether a new environment is suitable for receiving a project.
2) **Economic dimension** addresses the viability to pursue scaling up or replication. This means validating whether cash flow analysis metrics (e.g. cost-benefit ratio, Net Present Value, Internal Rate of Return, etc.) and business models hold at a larger scale or in a different setting than the original case. However, no CBA or economic analysis has been carried out at the demonstrations level and therefore, even though this aspect may constitute a major barrier or driver, conclusions were difficult to draw.
3) **Stakeholders'acceptance dimension** reflects the extent to which the current social environment (end-users, regulators, authorities, etc.) is ready to embrace a scaled-up version of a project.
4) **SUCs dimension** is based on the qualitative analysis of the set of system use-cases (SUCs) of each demo, as well as SUCs interaction in order to identify potential barriers/constraints or drivers that may affect the replicability.
5) **Data-models attributes and communication protocols dimensions** reflect the level of standardisation of the former and the latter and how this affects replicability.
6) **Technical components dimension** analyses whether the solution developed in a particular project is inherently scalable and/or replicable, i.e., whether it is feasible to scale-up and/or to replicate. Paying attention to this dimension only will not automatically guarantee scalability or replicability, but a failure to do so will rule out many chances to it.

A questionnaire has been defined for the EU-SysFlex demonstrations (See Annex 1) that addresses these topics by means of a structured assessment aiming at identifying potentially critical aspects and actions that were performed to mitigate risks, future actions that may, in the future, remove the barriers. Table 3 summarizes the proposed SRA dimensions and the main factors affecting the scalability and replicability. The following subsections describe these factors in more detail.

TABLE 3: FACTORS AFFECTING SCALABILITY AND REPLICABILITY

Dimension	*Scalability*	*Replicability*
Regulation	Regional regulation or market rules	National / International regulation or market rules
Economics	Costs and Revenues Foreseen economies of scale Foreseen regulation evolutions	Sensitivity to Market Design Business model (e.g. viability in another EU member state).
Stakeholder's acceptance	Acceptance of larger size concept Willingness to take part in the concept	Acceptance of the concept Willingness to take part in the concept
SUCs		Variations according to changes in boundary conditions
Information attributes and communication protocols		Compliance to Standards
Technical Components	Modularity Expected technology evolutions Complexity of interface design (interconnection with other systems) Requirements on current infrastructure Adaptability of software tools	Compliance to Standards Interoperability Host network configuration (to what extent does the solution depend on given resources – solar, wind - and infrastructures)

It shall be mentioned that dimensions and items might be removed according to the particular context of a demonstration.

3.1 DIMENSIONS AFFECTING THE SCALABILITY

3.1.1 BUSINESS RELATED DIMENSIONS

3.1.1.1 REGULATORY

The Regulatory dimension analyses whether there are any national/regional regulatory barriers with respect to the size and scope of the solution. Regulation defines the roles and responsibilities of agents, the rules and requirements to provide services, the rules on how to remunerate regulated activities and the rules on interaction between agents. With respect to scalability, regulation is understood in terms of its impact on the size and scope of the project. Usually, the rules and requirements to provide certain services mostly affect scalability, for instance, a low level of remuneration for a given flexibility service may be a temporary hindrance to scalability. Rolling out the demonstration to an industrial scale would then necessitate a change in regulation to enhance the economic viability.

3.1.1.2 ECONOMICS

The Economic dimension analyses the economic viability of an up-scaled industrial version of the demonstration, to what extent the cost-benefit ratio (or the net present value) grows when increasing the solution size. This may mean a decrease in specific costs through technological improvements and econmies of scale. At least, profitability should at least maintained which means that the increase in benefits should be at least equal to the increase in costs.
Note that the demonstration itself does not necessarily need to be viable and the analysis only looks at the effect of increasing its size. Therefore, economies of scale should apply.
Interactions with other dimensions also have to be contemplated. For example, if a particular demonstration is inherently scalable due to its technical characteristics but economic vialibilty is put at risk due to a low remuneration, then the project is deemed to be potentially not scalable (or at least partially).

3.1.1.3 STAKEHOLDERS' ACCEPTANCE

Finally, this section studies the extent to which stakeholders like regulators, policy makers and end users are ready to embrace an enlarged project and whether any challenges are expected. An assessment is necessary of how critical stakeholders'acceptance is and whether it can be gained from the involved stakeholders.

3.1.2 DIMENSIONS RELATED TO COMPONENTS

The dimensions related to components cover the extent to which the solution itself, as far as the hardware, softwares and ITC architecture are concerned, is inherently scalable. This encompasses the modularity and the easiness to add extra components, the expected technological evolutions that would facilitate an increase in size, and the ability of the components to cope with the effects of the enlargement such as, for example, the volume of data to process. They also address the compatibility with the host environment the solution will be implemented in, and the interaction between the components of the solution and the outside world.

3.1.2.1 MODULARITY

Modularity is a basic precondition for the scaling-up of a demo. It refers to whether a solution can be divided into interdependent components, how easy it is to add extra components and whether there are limits to it. On the one hand, a monolithic solution will seldom be appropriate for implementation at a larger scale. On the other hand, clearly defined and separated constituent parts make it easier to extend the solution to a larger scale.

3.1.2.2 EXPECTED TECHNOLOGY EVOLUTIONS

Expected technology evolution, depending on its extent may facilitate an increase in solution size. During the time lapse between the original concept and the roll-out of an enlarged version, the evolving state-of-the-art in underlying technology (battery energy storage systems costs, computing power and cost, telecommunication speed and capacity, etc.) may substancially increase the potential for scalalability. On the contrary, the foreseen obsolescence of the technology may become an impediment for scalability.

3.1.2.3 COMPLEXITY OF INTERFACE DESIGN (NUMBER OF INTERACTIONS AMONG COMPONENTS)

The number, complexity and intensity of interactions among the components and with the outside world need to remain manageable to allow the scale-up of the solution. Interface design explicitly addresses the number of interactions among components. If they increase more than linearly with the size, the industrial-size solution may turn out to be too complex at the desired scale.

3.1.2.4 REQUIREMENTS ON CURRENT INFRASTRUCTURE

Demonstrations are bound by pre-existing conditions of their host settings. The current infrastructure may create limits on the maximum scale that can be reached. These limits can range from mild constraints to impediments; therefore, the requirements of a scaled up solution on the existing infrastructure have to be analyzed. For instance.

3.1.2.5 ADAPTABILITY OF SOFTWARE TOOLS

The various software tools developed (e.g., simulation models, databases, etc.) need to be able to cope with an increased size. This might be facilitated by favorable technological evolutions that would, for example, allow to keep an acceptable computation time when the volume of the data increases drastically.

3.2 DIMENSIONS AFFECTING THE REPLICABILITY

3.2.1 REGULATION

For successful replication, it is important that regulation in the envisaged EU member states allows the wide-scale deployment of the concept. However, this is not always easy due to the lack of unified European regulatory framework and the different remuneration schemes across Europe.
Besides, the host area's market design is another determining factor. This involves, among others, questions on what market model is used, who the players are, how they interact, what tariff structure is in place and whether additional constraints as taxes or subsidy schemes may apply. For example, some demonstrations tested among others the ability of the DSO to aggregate renewable sources and storage to provide frequency regulation. However, at the moment, the DSO is not allowed to own storage in Europe for market-based activities which means that regulation evolutions in the short to medium term are crucial to allow the deployment of these solutions.

3.2.2 ECONOMICS

The host setting can have a strong impact on the business model. For example, a flexibility service may be profitable in a given member state whereas an absence of appropriate remuneration in another host area could hamper its replicability. However, if the business model can be adapted, the project might get replicable again.
Besides, one has to keep in mind that demonstrators are not necessarily inherently economically profitable and may be subject to special regulatory treatment. Technology performance evolutions and economies of scale should then apply in order to ensure profitability of an industrial scale version.

3.2.3 STAKEHOLDERS' ACCEPTANCE

Here the main question is to what extent stakeholders'acceptance problems are expected when exporting the solutions to other countries. The acceptance of the solution by key stakeholders may imply a more fundamental consent than the one required for scalability: stakeholders have to be willing to embrace something entirely new, which may be more difficult than accepting a larger version of something that already exists.

3.2.4 SUC, INFORMATION ATTRIBUTES AND COMMUNICATION PROTOCOLS

Here, the analysis focuses on the main functions developed within the project and their interrelation (exchanged information). It is based on the qualitative analysis of the set of system use cases (SUCs) defined for each demonstration, as well as SUCs interaction in order to identify potential barriers/constraints or drivers. In particular, the variation of SUCs with respect to changes of boundary conditions is of importance for replicability purposes. This might encompass changes in the characteristics of the host distribution grid on which the solution is to be deployed, the load profiles of consumers, etc.

Regarding the exchange of information, data-models attributes and communication protocols, compliance to standards will be key to allow the wide-scale deployment.

3.2.5 COMPONENTS

The solution itself should comply to standards or be easily made standard compliant. This helps avoiding very specific solutions that may only function well in a given setting. However, standardization in itself is not enough. Solutions also have to be interoperable (i.e. able to interwork, to exchange and use information to perform required functions). This is a core requirement for replication.

Furthermore, the solution has to be as much as possible non-system-specific, that is to say independent from the external conditions imposed by the host system configuration. This refers to elements, which are given and cannot be changed within the scope of a project (e.g., climate conditions such as grid characteristics, solar resource, wind, local generation mix, consumption mix and profiles, etc.). For example, if a project focuses on the joint use of storage systems and variable renewable sources, the replication of these solutions depends very much on the resource in the new host area.

3.3 SUMMARY

The main potential drivers and barriers for scaling-up and replicate a solution are described in detail in the previous paragraphs. They are summarized in Table 4 and classified according to the corresponding SGAM layer and SRA dimension. The questions raised form the base of the SRA questionnaire which has been used by the demo leaders (see Annex 1 and §4).

TABLE 4: IDENTIFICATION OF SCALABILITY AND REPLICABILITY DRIVERS/BARRIERS

SGAM Layer	*SRA Dimension*	*Identification of potential drivers/barriers*
Business	Regulatory analysis	Could current (national or local) regulation create barriers to the new solutions? (wrt the size and scope of the solution?, wrt to replication?) What is the dependence of the solution on a given market design?
	Economic analysis (CBA)	What would be the costs and benefits of a scaled-up implementation of the solution? (does the Net Present Value (NPV) grow?, are there expected economies of scale?) Is the flexibility solution viably replicable?
	Business model aspects	What is the market readiness for a given solution? market preparedness?, market maturity?, competition level?, ease of doing business?
	Stakeholders' perspectives	Are the different groups of stakeholders ready to embrace an enlarged project? What would be the willingness of different groups of stakeholders to participate in the innovative solution?
Function	System use-cases	How would the expected results from project's use cases vary to changes in boundary conditions such as the characteristics of the distribution grid on which they are implemented, the load profiles of consumers, etc.
Information	Software scalability	Software modularity Software capabilities, Memory requirements, Computational times (wrt communication time), etc.
	Software replicability	open- source, libraries, etc.
Communication	ICT scalability	How can different applications affect the parameters such as the use of bandwidth, data latency or data loss?
	ICT replicability	Is the communication technology used based on open protocols? modularity, standards, open protocols, etc.
Component	Hardware scalability	Is the technology modular? Is the solution specific to one manufacturer? Complexity of interface design (foreseen increase in interaction among components with scale-up) Are there expected technology evolutions that could facilitate the scale-up?
Component	Hardware replicability	Does it comply with standards? How Dependent is it on the local context (dependence on infrastructures, given resources – solar, wind)

4. SRA QUALITATIVE ANALYSIS QUESTIONNAIRE

The developed questionnaire consecutively evaluates the barriers and drivers related to all dimensions (Table 4), the importance of the latter being different from demonstration to demonstration. Demo leaders have been requested to fill in the questionnaire and their answers have been analysed in order to identify the achievements, drivers and barriers of each demo and also carry out a cross-analysis per group of demonstrations (e.g. VPP or data exchange).

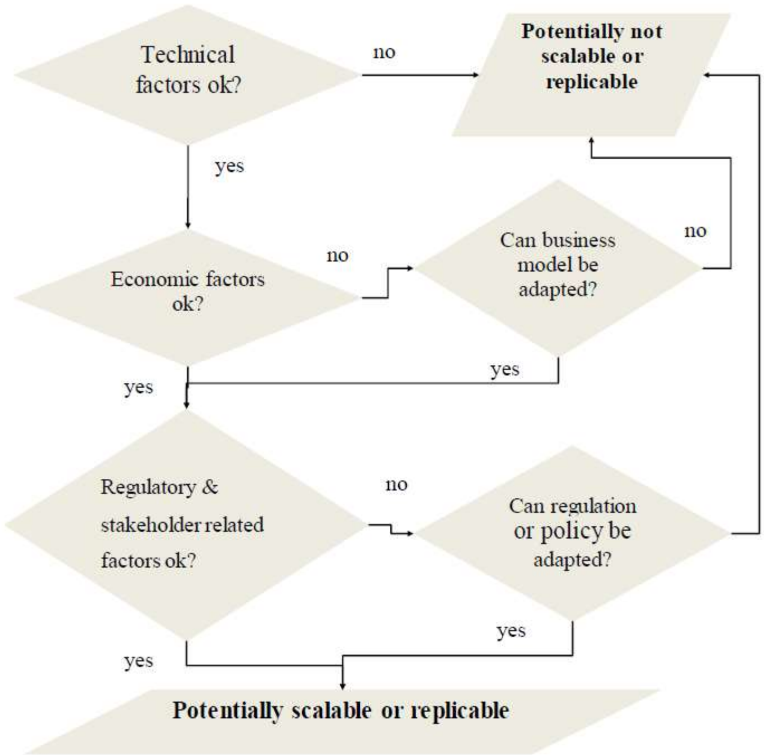


FIGURE 5: OVERVIEW OF THE METHODOLOGY FOR ASSESSING THE DIMENSIONS [SIGRIST L ET AL., 2016]

The evaluation of the answers to the questionnaires has been carried out according to the SGAM layers and their associated dimensions. The diagramme in Figure 5 summarizes the evaluation process and suggests priorities and order of importance of the various aspects. Before all, a demonstration needs to be technically scalable and replicable (otherwise it will not be scaled-up or replicated). For instance, if a demonstration is not technically scalable, it will not be scaled-up even though it is scalable with respect to regulation. Moreover, it also has to be scalable and replicable with respect to economics (otherwise it is not worthwhile to scale it up or to replicate it). On the contrary, impediments with respect to regulation and market design might wane with foreseen evolutions of the former and the latter in the short to medium term.

It is important to mention that the answers from the demonstration leaders reflect the experts'view and results. The advantage of this bottom-up approach is that the experts involved in the demonstrations are the one having the best understanding of the context and the results. A drawback resides in the fact that sometimes the same experts have rather a technical background and may have to find support to answer questions related to non-technical fields such as regulation or economics.

The following paragraphs detail the Scalability and Replicability Analysis of each demonstration. It is followed by a cross-analysis.

5. FINNISH DEMONSTRATOR SRA (WP6)

5.1 SHORT DESCRIPTION OF THE FINNISH DEMO

The Finnish demonstration, located in Helsinki, tested a novel approach for providing services from distributed resources such as various size Battery Energy Storage Systems (BESS) (industrial scale, office scale, customer scale), EV charging stations, residential electricity storage heating load and a PV plant connected to the medium and low voltage distribution networks. These resources are aggregated to be traded by a retailer on the TSO's existing market places and for the DSO's needs. The aim was to provide frequency stabilization services to the TSO and help the DSO manage its reactive power exchanges with the TSO (the reactive power control assists voltage control of the TSO). The specific Finnish demonstrator objectives were:

- The aggregation of small distributed assets in LV and MV distribution networks to the TSO ancillary markets (FCR-N, mFRR/RR) for frequency management
- The introduction of a market based approach for a DSO to purchase reactive power control resources from a local reactive power market (voltage support at the TSO/DSO connection points),

This implied i) forming appropriate forecasting, optimization and control signals for different flexible resources, ii) demonstrating the value chain of harnessing small distributed assets to the benefit of the higher voltage grid stability and iii) evaluating the business potential of the demonstrated solutions (in cooperation with WP11).

A detailed description of the Finnish demonstration will be found in Deliverable D6.9 along with all the results.

5.2 COMPONENT-RELATED DIMENSIONS

5.2.1 HARDWARE

The Finnish demonstrator has been implemented in the low voltage distribution network (400 V), with the exception of an industrial-size BESS and PV power plant, which are connected to the medium voltage grid, as well as to the TSO/DSO connection point (400kV/110kV). The industrial-size BESS and the PV power plant are MV customers for practical reasons. Figure 6 below gives a high level description of the hardware (HW) components involved in the demonstrator.

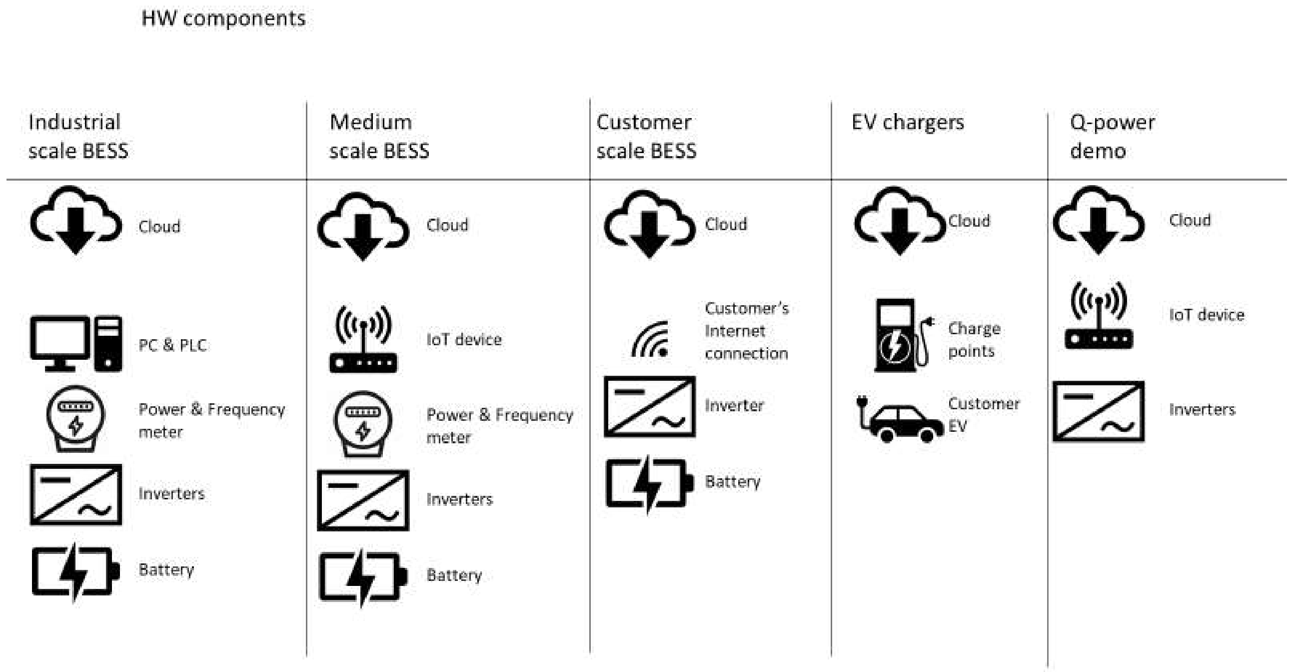


FIGURE 6: HARDWARE (HW) COMPONENTS INVOLVED IN THE DEMONSTRATOR

The DSO's field devices consist of AMR meters. In Finland, every customer has an AMR meter. In the demonstrator area, the electricity heating load of the residential storage electricity heated houses were controlled through AMR meters.

No specific barrier has been identified with respect to hardware scalability and replicability. All hardware components are modular, interoperable, interchangeable. They are standard compliant (mandatory standards). An improvement is however needed concerning the aggregation of customer heating loads. At the moment, the latter is operated via DSO's owned AMR meters and manufacturer specific systems.

5.2.2 TOOLS, SOFTWARES AND SYSTEMS IN THE FINNISH DEMONSTRATOR

Core software tools have been developed during the project:

- a set of forecasting tools that make estimations of the available flexibility of each type assets and the market places where they can be traded. An aggregation platform (that already existed prior to the project) further decides how to form the appropriate bids;
- a proof of concept of reactive power market mechanism (which manages the reactive power bids received from the aggregator and sends activation request to asset operators) and a reactive power dispatch tool.

In addition, communication channels between the assets and the aggregation platform have been developed. Assets are controlled in an IoT-platform with user interface (UI) with built-in control functions. Data is transferred from assets to a cloud service data base.

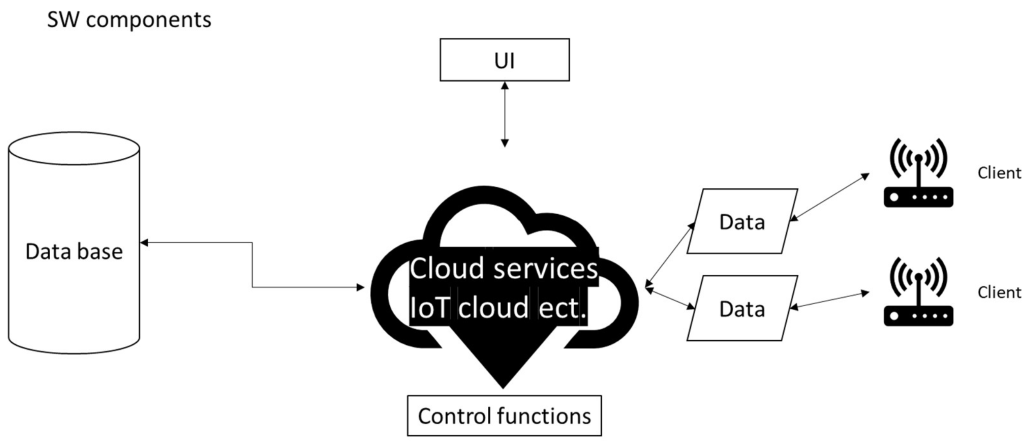


FIGURE 7: IOT PLATFORM AND CLOUD SERVICES

No specific barrier has been identified with respect to softwares scalability and replicability. Softwares are modular, interoperable, portable (Web based cloud service is used). They are not system-specific. Additional functions are easy to implement into the IoT-platform but would however add complexity to the overall system and require more maintenance. Most of the softwares are not open-source because security if crucial as the IoT-platform is licensed and no alternative open source fullfills the requirements. Some applications however use common programming languages such as C#.

5.2.3 ICT IN THE FINNISH DEMONSTRATOR

Figure 8 presents a simplified ICT architecture applicable to most of the Finnish demos. Proxy gateway and trading servers are only used with industrial and medium scale BESS.

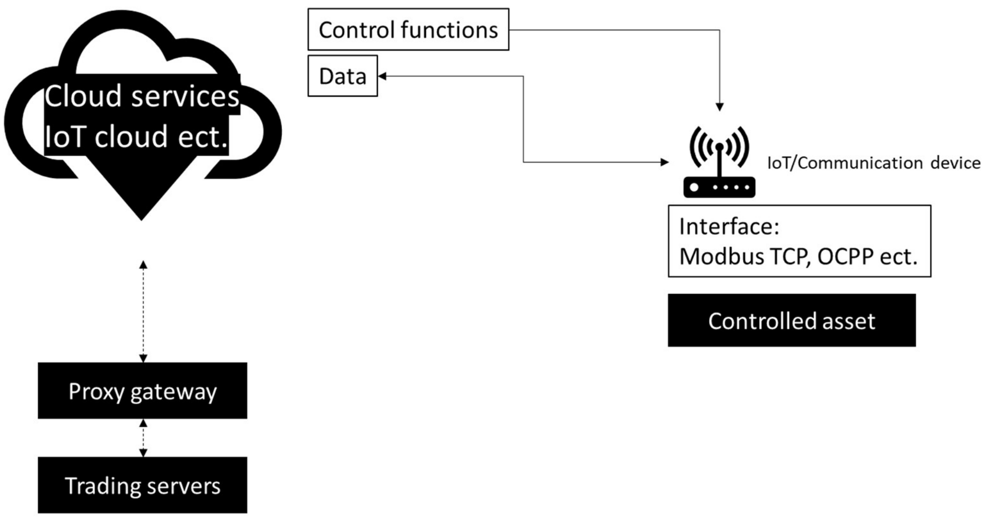


FIGURE 8: SIMPLIFIED ICT ARCHITECTURE APPLICABLE TO MOST OF THE FINNISH DEMOS

There are no hindrance to scalability and replicability from the point of view of ICT architecture. The latter is modular (components such as a forecasting tool can be added to the IoT-platforms) and standard compliant. The current implementation has centralized controls but is planned to have both centralized and decentralized controls as assets of high importance might be better controlled locally.

5.3 BUSINESS RELATED DIMENSIONS

5.3.1 SHORT DESCRIPTION OF THE BUCS OF THE FINNISH DEMO

The BUCs of the Finnish demonstrator are dealing with the aggregation of flexibilities in the distribution grid to meet requirements of both the DSO and the TSO. The BUCs of FI-AP1, FI-AP2 and FI-RP below are reported as they were demonstrated in the Finnish demonstration within the EU-SysFlex project.

- **FI-AP1: Manage active power flexibility to support FCR-N.** Helen, acting as a flexibility aggregator, uses one large BESS, one office-scale BESS and small customer-scale BESSes to participate in the hourly market of the TSO for Frequency Containment Reserves for Normal operation (FCR-N) in Finland. The FCR-N market in Finland is a combination of a yearly capacity market (out of scope of the demo) and a day-ahead, single buyer market cleared on an hourly basis. The energy settlement is made through the usual balance settlement of the associated BRPs. The objectives of this BUC are twofold:
    - Stabilize frequency: The main objective of the use case is for the TSO to stabilize the frequency in response to deviations occurring due to the normal variations in production and consumption.
    - Increased revenues: The aggregator aims at increasing the revenue associated to the operation of its resources. In the case of the demo, this means increasing the income from the operation of the battery systems.
- **FI-AP2: Manage active power flexibility to support mFRR/RR.** Helen, acting as a flexibility aggregator, uses distributed resources to participate to the manual balancing power market (mFRR/RR) of the PSO (Fingrid). This BUC uses residential electric storage heating loads operated through the DSO's owned AMR and their communication and controlling infrastructure. The objectives of this BUC are as follows:
    - Bring the frequency back to the required value: The system frequency after the resources activation should be back within the defined values.
    - Increased revenue: The Aggregator's objective is to improve its revenue by better utilizing its available resources.
- **FI-RP: Manage reactive power flexibility to support voltage control at the TSO/DSO connection points.** This BUC involves the creation of a new market for reactive power - Traditionally, the DN_O controls the reactive power with reactors and capacitors. The market is operated by the DN_O and would be open to all the resources connected to the network which satisfy the requirements. In the demonstration however, only one aggregator participated to the market. Reactive power flexibilities of MV assets were aggregated to offer ancillary services bids to the experimental DSO Reactive Power Market Place. This will enable the DSO to avoid penalties for reactive power exchanges being outside of the allowed PQ-window determined by the TSO. This BUC has two main objectives:
    - Avoid penalties : The DN_O's targets to avoid penalties for reactive power exchanges being outside of the allowed PQ-window determined by the TN_O

- Increase revenue: The Aggregator aims to increase the revenue it gets from operating its resources by providing reactive power services to the DN_O

In the description of the BUCs, the role models are harmonized. In addition, the BUCs described above, e.g. Helen as an Aggregator demonstrated managing active power flexibility to support FCR-D (Frequency Containment Reserves for Disturbance) utilizing EV batteries as a load type (similarly like FI-AP1 but a different market place, now FCR-D).

5.3.2 REGULATION

Fingrid's frequency containment reserve (FCR-N and FCR-D) and mFRR markets apply only in Finland. Therefore the technical solutions implemented in **FI-AP1** and **FI-AP2** rely on elements of current national regulation and market rules that are specific to Finland. However, replication in another member state would only imply minor adaptations since the frequency regulation services are based on similar principles.

The analysis carried out shows that only mild constraints have been identified in terms of national regulation for up-scaling the concept and, as such, some adaptations would be beneficial to facilitate aggregation of a large number of assets:

- Whenever aggregation is necessary, which is the case of small size Battery Energy Storage Systems (BESS) less than 100 kW providing FCR-N or EV charging stations providing FCR-D, lower bid limits for FCR-N (<0.1-MW), FCR-D (<1M-MW) and mFRR (<10 MW with manual activation and <5 MW with electronic activation) would be beneficial due to the increased complexity related to the simultaneous management of a large number of assets.
- The fast response time required for FCR-D (< 5 s) is also seen to be difficult to fulfill.

Regarding the reactive power aspects (**FI-RP**), at the moment, there are no reactive power markets and thus no rules. The demonstration will therefore contribute to define and propose appropriate rules.

5.3.3 ECONOMICS

Economic viability is difficult to assess since there has been no CBA at the demonstration level.

- Regarding the aggregation of battery systems, BESS remain expensive in small (< 100 kW) and mid (< 1000 kW) scale although costs are decreasing. Electricity and power has been cheap and there has not been enough volatility to reach major market income. Moreover, added costs from transmission and taxes might affect negatively the viability. Economies of scale are foreseen for BESS as well as for the IoT platform but complexity increases also with scale. There is therefore a need for a sustained decrease in costs. At the moment, major battery manufacturing facilities will come online in the next years to produce batteries for EVs and this will benefit stationary BESS projects by decreasing battery prices.
- Considering distributed heating loads, the possible benefit to a single household customer (small load) is small. The costs of interface and platform (Aggregator) and possible costs for the DSO are unknown. Again, economies of scale are foreseen.

In the future, the increased penetration of RES in the network will increase the demand for flexibility. It is also very likely that new flexibility markets will bring new income possibilities. This could have a positive effect on the cost-benefit ratio of an up-scaled project.

Business-models have been identified in WP11 (Deliverable D11.29): Fingrid's FCR-N and FCR-D markets, Peak shaving applications, aggregation of heating loads for the mFRR market, aggregation of Q-ressources for Q-markets (see Table 5).

TABLE 5: BUSINESS MODELS OF THE FINNISH DEMONSTRATIONS

Aggregation of BESS	Participating to Fingrid's FCR-N market and sharing market income among BESS owners (this is not viable currently for customer scale BESS). Peak shaving applications in offices, small industrial sites and certain industries with high power peaks. Service sales. BESS sales.
EV Charging stations	Aggregating charging stations to participate in FCR-D market (not viable currently). More EV-charging and energy sold to EV owners. Service sales.
flexibility of electric heating loads via AMR control	For the Aggregator: aggregating heating loads of household customers to participate to the mFRR market and sharing the market income among household customers. For the households: Providing heating loads to the Aggregator and receiving profit from the Aggregator.
Reactive power market	For the DSO: saving of tariff costs (TSO/DSO tariff in the TSO/DSO interface). For the Aggregator: aggregating reactive power resources of asset owners, providing these to the Q-markets and sharing the market income among the asset owners. For the asset owners: providing reactive power resources to the Aggregator and receiving profit from the Aggregator.

Market are fully ready for industrial-scale BESS and it is a strong case for immediate scalability. However, regarding the other applications considered in the Finnish demo, markets are not fully ready yet:

- Medium and small-scale BESS prices are still high (€/kWh). Added costs from transmission fees and taxes might also affect negatively the scalability,
- There is the need of additional infrastructure for EVs (more chargers). Also, the market revenue is currently small,
- The demo of electric heating loads via AMR control was only simulated. The technical solution is unfinished and therefore there is no market yet,
- There is no reactive power market yet. The market size would be limited.

Competition is likely to be high in the near future since aggregating distributed assets to provide services to the TSO will become critical. Multiple companies have already tested and implemented the provision of frequency control with aggregated BESS in several countries. The aggregation of EV charging stations is also being tested (e.g. the Equigy platform) for congestion management or providing FCR and aFRR.

For all assets owned by end-use customers, the acceptance is very critical. The replicability can not be reached without these customers. Accessing data requires agreements. Besides, the smaller the customer the smaller are the profits. Therefore, the technology, equipment, control systems should be simple enough to use and economical.

5.4 FUNCTIONS AND SERVICES, INFORMATION AND COMMUNICATION

The Finnish demonstrator is based on four System Use Cases (SUC):

- **FIN - FC, Forecast available resources (for P and Q)**. The implemented functionality in this SUC is the forecast of distributed assets (EV resource, BESS resource, small batteries, electrical heating loads, PV resource);
- **FIN - FL AG, Aggregate flexibilities (for P and Q).** The implemented functionalities in this SUC are the flexibility aggregation and the Bid making tool;
- **FIN - RP MN, Manage reactive power** (Q only). This includes functionalities of State estimation of PQ window and Estimation of DSO's need of distributed resource (Q)
- **FIN - RP MK, Perform DSO reactive power market** (Q only). This includes functionalities for Resource validation and Reactive power market mechanism

These SUCs are not expected to vary according to changing boundary conditions which is favourable to replicability.

Information exchange is needed for active power trading on the TSO market and also for trading reactive power on the DSO market. However, in the Finnish demonstrator, the two SUCs, namely "FIN – FC" and "FIN – FL AG" are needed for both active and reactive power trading. Forecasting ("FIN – FC") and aggregation ("FIN – FL AG") are the two needed steps in proceeding to the FCR-N market or to the mFRR market for active power as well as for proceeding to the DSO reactive power market place.
Reactive power trading on the DSO market includes additionally the SUCs "FIN – RP MN" and "FIN – RP MK", which together determine the operation of the DSO's market place.
The Finnish demonstrator almost entirely focused on developing new systems and features, and also a novel market approach for reactive power as a proof of concept basis. Existing protocols and data models have been used.

Data communication takes place for active power between the TSO, the forecasting tool, the aggregation platform and the field assets. Regarding reactive power, data communication exists between the DSO, the forecasting tool, the aggregation platform, the field assets and the Q market place.
For the "**Simulated scenarios: flexibility of electric heating loads via AMR control**", in EU-SysFlex, the communication was only tested between the AMR reading system of a specific manufacturer and the present

generation AMR meters. The communication between Aggregators and AMR reading systems was not tested. The next generation AMR meters are to be installed during the next decade.

For the “**Reactive power market demo”** the communication between the forecasting tool and the DSO, the DSO and the Q market place, Q market place and the Aggregator took place in the demonstration by emails and csv-files. There is not seen any near future of the reactive power market, so the questions related to the communication layer are not answered here.

The communication protocols used in the Finnish demo are REST, Modbus TCP, IEC104, OCPP (EV-chargers). They are standard which is favourable for replicability. There are no limitations foreseen upon upscaling (volumetry, …). Latency is in general not critical. However, it could become critical when FCR-D (disturbance) market assets are controlled from the cloud and not from a local control logic. At present, when control signals are sent from the cloud (in the case on EV-chargers), FCR-D assets don’t react fast enough (< 5 s) to meet requirements. BESS used for providing FCR-N (normal) have a much longer (and favourable) response time requirements (3 min). This can be considered as an hindrance in the SRA with respect to communication even though this could be solved in the short to medium term by adapting the rules to allow a slower reaction.

5.5 SUMMARY OF THE FINNISH DEMO SRA

The Finnish demonstration is technically scalable and replicable. The potential hurdles are related to the regulation and economic dimensions of the SRA.

No barriers have been identified in terms of national/regional regulation for frequency regulation (lower bid limit for FCR-N and FCR-D would be beneficial to facilitate aggregation). Some adaptations would however be beneficial to facilitate aggregation of a large number of assets: lower bid limits and a larger fast response time required for FCR-D which is currently seen as difficult to fulfill.

FCR-N, FCR-D and mFRR markets apply only in Finland but in other countries frequency regulation services rely on similar principles and therefore only minor adaptations would be needed to adapt them to the new context.

In contrast, there is at the moment no DSO reactive power market in Finland and elsewhere and thus no rules. This means that there is a need for changes in regulation/market rules to allow the related BUC (FI-RP: Manage reactive power flexibility to support voltage control at the TSO/DSO connection points). This is a hurdle that could be long-lasting as compared to the limitations related to the frequency regulation services.

Some concerns have been raised about economic viability. BESS are still expensive in small (< 100 kW) and mid-scale (< 1000 kW) and that could compromise the profitability of such a project on the short term. Moreover, electricity and power has been cheap and there has not been dramatic volatility. On the contrary, if having high electricity and power prices and major volatility totally different market opportunities could be available to reach higher income from the markets. On the other side, added costs from transmission and taxes might affect negatively the viability. This could be slightly compensated by economies of scale which are foreseen in a scaled-up concept. There is in all cases a need for decrease in battery costs and this is expected to happen on the short to medium term due to the current development of the electric mobility.

Business-models have been identified in WP11. However, the market not fully ready yet: there is the need of additional infrastructure for EVs and the establishment of a reactive power market.

For all assets owned by end-use customers, stakeholders'acceptance is very critical. The replicability can not be reached without these customers. Agreements are needed e.g. to operate the customer owner assets and to benefit the customers from the flexibility operations with their assets.

Communication protocols are standard. No limitations are foreseen upon upscaling (volumetry, …). Latency could be critical if FCR-D (disturbance) market assets are controlled from the cloud and not from the local control logic.

Hardware components are modular, interoperable, interchangeable.

Softwares are modular, interoperable. They are not system-specific. No problems have been identified in terms of programming language.

ICT is modular , centralized control. It is planned to have both centralized and decentralized controls depending on the asset type and importance. An asset with high importance might be better to control locally.

6. GERMAN DEMONSTRATOR SRA (WP6)

6.1 SHORT DESCRIPTION OF THE GERMAN DEMO

The German Demonstrator has been implemented in the HV (110 kV) distribution grid of Mitteldeutsche Netzgesellschaft Strom mbH (MITNETZ STROM) in the south of Brandenburg and Saxony-Anhalt and in the west and south of Saxony. The high share of Renewable Energy Sources (RES) in the northern and eastern part of Germany causes congestions in the transmission and distribution grids and substantial ReDispatch (schedule adjustments) measures are necessary. As a matter of fact, the ReDispatch potential in the transmission grid reached its limits due to the minimum capacity of conventional power plants. It makes it necessary to move to more efficient congestion management processes with a good coordination of actions between TSOs and DSOs. The German demonstration aims at enabling the provision of active and reactive power flexibility range to the TSO (50Hertz) from decentralized resources connected to the HV distribution grid of MITNETZ STROM to support congestion management and voltage control at the interface grid node with the transmission system in a system with a high share of RES.

In the grid area of MITNETZ STROM the installed capacity sums up to 10.2 GW of distributed energy resources (DER), of which more than 8.5 GW are renewable energy resources (RES). The German demonstrator uses the assets connected to HV with an installed capacity of 5.2 GW DER, thereof are 3.7 GW RES. The aim was to offer these available flexibilities to the TSO, who operates the extra-high voltage (EHV) grid of 220 kV and 380 kV.

The main objectives aimed at:

- Setting-up a new process and coordination for **congestion management**;
- Developing a new automated tool for **voltage control and reactive power management**.

To fulfill these objectives, the following tasks had to be pursued:

- forecasting generation and consumption connected to the HV grid;
- predicting power flows in the HV grid, including possible power flows due to contracted capacities for frequency stability services which might be activated by the TSO;
- taking into account all grid constraints due to security reasons in the distribution grid including flexibility activation for congestion management in the distribution grid;
- providing information of the available flexibility potential of active power (day-ahead and continuous intraday update) and reactive power (first indication day-ahead and continuous intraday update) to the TSO;
- enabling the delivery of flexibility services and the execution of the TSO’s calls for flexibility.

A detailed description of the German demonstration will be found in Deliverable D6.7 along with the all the results.

6.2 COMPONENT-RELATED DIMENSIONS

6.2.1 HARDWARE COMPONENTS OF THE GERMAN DEMONSTRATOR

The hardware aspects are out of scope of the SRA of the German demonstration which uses existing assets.

Table 6 shows a summary of these resources. The Demonstrator included 17 TSO/DSO interfaces at the EHV/HV interface with 42 transformers. Only generation resources were used by the demonstration for providing flexibilities. Nonetheless, the developed system is prepared to include other flexibility resources such as loads connected to the HV grid as well.

TABLE 6 – HARDWARE RESOURCES INVOLVED WITHIN THE GERMAN DEMONSTRATOR.

German Demonstrator	
DSO operating voltage	110 kV
Operating voltage at TSO/DSO interface	• 380 kV / 110 kV • 220 kV / 110 kV
DSO assets	-
Flexibility resources	• 2.7 GW wind (HV grid) • 1 GW PV (HV grid) • 1.5 GW thermal power plant (HV grid)
DSO field devices	• Out of scope

6.2.2 TOOLS, SOFTWARES AND SYSTEMS IN THE GERMAN DEMONSTRATOR

For the implementation of the German Demonstrator multiple tools have been used and developed. Table 7 shows a summary of these tools.

TABLE 7: SOFTWARE TOOLS DEVELOPED FOR THE GERMAN DEMONSTRATION

German Demonstrator	
Tools/ Software/ Systems	• DSO SCADA system - enhancement • BeeDIP (Optimization, State Estimation, Congestion Management) • Forecast System (supports the BeeDip system with day ahead and intraday forecast of generation and load considering weather and grid data) • State estimation for day-ahead and intraday load flows and voltage levels based on forecast system and grid data (e.g. maintenance, switching states, etc.) • Active power loss optimisation • Active power coordination tool • Reactive power coordination tool

The DSO SCADA system already existed and was used. Its functions have been enhanced due to the development of the beeDIP system. The functions of beeDIP are state estimation, topology analysis, grid optimisation and congestion management. The forecast system supports the beeDIP with day ahead and intraday forecast of generation and load. To enhance the forecast, weather and grid data will be considered.

No specific barrier has been identified with respect to softwares scalability and replicability. Softwares are modular and, provided that minor modifications are brought, allow an easy addition of extra functionalities. There are no foreseen limitations that could affect the proper operation of the software tool apart from the calculation power which may be affected by a large increase in grid size. Besides, the current computer architecture (memory size, CPU time, data storage), apart from the software tool itself, do not impose any limitation on the maximum size of the system.
The tools are not too system-specific. They can easily be adapted to another host grid with minor changes which is favourable to replicability.
The programming languages which are used are Pandapower (open-source) and AMPL (licensed tool) and the developments are Linux-based. The tools are standard compliant, use open-standards and are interoperable which is a strong case for replicability.

6.2.3 ICT IN THE GERMAN DEMONSTRATOR

The ICT architecture aspects are out of scope of the SRA of the German demonstration which uses existing components.

6.3 BUSINESS USE-CASES OF THE GERMAN DEMONSTRATOR

The German BUCs (see Table 8) are designed to enable the provision of flexibility services from DSO connected sources to the TSO for congestion management due to line loadings and for voltage control. In addition, the DSO itself is using the same services in order to sustain a stable and secure grid operation in the distribution grid:

TABLE 8: BUCS OF THE GERMAN DEMO

Demonstrator	Business Use Case	BUC ID
German	Manage active power flexibility to support congestion management and voltage control in the German demo	DE-AP
German	Manage reactive power flexibility to support voltage control and congestion management in the German demo	DE-RP

The BUC DE-AP addresses active power management mainly for solving congestions whereas the BUC DE-RP describes the reactive power management mainly for voltage control, both services delivered to the transmission grid. These business use cases enable the TSO to react on active and reactive power needs respectively for congestion and voltage control management with a known flexibility at the DSO-TSO interface. The strong link between active and reactive power management leads to a similar process for both BUC. The result is a P/Q-map of set points and flexibility ranges at the TSO-DSO-interface. The DSO has de facto priority to use resources connected to its own grid. The DSO studies its constraints and if some appear, solves them with the flexibility available before offering the remaining flexibility to the TSO. The flexibilities are not prioritised according to the voltage level but rather according to the sensitivity on the congestion and the costs. The underlying principle of this approach is that only a distribution grid without congestions and voltage issues can make distribution grid connected flexibility for transmission grid available.

6.3.1 REGULATION

As far as regulation is concerned, there is no identified barrier at regional/national level or in other countries. The current regulation authorizes[1] re-dispatching, curtailment (mandatory provision) and reactive power provision. The two BUCs do not need new regulation but only agreements between actors to follow the process of the BUC. Furthermore, a regulatory change could enlarge the scope of the use cases by allowing loads to participate to a 'local market' instead of the present mandatory design where only generation can participate. This would be a positive development.

6.3.2 ECONOMICS, STAKEHOLDERS

The demonstrator is already at industrial scale and the market is ready for the deployment of such a solution even if there is at present no clear knowledge of possible competitors.
No barrier has been identified in terms of stakeholders'acceptance.

6.4 FUNCTIONS AND SERVICES, INFORMATION AND COMMUNICATION

The innovation of the German Demonstrator is the inclusion of RES in congestion management by setting up a new and coordinated process for congestion management and developing an automated tool for voltage control and reactive power management. For those reasons, the integration of new and improved forecasts for RES generation and load were needed. The SUCs of the German demonstration are as follows:

- DE – COM, Perform data communication for the German Demo
- DE – DATA, Perform data management for the German Demo
- DE – FC, Forecast of load and in-feed for German Demo
- DE – OPF, Optimize network state for the German Demo
- DE – APC, Enabling Provision of Active Power Flexibility from DSO for TSO in the German Demo
- DE – RPC, Enabling Provision of Reactive Power Flexibility from DSO for TSO in the German Demo

In order to fulfil the tasks defined in the System Use Cases, 14 functionalities needed to be implemented. Figure 9 shows the mapping of functionalities with the respective SUCs.

[1] The German regulation actually changed at the beginning of the EU-SysFlex project to allow for redispatching in the DSO network.

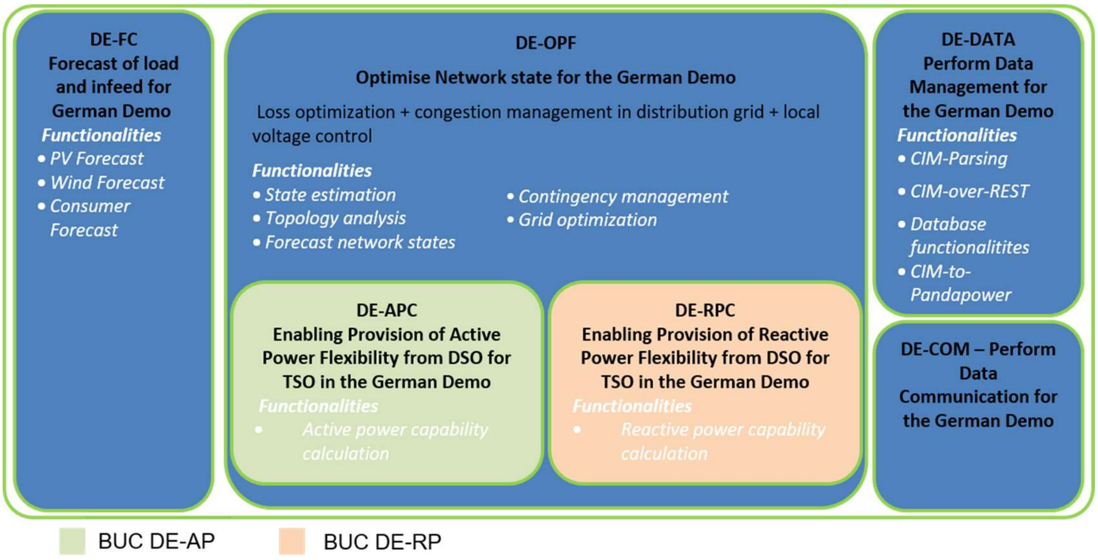


FIGURE 9: MAPPING OF SUCS AND FUNCTIONALITIES

In the German demonstration the data exchanges between the DSO and external roles are described in one SUC, namely "DE–COM - Perform data communication for the German Demo". The data exchanges that the Forecast Provider needs with external roles is described in the SUC "DE–FC - Forecast of load and in-feed for German Demo". The processing of the data is described in the other SUCs. The German demonstrator's internal communication is described in the SUC "DE–DATA Perform data management for the German Demo".
The expected results from the system use cases (SUCs) are not expected to vary to changes in boundary conditions and this is favourable to replicability.

The protocols used in the German demonstration are already used by the DSO for various other data exchange purposes and no new additional protocol is needed. They are are standard and therefore would facilitate replication. Figure 10 and Table 9 summarize, for each pair of systems, the information exchanged, what kind of systems communicate, the protocol used for the data transfer and the reason for choosing that protocol. In Figure 10 the plain arrows show communication channels used and implemented in the demonstrator. They are tagged with the data models (e.g. CIM) and the communication protocols (e.g. IEC 60870-5-101) used for the exchanges. The dotted arrow represents communication that is relevant for the system but are out of scope of the demonstrator.

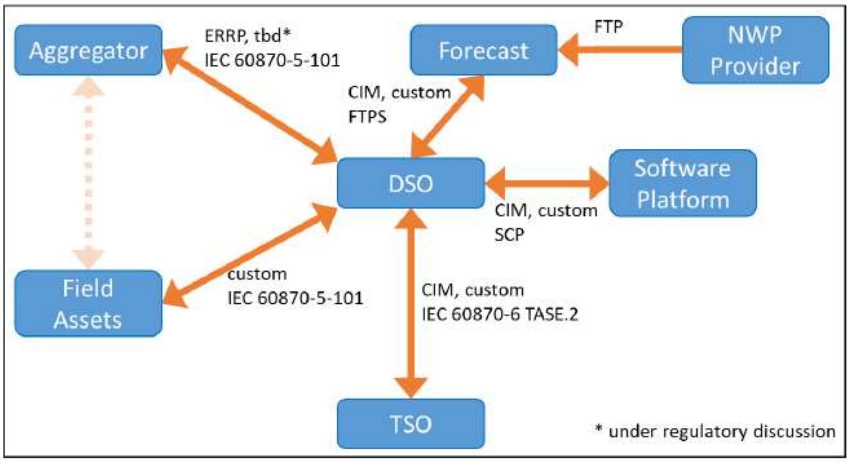


FIGURE 10: SIMPLIFIED COMMUNICATION IN THE GERMAN DEMONSTRATOR (THE DASHED ARROW IS AN INTERACTION OUT OF THE DEMONSTRATOR'S SCOPE)

SYSTEM 1	SYSTEM 2	PROTOCOL	REASON
DSO	FIELD ASSETS	IEC 60870-5-101	Historical, security
DSO	AGGREGATOR	Regulation under discussion	Historical
AGGREGATOR	DSO	IEC 60870-5-101	Security
DSO	SOFTWARE PLATFORM	SCP	Security
SOFTWARE PLATFORM	DSO	SCP	Security
DSO	FORECAST	FTPS	Security
FORECAST	DSO	FTPS	Security
TSO	DSO	IEC 60870-6 TASE.2	Security
DSO	TSO	IEC 60870-6 TASE.2, CIM	Security
NWP PROVIDER	FORECAST	FTP	System given by Provider

TABLE 9: COMMUNICATION LAYER SUMMARY FOR THE GERMAN DEMONSTRATOR

An additional important point for the demonstration is the availability and accessibility of the data needed.

6.5 SUMMARY OF THE GERMAN DEMO SRA

The German demonstration is already at industrial-scale therefore the main focus was replication of the concept in a different host environment and not the increase in size.

No barriers have been identified in terms of regulation whether at regional/national level, or in other countries. The current regulation authorizes re-dispatching, curtailment (mandatory provision) and reactive power provision. The two BUCs do not need new regulation, but only agreements between actors to follow the process of the BUC. As for the other demos, the economic viability has not been studied in the project (no CBA). However the market is ready but there is no clear knowledge of possible competitors.

There is no barrier either in terms of stakeholders'acceptance.

Expected results from SUCs don’t change with boundary conditions which is favourable to replication. Communication protocols are standards. There is no limitation foreseen in terms of volumetry or else.

The hardware and ICT architecture were already existing and were not part of the innovation. They were thus out of scope of the SRA. Softwares are modular and can easily be added extra functionalities. There could be possible limitations due to grid size (in terms of calculation power) and a slight dependance on the grid topology. The tools are standard compliant, use open-standards and are interoperable which is a strong case for replicability

7. ITALIAN DEMONSTRATOR SRA (WP6)

7.1 SHORT DESCRIPTION OF THE ITALIAN DEMO

The Italian demonstration site is located in the area of Forlì-Cesena (Emilia Romagna region) which is characterized by a strong penetration of renewable generation (mainly PV), along with low consumption in comparison with the generated energy. The back-feeding phenomena from MV to HV is observed frequently. The Demonstrator explored the evolution of distribution network infrastructure, by integrating the monitoring systems with advanced smart grid solutions, for encouraging the ancillary services provision (e.g. voltage control, congestion management, frequency balancing) taking into account both TSO and DSO needs and constraints. This was made possible due to:

- tools/systems/devices development and integration within the DSO infrastructure;
- the development of new actions needed for a better coordination between the TSO and the DSO;
- the improvement of the real knowledge of the network state and its utilisation thanks to updated network observability and forecasting systems;
- optimization of the distribution network operations, by exploiting DERs and DSO assets.

In the Italian Demonstrator, these goals have been reached thanks to:

- The definition of the data exchange automated process between DSO and TSO;
- Power modulation at HV/MV substation level for TSO necessity.

The first point allows a better coordination between DSO and TSO and a better observability from TSO of the power system allowing it a more accurate management of the system. The second one allows the distributed resources to provide ancillary services to the transmission network. This facilitates not only a better management of the transmission network, but also a better management of the distribution network thanks to the advanced controls adopted by the DSO.

The innovation of the Italian Demonstrator consists in including RES, Storage and STATCOM in the congestion management, balancing and voltage regulation of both transmission and distribution networks. From a technical point of view, the most important innovative elements developed in the project, improving the results coming from the activities performed within Grid4EU, are listed below:

- The installation of a STATCOM, a new element in the grid of e-Distribuzione to pursue voltage support by reactive power regulation;
- The function of aggregated reactive power capability calculation. This function allows the DSO to determine the reactive power that can be provided by local resources to the TSO;
- An improvement of optimization algorithm that can optimize the network state in order to obtain a desired exchange of active and reactive power at the Primary Substation (HV/MV substation);
- Improved exchange of data between DSO and TSO for a better coordination and a better observability for the TSO of the aggregated flexibility at the primary substation interface.

A detailed description of the Italian demonstration will be found in Deliverable D6.8 along with the all the results.

7.2 COMPONENT-RELATED DIMENSIONS

7.2.1 HARDWARE

The Italian demonstrator includes one existing HV/MV substation (Quarto primary substation 132/15 kV) and all the MV feeders connected to it. The primary substation of Quarto includes two transformers named Red and Green transformers. The involved portion of distribution network includes:

- 1 HV/MV (132/15 kV) substation and all 8 MV feeders connected to the substation;
- About 330 MV/LV (15/0.4 kV) substations;
- Installed DER Capacity: 39.8 MWp
- Average energy produced per year: ~46 GWh/y.

The central management of the MV network portion (and of the Italian demonstrator) is carried out by the Operating Center located in Bologna. It also includes different types of flexible resources:

- four PV generators,
- a 1MVA/1MWh Battery Energy Storage System (BESS),
- 1 STATCOM module per MV busbar,
- 2 OLTCs at HV/MV Transformers

The BESS and the STATCOM are managed by the DSO, within the limits of the present Italian regulations.

All the available resources are involved in voltage regulation services tested in the field, while the integration of RES and Storage for congestion management and frequency balancing for the transmission grid is only simulated because the national regulation framework is still in progress. The voltage regulation is tested by interfacing RES and DSO resources (Storage, STATCOM and OLTC) with the existing infrastructures, composed by field devices and SCADA system.

7.2.2 TOOLS, SOFTWARES AND SYSTEMS

The core tools that have been developed during the project are

- a forecast system (observability),
- a dedicated software optimisation tool, embedded in the NCAS (Network Calculation Algorithm System) module of the Local SCADA. This tool includes also a network simulation functionality. Through this optimization tool, the system operator can manage its own assets and other controllable resources, minimizing the dispatching costs, avoiding network violations and RES curtailment (hosting capacity of the network is also positively affected).

Table 10 shows a summary of these tools.

TABLE 10: SOFTWARES DEVELOPED AND USED IN THE ITALIAN DEMONSTRATION

Resources	Italian Demonstrator
Tools/Software/Systems	- DSO Central SCADA (OCS – Operative Central System) - Local SCADA (at HV/MV substation) located in the primary substation with local control and Network Calculation Algorithm System - Optimisation tool (including network simulations) embedded in the Local SCADA - Forecast System

In red: already existed prior to the EU-SysFlex project

7.2.3 ICT

The HV/MV substation RTU TPT2020 implements standard remote-control features and manages advanced voltage regulation functions. In compliance with IEC 61850 standard, it sends commands and setpoints to Primary and Secondary Substation IEDs (Intelligent Electronic Devices) which are amongst others:

- DV7500, the Integrated Transformer Protection performs automatic voltage regulation, acting on the OLTCs of HV/MV Transformers
- DV7203, the HV/MV Substation feeder protection panel, with advanced network automation features;
- RGDM, the MV/LV Substation advanced fault detector, able to guarantee advanced network automation features.

This new generation of IEDs is also called to collect measurements of voltage, current, active and reactive power, power factor and so forth, with a high accuracy, along the whole distribution network, thanks to an always-on communication infrastructure.

RGDMs can communicate with IRE (Energy Regulation Interface), exploiting GOOSE messages publishing and subscription, in order to implement set-points on full controllable PV plants involved in the experimentation, and to acquire from the active users all the local measurements, with a time step of 10s, to be sent to the TPT2020 and then to the DSO SCADA.

7.2.4 IMPACT OF COMPONENTS ON S&R

Technically the demonstration is scalable and replicable. No barrier has been identified regarding components that could hamper the ability to enlarge the size or deply the solutions in another host grid.

The hardware is modular and would require only moderate change when adding additional assets. The devices installed in the distribution network allow high modularity. The conversion of a primary substation requires installation and configuration activities by field crews, even if the communication design is available. The IEC-61850 is used by Enel in a mandatory way. Device manufacturers must homologate their devices by respecting Enel imposed profiles. There is thus the possibility to integrate a higher number of devices and to manage a higher number of data coming from the field.

Besides, the hardware is standard compliant and interoperable which can facilitate replication. Each kind of device is called to perform specific functions and every component is designed to be connected to other devices. This is allowed by the mechanism of Client-Server Communication typical of IEC 61850 IEDs. As a consequence, it is possible to connect several kind of RTUs to different kind of Fault Detectors or devices, by respecting the same communication protocol.

Software components are modular and would allow an easy addition of extra functionalities such as new regulation algorithms that could be integrated within the platform. Limitations in terms of computational efforts when adding extra functionalities are hard to predict for Network Calculation since it would depend on the specific characteristics of such functionalities and/or the performances of the hardware itself. This would however affect moderately the scalability. Regarding the SCADA issues, it could be necessary to increase the virtual machine memory included in the platform. However, normally the latter is oversized which facilitates a scale-up.

Broadly speaking, the software tools are interoperable and can be implemented in different control architectures and are able to model a wide range of infrastructure; specific devices and infrastructure models can be added with minor efforts but, in general, mild tune-ups should be made every time the tools are applied to a new infrastructure system or control architecture, as it is in the most practical applications. In any case the platform can manage any network topology which is favourable to replicability.

The platform is an evolution of the used remote control system in DSO operations and it is already developed in Linux environment. It is compliant to any communication standard already used by the DSO towards other external systems and devices The SCADA is standard compliant and uses proprietary standards.

The ICT architecture is modular. Its control is dencentralised. It is standard compliant (proprietary).

7.3 BUSINESS-RELATED DIMENSIONS

The Italian BUCs were defined within the activity performed in Task 3.3 *Functional specification of system services in terms of Business Use Cases* and are detailed in Deliverable D3.3 - *Business use cases for innovative system services* [1] and are respectively:

Demonstrator	Business Use Case	BUC ID
Italian	Manage active power flexibility to support mFRR/RR and congestion management in the Italian demo	IT-AP
Italian	Manage reactive power flexibility to support voltage control and congestion management in the Italian demo	IT-RP

The BUC IT-AP describes a business process focused on provision of active power flexibilities from distribution grid for mFRR/RR and congestion management services to the transmission network, in real-time operations. The main scopes of this business process are procuring aggregated flexibility services at Primary Substation interface, guaranteeing secure operations of the distribution grid, and increasing distributed energy resources participation in the transmission network mFRR/RR market. Therefore the business process described in the BUC IT-AP needs, specifically, the availability of tools for network state evaluation and flexibilities forecast and functions for network techno-economical optimization.

The Italian demonstrator contains some DSO-owned assets, specifically the battery storage, that through the injection/absorption of active power, may alter the network state and potentially influence the local market operations. Furthermore, since it is owned and managed by a system operator (which is not allowed to trade energy by the regulation), it cannot participate to the market like other flexible resources. For these reasons, within the boundaries of the BUC IT-AP and the project activities, it is exploited only for solving imbalances (counter-activations in case of activation of flexibilities for local congestion managements) and, in general, for market facilitation purposes.

The BUC IT-RP describes a business process focused on the management of the reactive power exchange at primary substation interface, for supporting voltage control and congestion management services for the transmission network, in real-time operations. The main scopes of this business process are the management of a reactive power flexibility portfolio, focused at the provision of a broad reactive capability area at primary substation interface, and the optimisation of the distribution network state, allowing the DS_O to procure the contracted reactive while maintaining secure operations of the distribution network. Therefore the business process described in the BUC IT-RP needs, specifically, the availability of tools for network state evaluation and flexibilities forecast, tools for capability aggregation and for network optimization.

7.3.1 IMPACTS OF REGULATION ON S&R

As regards regulation, the main limitation that could affect the scalability of the proposed architecture, as of now, is related to the current prohibition for the DSO to own and manage storage which can be considered as a lasting impediment for scalability and replicability unless the role of DSO evolves. The technical solution implemented in the demo, which is considered as effective from a technical and and operational point of view, will only be deployed whenever there is an adaptation of the regulatory framework (implementation of EU Directive 2019/944 on common rules for the internal market for electricity). Without that, the technical solutions could neither be upscaled nor replicated.

Moreover, there is currently, in Italy, an absence of remunation mechanism of network and market services provided by DER and resources in general to the distribution networks. To be able to have a large-scale deployment of the concept, there is the need for these barriers to be removed and that new rules be enacted by Regulators regarding remuneration, roles and responsibilities for DSOs, Owners of DERs of DGs and finally (eventually) BSP.

7.3.2 IMPACTS OF ECONOMICS ON S&R

The business opportunities for the project deal mainly with the satisfaction of the needs related to the optimization of network management and operation in terms of voltage regulation, losses reduction, data exchange and observability for TSO, thus improving and updating the coordination process between the two system operators.

As far as the economic viability is concerned, the absence of remuneration mechanism and the incomplete knowledge about price levels of local flexibility services in real conditions does not allow to do a comprehensive cost / benefit analysis. It is however possible to define a technical benefit taking into account savings for voltage level violation avoidance or an estimation of contribution for dispatching optimization, but it is impossible to determine a cost-benefit ratio or a Net Present Value (NPV). Furthermore, the current growth of more advanced flexibility services markets such as in the UK indicates that the business model is sufficiently sustainable from an economic point of view in Europe.

The market is not ready yet since current regulation rules don't allow the deployment of the concept. With respect to this aspect, the transposition at national level of European (continental) of Networks Codes and rules (in force and new) is very important, and this supports a general standardization process of the elements and solutions which have been analysed in the demo.

7.3.3 IMPACTS OF STAKEHOLDERS'ACCEPTANCE ON S&R

A transparent and participatory process including all relevant system users and transmission system operators to establish the specifications for the flexibility services procured and, where appropriate, standardized market products will be crucial to obtain acceptance. In particular, co-ordination with the TSO and wider energy markets will be key. The stakeholders' willingness to embrace a scaled-up project will indeed depend on the price level i.e. the profitability of the services and the conditions of participation (for example the qualification criteria). The acceptance of the following stakeholders is considered as important: customer associations (including consumers, prosumers, producers), other utilities, technical committee in general to define exactly general requirement for devices, systems and apparatous in accordance with requirements, rules, functions, etc …

The main challenge remains the stakeholders' involvement. A 'learning by doing' approach to trial and test several aspects is needed, in order to define common products and standardized contractual terms, ensure visibility and ease of access i.e. low barriers to entry (e.g.: size). Marketing support will be necessary to favour engagement and drive initial participation, accessibility (e.g. co-design of new arrangements) transparency and neutrality (e.g. publish tender framework, assessment criteria, tender results) are essential to succeed in the long run.

Similar approaches have been adopted in other Enel projects and shared with local Authorities of other countries.

7.4 FUNCTIONS AND SERVICES, INFORMATION AND COMMUNICATION

The SUCs of the Italain demonstration are as follows:

- IT – NT SE: Perform network state analysis for Italian Demo
- IT – RPC:Perform reactive capability calculation for the Italian Demo
- IT – AP OP: Perform distribution network optimization after local market closure
- IT – RP OP: Perform distribution network management and optimization for the Italian Demo

Expected results from the system use cases (SUCs) will vary moderately to changes in boundary conditions, for instance, in case of change of model adopted to manage the planning and execution of service by the DSO with respect to the TSO. This would not affect replicability.

For each of the four SUCs listed above, the information exchanges take place between the following systems:

- Data communication between the SCADA systems, the remote terminal units and the field devices for network state estimation

- Data communication between the central and local SCADA systems
- Data communication between the DSO's central scada and the market operator
- data communication between the SCADA systems, the remote terminal units and the field devices for network optimization

Most of the protocols were already defined because the majority of the systems were already in place at the beginning of the demonstrator. The innovations of the demonstrator regarding the communication lied mainly in **updating and extending the existing data models and profiles in order to integrate new devices (e.g. STATCOM) or extensions of functionalities**.

Figure 11 and Table 11 summarize, for each pair of systems, the information exchanged, what kind of systems communicate, the protocol used for the data transfer and the reason for choosing that protocol.

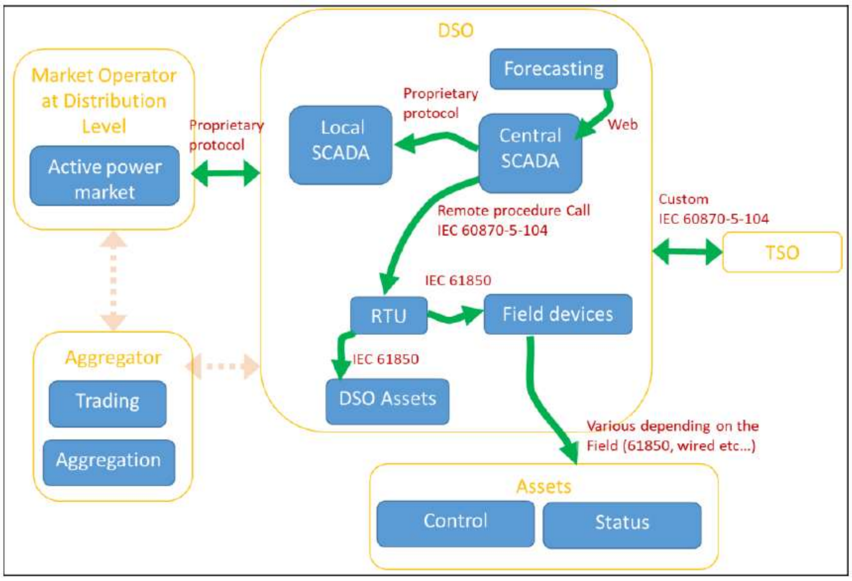


FIGURE 11: SIMPLIFIED COMMUNICATION IN THE ITALIAN DEMONSTRATOR

SYSTEM 1	SYSTEM 2	PROTOCOL	REASON
CENTRAL SCADA	RTUS	RPC (PROPRIETARY STRUCTURE) IEC 60870-5-104	HISTORICAL SECURITY
FIELD DEVICES	RTUS	IEC 61850	INNOVATION
RTUS	DSO ASSETS	IEC 61850	INNOVATION
CENTRAL SCADA	LOCAL SCADA	PROPRIETARY	SECURITY
CENTRAL SCADA	MARKET OPERATOR SCADA	PROPRIETARY	SECURITY
DSO	TSO	IEC 60870-5-104 TELEPHONE MAIL	SECURITY
TSO	DSO	TELEPHONE MAIL	SECURITY
DSO	FORECAST	FTPS	SECURITY

TABLE 11: COMMUNICATION LAYER SUMMARY FOR THE ITALIAN DEMONSTRATOR

The main used standard is IEC61850 within smart grid devices in primary and secondary substation. This standard allows to transmit a high amount of signals, events and measurements from several devices to a centralized SCADA.

Moderate limitations could arise in terms of communication volumetry, use of bandwidth, data latency or data loss with the increase of the number of connected equipments or due to bottlenecks created by low latency network. However, this should not not be a hindrance provided that the communication network is properly designed.

7.5 SUMMARY OF THE ITALIAN DEMO SRA: REGULATORY EVOLUTIONS ARE NEEDED

The technical solution implemented in the demo, is considered as effective from an operational point of view. However, there is a lasting impediment from the regulation standpoint related to the current prohibition for the DSO to own and manage storage. Furthermore there is, in Italy, an absence of remunation mechanism of network and market services provided by DER and resources in general to the distribution networks. To be able to replicate the concept, there is the need for the role of DSOs to evolve and that new rules be enacted by Regulators regarding remuneration, roles and responsibilities for DSOs, Owners of DERs of DGs and finally (eventually) BSP.

The business opportunities for the project are mainly related to the satisfaction of the needs about optimization of network management and operation in terms of voltage regulation, losses reduction, data exchange and observability for the TSO, thus improving and updating the coordination process between the two system operators. As far as the economic viability is concerned, the absence of remuneration mechanism and the incomplete knowledge about price levels of local flexibility services in real conditions does not allow to do a comprehensive cost / benefit analysis. The market is not ready yet since current regulation rules don't allow the deployment of the concept. With respect to this aspect, the transposition at national level of European (continental) of Networks Codes and rules (in force and new) is very important, and this supports a general standardization process of the elements and solutions which have been analysed in the demo.

Regarding stakeholders, There is no problem in terms of acceptance and their willingness to embrace a scaled-up project will depend on the price level i.e. the profitability of the services.

The main used standard is IEC61850 within smart grid devices in primary and secondary substation. This allows to transmit a high amount of signals, events and measurements from several devices to a centralized SCADA. In scaling-up the solution, the communication volumetry might meet moderate limitations

Hardware is modular, interoperable and standard compliant (IEC-61850). Software tools are modular and can manage any network topology. The platform is compliant to any communication standard already used by the DSO towards other external systems and devices

8. PORTUGUESE FLEHUB DEMO SRA (WP7)

8.1 SHORT DESCRIPTION OF THE FLEXHUB DEMO

An increasing share of RES is expected in the Portuguese grid. The re-dispatch potential in the transmission grid will soon reach its limits due to the closure of conventional thermal plants and the increment of distributed generation. This will increase the needs of using distributed resources to provide both active and reactive power management, and new flexible mechanisms need to be designed. This in turns increases the need of strong TSO-DSO coordination to provide these services without causing additional problems to the distribution grids. In addition, the traditional passive nature of the distribution grid is evolving and the latter is becoming more dynamic and complex, which should be properly modelled and considered by the TSO for both voltage and frequency disturbance analysis.

The FlexHub Portuguese demonstration has been developed at the distribution grids of two demonstration sites: 1) the HV level distribution grid connected at the TSO-DSO linking substation of Frades and the feeder associated with Évora substation (MV level – MV line EV15-46), see locations in Figure 12 (1- Frades, 2- Évora).

FIGURE 12: FLEXIBILITY HUB – DEMOSITE LOCATIONS

In Frades, both the reactive power and the equivalent dynamic model BUCs have been be tested. The active power related BUC was tested in Évora. Frades is a 20 MW TSO/DSO substation located at the north of Portugal, with 40 transformers that provide service to about 8000 grid connection points, 90 MW of installed RES (larger than the grid consumption), and 2 distribution high/medium voltage (HV/MV) secondary substations (Vila da Ponte & Caniçada). Flexibilities come from 46 MW of wind active power, with reactive power ranging between 50 Mvar and +50 Mvar. On the other side, Evora feeder grid was used due to the possibility of managing a storge facility located at this grid for provision of active power flexibility. The two demonstration sites, along with the assets involved, are detailed in Figure 13.

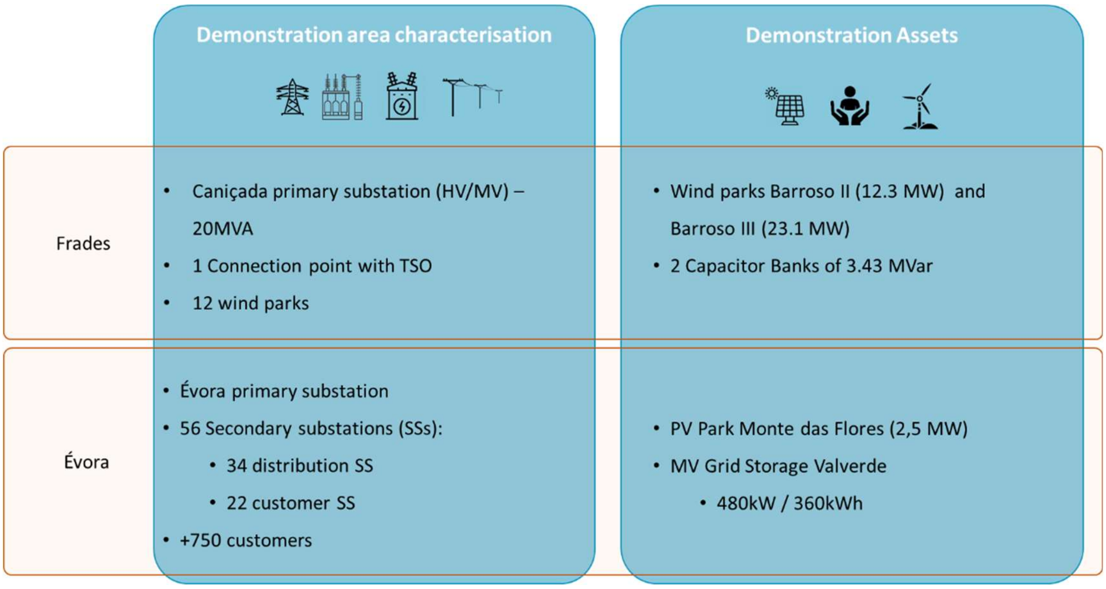


FIGURE 13: FLEXIBILITY HUB - EU-SYSFLEX DEMO SITES, ASSOCIATED CHARACTERISTICS AND ASSETS

TheFlexibility Hub is coordinated by the DSO to operate as flexibility markets facilitator, providing technical validation of active power flexibility activated to fullfill TSO needs from resources connected to the distribution system (with traffic light concept from EC Smart Grids Task Force), voltage control with DSO owned resources (e.g., capacitor banks, OLTC, flexible network topology) as well as freely use and offer to the TSO resources available in a reactive power local market. It also provides an equivalent dynamic model of the distribution grid to be used in dynamic frequency and voltages disturbances analysis at the DSO/TSO interface node. The Flexibility Hub aims at addressing several barriers linked to high RES penetration in 2030 and has several innovative aspects:

- **Local market for reactive power provision to TSO from the DSO grid** using distribution grid resources in a close to real time intraday market to provide reactive power flexibility to both, DSO to balance its reactive power grid, and TSO to supply a required profile at the TSO-DSO connection point;
- **New market to provide active power from resources connected to both the transmission and distribution grids**, as a redesign of the current restoration reserve;
- **Equivalent Dynamic Model of the DSO grid** for voltage and frequency disturbance analysis. The DSO will send the distribution network dynamic model to the TSO for operation and planning purposes

Figure 14 shows the high-level architecture of the Flexibility Hub, illustrating the project's main partners, environments involved and tools to be used on the scope of the project.

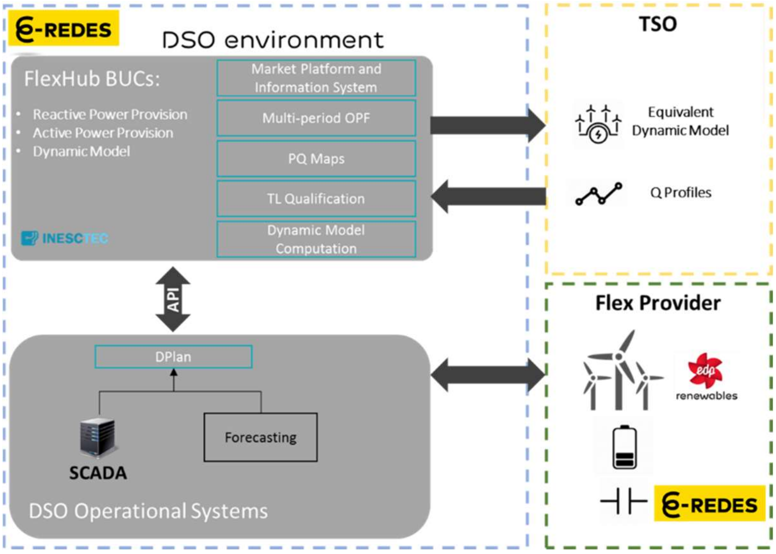


FIGURE 14: FLEXIBILITY HUB - DEMO HIGH LEVEL ARCHITECTURE

A detailed description of the Portuguese FlexHub demonstration is in Deliverable D7.5, while Deliverable D7.6 complements D7.5 with all demonstration results.

8.2 COMPONENT LAYER

8.2.1 HARDWARE COMPONENTS OF THE FLEXHUB DEMONSTRATOR

The FlexHub demo deals with a few physical assets in which the set points defined by the markets are implemented. E-REDES assets participating in the PT-FXH-RP demo consisted of two 4,43MVAr capacitor banks which could be switched on or off independently. These are located in the MV (15kV) of Caniçada substation which is directly connected to the Frades interconnection point. In this same demo (PT-FXH-RP) EDP Renewables participates with two wind farms: Barroso II (12.3MW) and Barroso III (23.1MW).

E-REDES also had an asset participating in the PT-FXH-AP demo which is a Storage unit with a 365kWh rated storage energy. Although, for security reasons it is operated not to pass the 255kWh stored energy maximum. The maximum charging, or discharging, power is 500kW and it is connected to a 15kV network near Évora city. The feeder that connects the storage unit to the network also connects the EDP Renewables PV plant, Monte das Flores, a 2,5MW PV Plant. Since this PV plant is bidded in the market no setpoint was implemented.

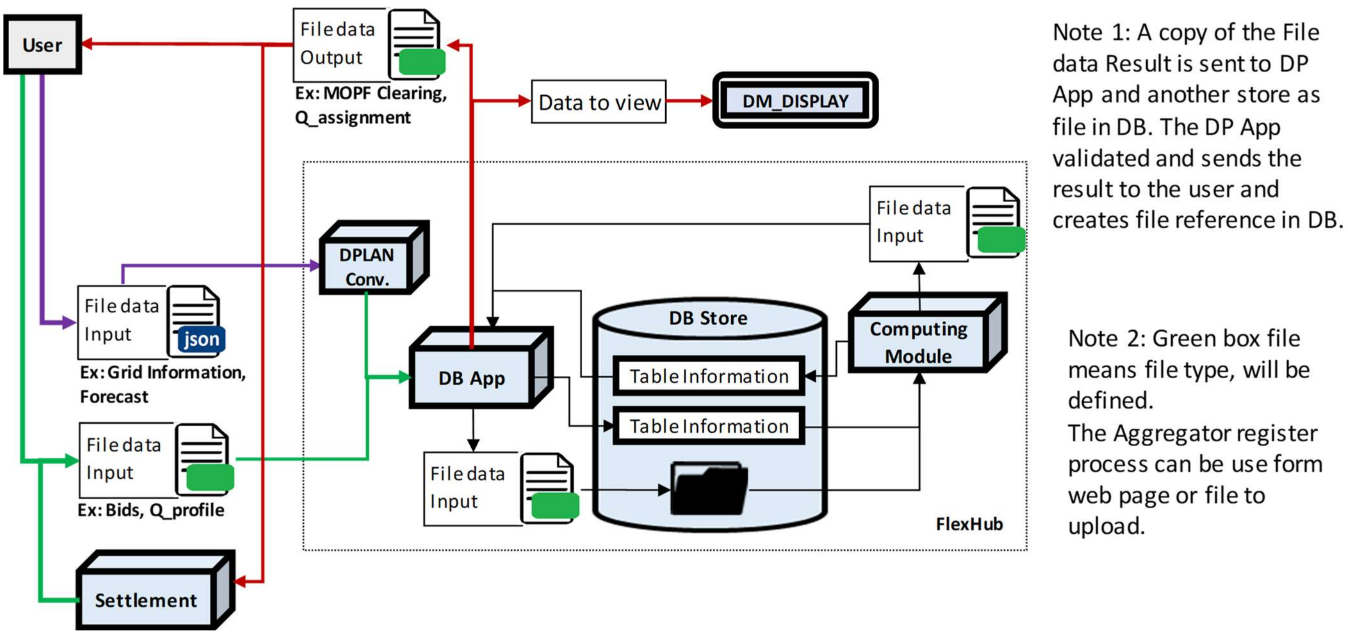
As part of the management systems of these assets, the SCADA systems at E-Redes and at EDP Renewables are also components that are worth mentioning.

The communication equipment for this demo consisted of several virtual servers to run the necessary Webservices and VPN over the internet was used to exchange information between the project's partners. Communication with the E-REDES field assets, either Storage unit or capacitor banks, was carried out by the existing SCADA system which controls them. A similar communication setting is established with EDP Renewables' assets (Wind farms and PV plant).

No specific problem has been identified with respect to S&R. The hardware is modular which is favourable to increase the number of concerned assets and enlarge the concept. The demonstration was focused on the market and the validation of several tools to achieve a market solution without the constraints to the network. This was achieved with a number of computer servers and a communication channel, and communication protocol, to potential bidders. Scaling up this demo would require building a larger infrastructure but all the building blocks were successfully demonstrated. Limitations may possibly arise if the number of assets participating in the market increases very significantly, potentially leading to an overload in the ICT infrastructure used. This, however, could easily be mitigated by appropriately sizing the ICT infrastructure that supports the FlexHub.

8.2.2 TOOLS, SOFTWARES AND SYSTEMS IN THE FLEXHUB DEMONSTRATOR

The main software components are depicted in Figure 15. Details for each BUC can be found in D7.2.



Additional legend:

- Red arrows: outputs FlexHub information;
- Green arrows: inputs FlexHub information during the processing;
- Purple arrows: Inputs Data Management information to DPLAN Convertor;
- Black arrows: communication data inside the Flex Hub or between users outside FlexHub;

FIGURE 15: FLEXHUB – ARCHITECTURE APPROACH

Softwares are modular and interoperable. The latter is favourable to scalability and the former to replicability. Additional functionalities could easily be added such as a local active power flexibility market based on the PT-FXH-RP platform and the PT-FXH-AP functions with shared responsibility at the TSO-DSO connection point to provide active power services to the TSO.

The sofware used and developed are standard compliant. A minor limitation could affect the proper operation of the OPF software when large grids with large number of resources are involved. As a matter of fact, if the number of assets increases in a significant manner, the OPF computation time could increase and reduce the operational feasibility, but, on the other hand, if the assets used show a larger flexibility (e.g. capacity to provide more active/reactive power) the concept's value is improved. Thus, this would be a moderate hurdle.

8.2.3 ICT IN THE FLEXHUB DEMONSTRATOR

The ICT architecture aspects are out of scope of the SRA of the Portuguese FLEXHUB demonstration which uses existing assets already used by E-Redes. The architecture used is modular and would allow scaling-up with moderate change. At industrial scale, FTP communications should probably be changed to other communication channels as are for example webservices. ICT architecture is standard compliant and could easily be made compliant (economically and technically) with a defined different set of standards.

8.3 BUSINESS USE-CASES OF THE FLEXHUB DEMONSTRATOR

The following BUCs have been designed for the **Flexibility Hub** of the **Portuguese demonstrator** (Figure 16) with harmonised role models (See D3.2):

1. **PT-FXH-RP - Provision of reactive power flexibility with resources located at the distribution grid**
    - A close to real time continuous intraday local market is proposed to provide reactive power flexibility to the TSO from the distribution grid.
    - The DSO manages and clears this market using an optimal power flow so that the activated resources do not compromise the secure operation of the DSO grid.
2. **PT-FXH-AP - Provision of mFRR/RR type reserves** with resources located at the distribution grid
    - A modified Restoration Reserve continuous intraday like market is proposed to provide this service, closer to real time, where distributed resources can participate;
    - When the TSO selects a bid with resources connected to a DSO distribution grid, the traffic light qualification (TLQ) of the bid is triggered to inform the TSO if the resources offered can be totally (green), partially (yellow) or cannot (red) be activated to provide the active power flexibility without causing congestion or voltage issue in the distribution grid and the actual active power that can be delivered is also provided.
3. **PT-FXH-DM - Provision of an equivalent dynamic model of the (active) distribution grid** to the TSO
    - The model substitutes the actual load or more simplified models used by the TSO;
    - The dynamic model represents the dynamic behaviour of the distribution grid under small voltage and frequency disturbances for TSO stability and dynamic grid analysis.

The FlexHub is, therefore, a new **platform concept** to promote the interaction and **coordination** between **TSO and DSO** for an enhanced system operation.

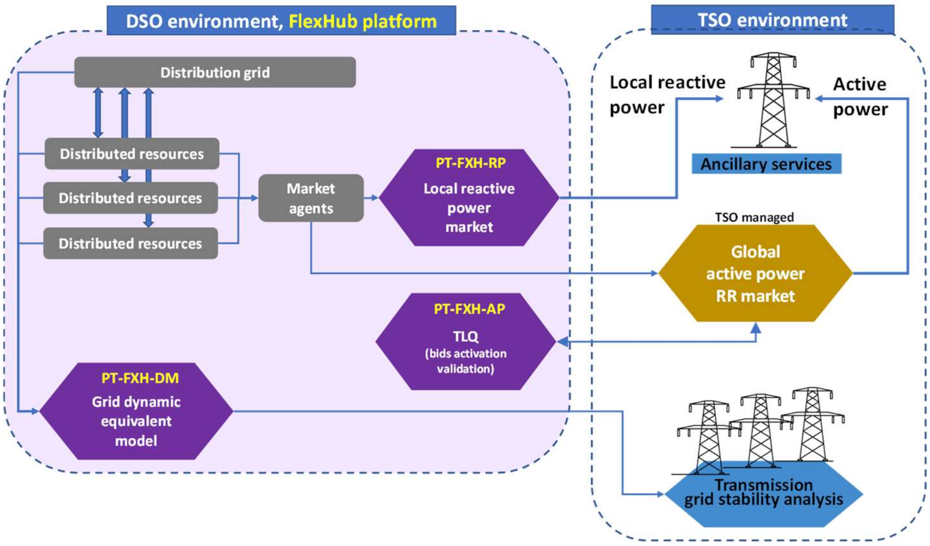


FIGURE 16: FLEXHUB SIMPLIFIED ARCHITECTURE OVERVIEW

8.3.1 REGULATION

The impact of regulation on the scalability and replicability of the proposed FlexHub solutions depends on the BUC considered:

1. PT-FXH-RP - Provision of reactive power flexibility with resources located at the distribution grid

- Current regulations don't consider reactive power markets yet, although existing research is ongoing (see examples in deliverable D1.2 of the EUniversal project).
- The progressive closure of synchronous generators (traditional providers of reactive power) and the increasing need of DSO's voltage control may boost the development of such services from distributed resources. However, more regulated frameworks could be possible instead of those market-based.
- Therefore, the solution proposed in PT-FXH-RP is probably further from being implemented since important regulatory changes are needed to allow both scalability and replicability, as the development of reactive power markets is not very common yet.

2. PT-FXH-AP - Provision of mFRR/RR type reserves with resources located at the distribution grid

- This BUC focuses on the DSO validation process of the activation of active power flexibility for the TSO by guaranteeing that this activation does not cause constraints in the DSO grid. This validation process is explicitely considered in the EU-regulation and in the ENTSOe-E.DSO ASM report, which and could make it easily aplicable if regulation evolves towards a better integration of DER in system services. This suggests a potential for its scalability and replicability.
- Current regulations are moving towards the integration of active power distributed flexibility in many countries, although, in many cases, still at pilot level projects. For example, Portugal has a pilot project to integrate large consumers in the provision of RR type reserve. However, RES generation is still not integraged.
- Although this BUC proposes an alternative design to the current RR Portuguese market (with 7 hours delivery horizon and bids with complex conditions), it could be easily adapted to the current market, provided that DER are allowed to participate.

3. PT-FXH-DM - Provision of an equivalent dynamic model of the (active PT-FXH-DM - Provision of an equivalent dynamic model of the (active) distribution grid to the TSO

- This coordination model requires the agreement between the DSO and the corresponding TSO to establish the procedure to exchange the data needed and the fitted model.
- This BUC could already be implemented depending on TSO and DSO coordination interest. However, it would imply an additional burden to the DSO obligations and require some kind of remuneration. It is not that dependent on regulation and could be progressively put in place under a TSO-DSO agreement. However, regulatory recommendations would certainly boost its development.

In conclusion, regulation is generally not allowing solutions such a as PT-FXH-RP and PT-FXH-AP yet since few countries allow distributed resources to provide flexibility. In particular, for the specific Portuguese case, but also applicable to other EU countries, is the need of developing the national regulations to:

- Integrate distributed flexibility into TSO markets,
- Allow and incentivize local flexibility markets for the provision of local (DSO) and global (TSO) system services using distributed flexibility,
- Allow DSOs to define their own local flexibility services and incentivize DSO to integrate market-based flexibility into their operation and planning processes.

This potential barrier related to both national and more generally European regulation could thus hamper scalability and replicability. Nevertheless, changes towards the integration of DER into system services with an improved TSO-DSO coordination are expected especially for the provision of active power flexibility with resources located at the distribution grid.

8.3.2 ECONOMICS

No CBA analysis has been carried out et the demonstration level. However, if allowed by regulation, current proposed services are likely be economically viable since their costs are rather low:

- **PT-FXH-RP:** if other local markets and coordination mechanisms are put in place, the cost of including reactive power market negociation does not seem to be very high. In addition, the cost of providing reactive power, although being partially assessed in the demonstration, is in general low. However, liquidity and the need for a capacity mechanism could be an issue, and therefore there may be a need to incentivize the participation.
- **PT-FXH-AP:** the situation is similar to the previous one without the need of an additional market platform, since in this case the objective is to integrate this coordination mechanism into the existing RR market platform by establishing the TSO-DSO coordination mechanisms.
- **PT-FXH-DM:** the cost of developing the model, provided a proper grid description, does not seem very high once the research process has already developed the methodology proposed.

In general economies of scale are likely to take place upon up-scaling as developments would be particularized to different frameworks without developing from scratch, once the methodology and the base software tools are available. This would be favourable to scalability. However, possible difficulties and extra costs are difficult to foresee at that stage. The main challenge is therefore to go towards a regulation promoting flexibility markets. Though the investments do not seem significant, their benefits should however be computed under different scenarios to prove a sufficient profitability.

8.3.3 IMPACTS OF STAKEHOLDERS'ACCEPTANCE

Stakeholders concerned by the Flexhub demonstration are the following categories:

- Potential market participants: renewable generators owners, large clients at the MV grid, potential investors in flexibility assets such as storage facilities.
- DSO, TSO
- Regulation entities
- Software developpers

Since the BUCs are oriented to MV grids, small consumers could only have an impact under more sophisticated aggregation and MV-LV coordination schemes which was not under consideration.

No problem is foreseen with respect to stakeholders'acceptance which is of major importance for the scalability and replicability of the FLEXHUB concept. To some extent EU countries and stakeholders seem to be aligned in adapting the regulation to unlock the distributed flexibility through local flexibility markets or more regulated alternatives. While the reactive power market relies in a local market, the PT-FXH-AP provides a functionality useful for providing distributed active power flexibility to the TSO in coordination with the corresponding DSO.
The willingness of potential market agents to participate in flexibility markets is essential, and very dependent on how regulation finally evolves.

8.4 FUNCTIONS AND SERVICES, INFORMATION AND COMMUNICATION

For the three FlexHub BUC, eight SUC were defined (Figure 17):

1. RP-DM: Reactive power market data management
2. RP-MC: Reactive power market clearing
3. RP-STL: Reactive power market settlement
4. AP-DM: Active power TLQ data management
5. AP-TLQ: Active power TLQ computation
6. AP-STL: Active power settlement
7. DM-DM: Dynamic model data management
8. DM-MC: Dynamic model computation

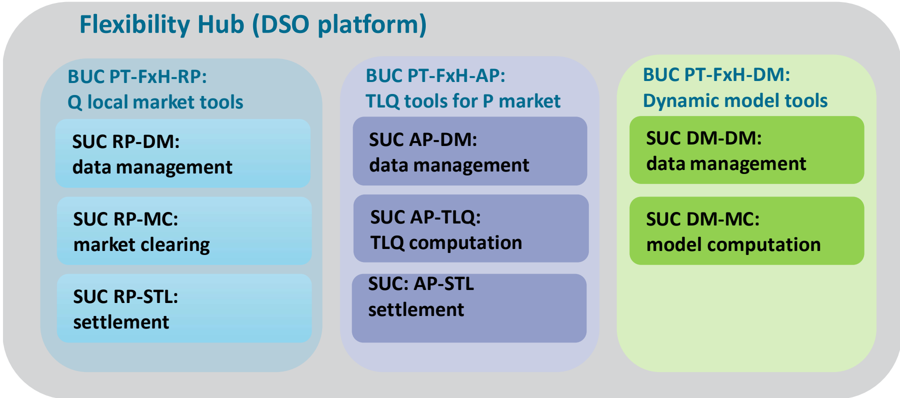


FIGURE 17: FLEXHUB – BUC AND SUC STRUCTURE

The SUCs which have been defined would only undergo a moderate variation in case of change in boundary conditions. The main impact could be the existence of multiple TSO-DSO connection points which would involve significant extra work. Although a methodology to address this issue was developed during the project in the German demonstration of WP6, it should be adapted and tested for the FlexHub tools, which may require significant extra work. This shouldn't be an issue for replicability.

Information exchanges among actors/modules are represented in Figure 18 for the BUC PT-FXH-RP, and in Figure 19 for the BUC PT-FXH-AP. As can be seen, colors are used to represent the modules of each partner: orange for E-REDES, red for EDP CNET, green for EDPR and blue for INESC TEC. Note that for the BUC PT-FXH-DM there is no online demonstration and no communication diagram was developed. All fluxes are detailed in D7.6.

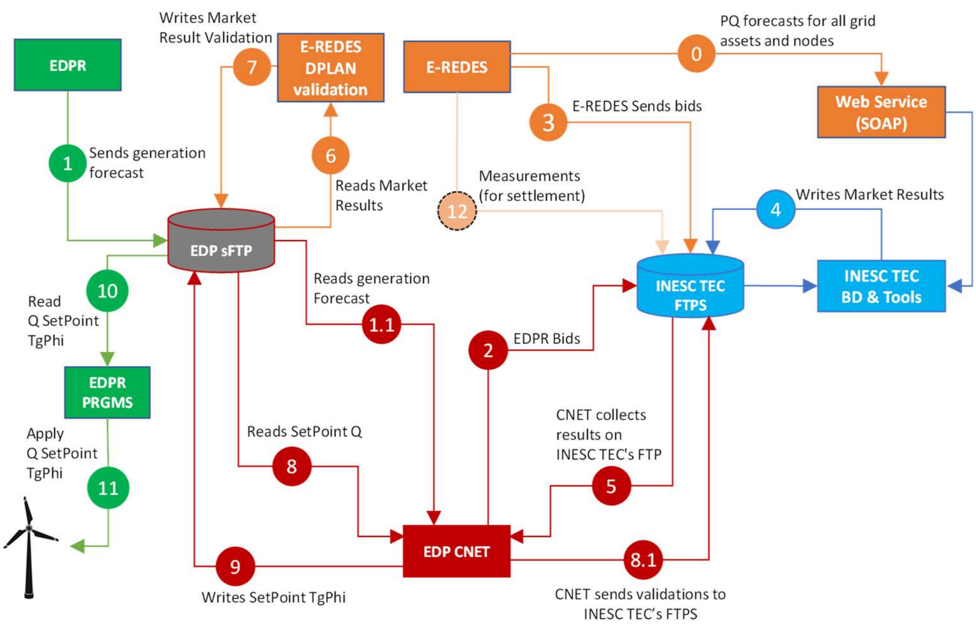


FIGURE 18: DATA FLUXES OF ONLINE RUNNING MODE OF THE PT-FXH-RP BUC

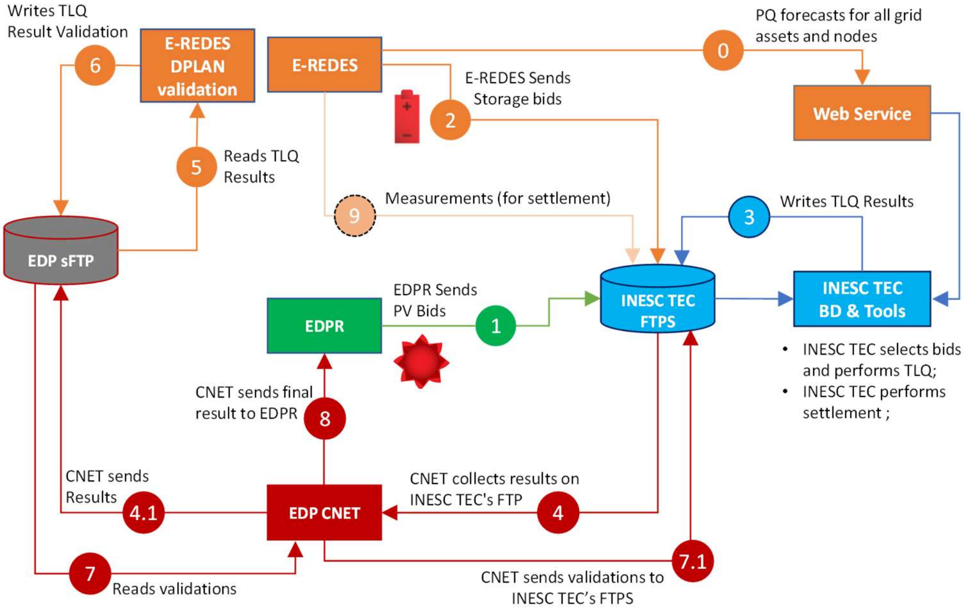


FIGURE 19: DATA FLOWS OF ONLINE RUNNING MODE OF THE PT-FXH-AP BUC

Depending on the BUC, information exchanged relates basically to grid topology changes, forecasts, TSO requests, bids, market results and measurements. The benefits and challenges expected are detailed in Table 12. Though attributes are not standard compliant, this may not be an issue for scalability and replicability as different translators should be used to match different grids topology input formats.

TABLE 12: DATA FORMATS OF THE FLEXHUB DEMO

which standards (mandatory, voluntary, open or proprietary)?	Benefits	Challenges
• Grid topology is provided in E-Redes internal standard (coming from DPLAN) • Other exchanged data are: ○ Forecasts ○ Bids ○ Market results	• Formats agreed with E-Redes. • Grid topology processing applicable to other E-redes grids • Other data are of low complexity and data formats and potential formats translations may not be an issue.	Different translator should be used for different grids topology input formats. However, this type of information usually does not require update for several months.

There is no barrier identified with respect to availability and accessibility of the data needed to the Flexhub solution.

The communication design used for the FLEXHUB is for demonstration purposes only, since the focus was on demonstrating the algoritms and functions needed to implement the conceptual designs of the different BUCs, and not to develop commercial systems for flexibility markets or TSO-DSO coordination communication processes. Therefore, when scaling-up or replicating another design will be used removing possible constraints and limitations. The communication protocols which have been used for the webservice are standard

- Communication protocol IEC 62325-504.
- Message using SOAP protocol and using compressed base64 do XML compacted by bzip2.
- INESC TEC's FTPs using the protocol SSL/TLS and encription inplicity Over TLS

There could be minor limitations in terms of communication volumetry when increasing the size of the solution. However, as mentioned above, the communication design of the demo is rather for demonstration purposes and should not be considered as the final choice. Besides, many market platform exist involving many participants and volumetry is definitely not an issue with their current technologies.

Whenever replicating the demonstration in a place with poor telecomunications service, small changes to the procedures may be required to handle communication data loss when communicating with the distributed asset.

8.5 SUMMARY OF THE PORTUGUESE FLEXHUB DEMO SRA: POSSIBLE HINDRANCE RELATED TO REGULATION

In the SRA of the Portuguese Flexhub demonstration, no hindrance has been found regarding technical aspects (SUCs, Data, communication and hardware). The demonstration of the three BUCs of the Flexibility Hub Platform confirms the technical viability of these solutions for high voltage grids. Moreover, it does not seem that its application to other grids should entail major problems.

A potential barrier to scalability and replicability has however been identified with respect to regulation. Currently, few countries allow distributed resources to provide flexibility. Changes towards the integration of DER into system services with an improved TSO-DSO coordination are expected:

- BUC PT-FXH-RP: reactive power markets are not considered yet. This BUC is still far from being implemented commercially,
- BUC PT-FXH-AP: Provision of mFRR/RR type reserves with distributed flexibility is at pilot stage in many countries. This BUC could be easily applicable if regulation evolves towards a better integration of DER in system services

Since regulation generally don't allow PT-FXH-RP and PT-FXH-AP, there are only few commercial applications and the market is not ready yet. However, there is a lot of R&D work involving industrial stakeholders.

Regarding economics, no CBA analysis has been carried out. However, if allowed by regulation, current proposed services are likely to be economically viable since their costs are rather low. This would help scale-up and replicate the demo.

Communication protocols are standard (IEC 62325-504, Message using SOAP protocol and using compressed base64 do XML compacted by bzip2). Minor limitations are foreseen in terms of communication volumetry when upscaling, however communication with the field assets in the demo is rather for demonstration purposes. This could be mitigated by appropriately sizing the ICT infrastructure that supports the FlexHub and therefore shouldn't have a negative impact on scalability.

Hardware is modular. Scaling up this demo would require building a larger infrastructure but all the building blocks were demonstrated. Software are modular and interoperable. A minor limitation could occur with large grids with large number of resources. This could increase OPF computation time which are at the base of the PT-FXH-RP and PT-FXH-AP BUCs.

The ICT architecture used is modular and would allow scaling-up with moderate change. At industrial scale, FTP communications should probably be changed to other communication channels as are for example webservices. ICT architecture is standard compliant and could easily be made compliant (economically and technically) with a defined different set of standards.

9. PORTUGUESE VPP DEMO SRA (WP7)

9.1 SHORT DESCRIPTION OF THE VPP DEMO

The Virtual Power Plant (VPP) is a concept of joint operation control of multiple power production units. By virtually combining different assets, e.g. renewable resources like wind and solar power, conventional generation units like diesel generators and storage like batteries and pumped hydro plants, the overall power generation and the flexibility of the energy production can be increased.

The Portuguese VPP demonstration is located in the north of Portugal and consists in a VPP coordinated by a market agent to provide flexibility from centralized resources, including pump storage plants (PSP) and wind power plants connected to the transmission level, and providing frequency regulation and balancing reserves. The resources used for the VPP demo comprised of a Variable Speed Hydro Power Plant 756 MW (2 x 378 MW), Venda Nova III, and two nearby Wind Farms (115 MW from 57 turbines & 50 MW from 25 turbines), the Alto da Coutada WF and the Falperra WF , as shown in Figure 20.

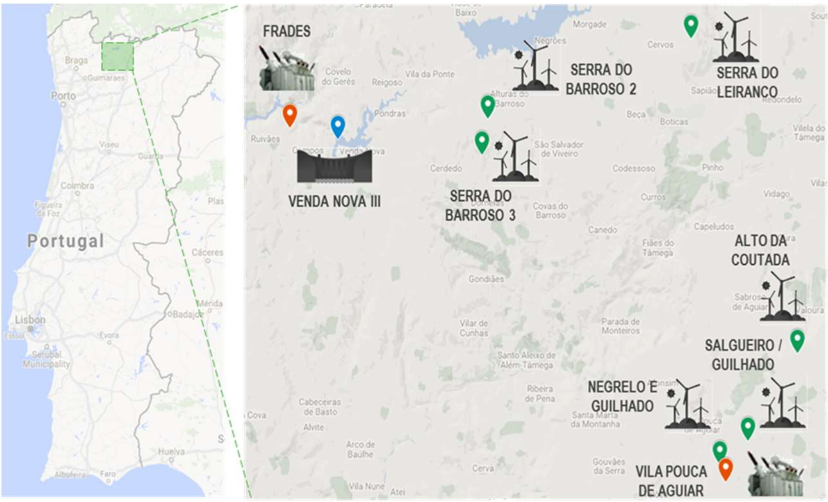


FIGURE 20: DEMO SITE 1 – RESOURCE LOCATION

The demonstration aimed at developing a power dispatch optimizer that will support a new balancing area concept, help decrease in the imbalances in participation of RES in energy markets, maximize the profit in Wind Parks operation, by reducing O&M expenses and therefore increase the revenue brought about by using a VPP, as opposed to the individual operation of the units. The forecasts accuracy of price and resource availability will be increased.

The demonstration has several innovative aspects:

- Real-time management of the storage and generation portfolio: based on mathematical models including short term balancing operations;
- Integrating forecasting modules for prices, energy supply and demand;
- Market bidding suite for the different markets, respecting long term strategies for storage management.

The necessary tools for the field tests have been upgraded and tailored for the Business Use Cases (BUC) developed within WP3 and subsequently integrated in EDP's systems.

9.2 BUSINESS LAYER

Two business cases have been defined for the VPP, corresponding to the provision of the following services:

- **Provision of aFRR**
  - The VPP can offer its generation bandwidth on the aFRR day-ahead market;
  - This service is currently done by the hydro power plant, Venda Nova III.
- **Provision of mFRR/RR**
  - VPP offer the resources on the RR day-ahead and intra-day market;
  - It will be a combined offer done for the VPP owned resources;
  - TSO requests the activation of the resource.

In the aFRR and mFRR/RR markets, the TSO is responsible for setting up the market, identifying the needs for ancillary services and contracting the services, to guarantee the security of the national electrical system. The flexibility provided by a VPP that combines variable speed pumped storage power plants and RES power plants will allow the Generation Aggregator (Market Agent) to make optimized bids into the markets and manage the portfolio more efficiently. The VPP tools will provide decision support for the bidding at the different markets (day ahead, intraday, XBID, ancillary services) and for optimized dispatching of the units within the VPP. The flexibilities coming from generation units (conventional and RES) are offered through a mandatory mechanism and are remunerated based on opportunity costs in case they are selected.

A detailed description of the Portuguese VPP demonstration will be found in Deliverable D7.6 along with the all the results.

9.2.1 IMPACTS OF REGULATION ON S&R

General approaches for market participation planning are based on a typical market set-up in Europe. Current regulation in several countries (including Portugal) do not allow the implementation of a multi-technology VPP. In Portugal the units participating in energy/reserve markets are grouped by technology and geography under balancing areas for balancing purposes. This applies to Hydro plants and also to thermal plants. The majority of the renewables units (wind, solar) are still under feed-in tariffs and hence do not participate in the markets.

For the time being, these conditions create constraints for a possible future scale-up and replication of the concept. However, energy and reserve markets in Europe are expanding beyond the borders of each individual country (projects XBID, MARI, PICASSO etc) and, in a near future, will most likely enable the implementation of multi-tech VPPs – or even crossborders VPPs – so this barrier seems likely to wane in the future. Therefore, the impediment is rather to be considered as temporary.

9.2.2 IMPACTS OF ECONOMICS ON S&R

The main business-model envisaged is the development and set up of the VPP as a commercial tool to be provided to utilities/asset owners to manage their portfolio of assets – on a subscription or license based agreement. VPP-type solutions already exist in different contexts – most of them focused on the aggregation of small rooftop PV producers, as a means of taking these small players to energy/reserve markets. Utility-level VPPs are less common.

No CBA has been done on the concept and therefore it is difficult to conclude on the economic viability at that stage even though economics seem favourable. In addition, economies of scale can be foreseen upon upscaling since the marginal cost of adding a new asset to be managed by the VPP should be negligible. In the short to medium term, economics could be further enhanced through additional liberalization of energy markets and decreasing costs for operational cloud deployment (scaled).

Even though regulation needs to evolve to allow the wide-scale deployment of the concept, there is a potentially large market related to aggregation (customers of the VPP tool or variants of it could be big utilities, aggregators, small DERs TSO/DSO, etc.) and the competition level is increasing due to rapid changes in overall energy provision/consumption (e.g. Tesla trying to bring their fleet of eCar-batteries to energy/reserve markets).

9.2.3 IMPACTS OF STAKEHOLDERS'ACCEPTANCE ON S&R

Stakeholders concerned by the scalability of the VPP concept are mainly Regulators and other market players (competitors). However, their acceptance of an enlarged solution is of moderate importance. There is no specific challenge related to it. This could only arise if some demand response scheme were considered as a new "asset" to be integrated in the VPP. At the utility level, acceptance is likely to be good provided the tool allows autonomous market participation planning and control of the units with good revenues. Regulators and TSO/DSO will keep an eye on potential effects on grid stability / market prices. The effects that are foreseen and demonstrated in this project are favorable for the grid.

Consumers acceptance is of importance for any product to scale-up (in terms of revenue). Regulators will give the frame/rule-set within the VPP tool needs to operate. If pooling is not supported, scaling-up makes no sense.

9.3 FUNCTIONS AND SERVICES, INFORMATION, COMMUNICATION

For the two BUCs of the demonstration, two SUCs were defined:

VPP-AP: Optimal Bidding. This SUC describes the functional processes through which the VPP, installed in EDP's trading unit (UNGE), optimises its portfolio (large scale storage, hydro and RES) by participating in the day-ahead/intraday, continuous (XBID) and ancillary services markets, offering aFRR and mFRR/RR.

VPP-AP: Optimal Dispatch. This SUC describes the functional processes through which the Virtual Power Plant (VPP), installed on EDP's trading unit (UNGE), optimises its portfolio (large scale storage, hydro and RES) in accordance to the participation in the day-ahead/intraday, continuous and ancillary services markets..

The expected results from the system use cases (SUCs) vary moderately to changes in boundary conditions and this shouldn't affect replicability. Important boundary conditions that influence potential performance increase with VPP solutions are: number of renewable assets, sizes of storages, weather forecast quality, market price variance.

The VPP software needs to collaborate with numerous external systems and actors to fulfil its function of optimized market participation and optimized power dispatching (Figure 21):

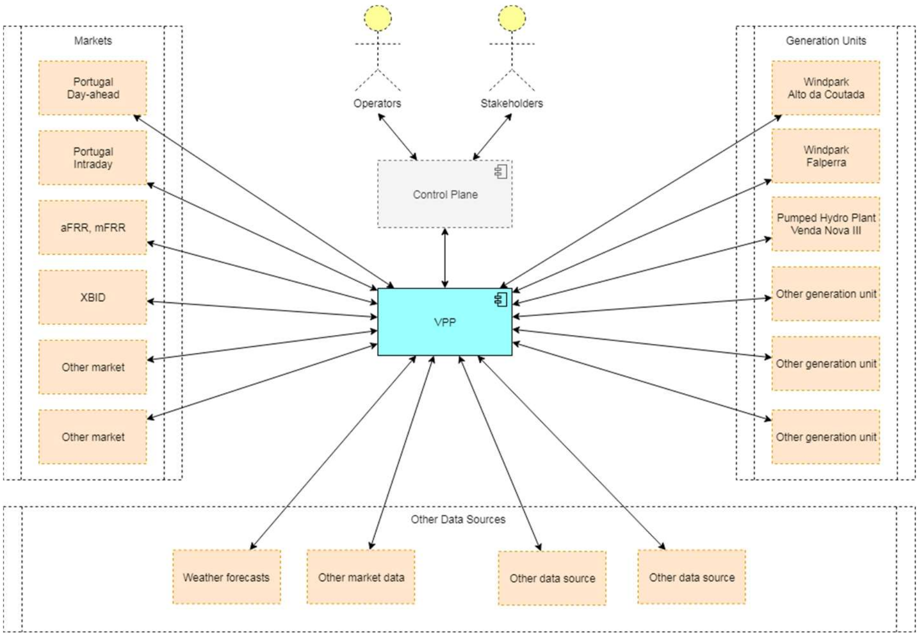


FIGURE 21: DATA EXCHANGE BETWEEN THE VPP SOFTWARE AND EXTERNAL SYSTEMS AND ACTORS

The overall concept for connectivity and deployment is depicted in Figure 22:

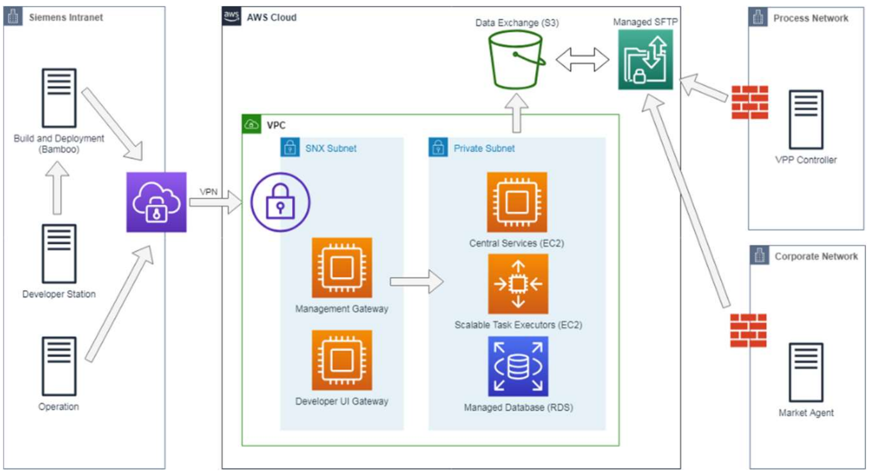


FIGURE 22: OVERALL CONCEPT FOR CONNECTIVITY AND DEPLOYMENT IN THE VPP DEMONSTRATOR

Improvements are needed with respect to availability and accessibility of the data needed. On the one hand, there is the need for a good data base for energy/reserve markets (live and historical). On the other hand, the technical integration and data availability on utility level is repeated manually and needs to be improved to avoid a burden to operators.

As far as communication is concerned, the final architecture / communications scheme for the Virtual Power Plant demonstration concept is shown in Figure 23. It reveals the interconnection of two separate EDP networks: the corporate where the main market information sits in the TDMI data lake; the process, composed by the SCADA systems and connections with different dispatch centres and hydro power units. The separation between the two networks is needed for security reasons.

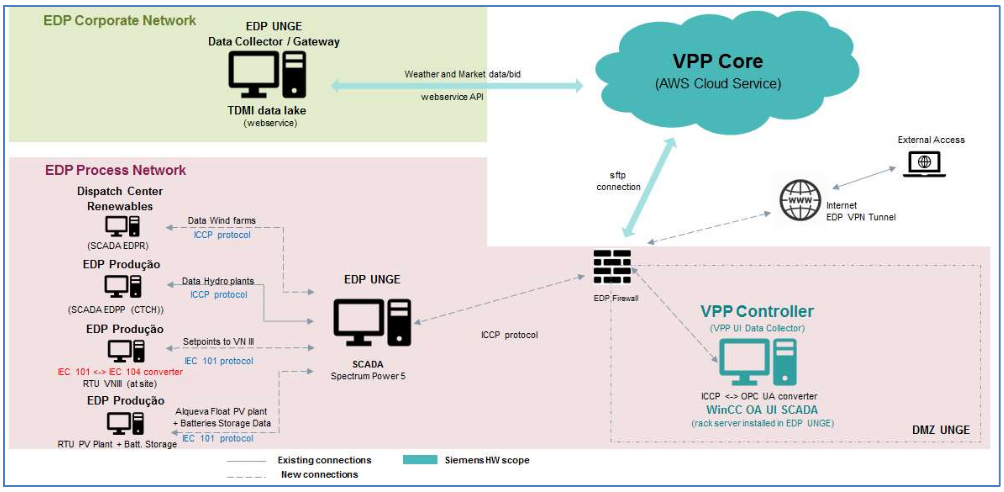


FIGURE 23: TECHNICAL INTEGRATION CONCEPT ONLINE DEMONSTRATION

The corporate one deals with the data exchanges interactions between EDP UNGE and the markets (wholesale and XBID), the TSO (ancillary services) and the weather forecast provider. The collected information is stored at the TDMI data lake and is the single point of contact with the VPP Core. The TDMI data lake exchanges information with the VPP Core, a cloud-based service, through APIs (REST, SOAP).

In the process network, EDP UNGE SCADA systems exchange information with four different systems:

- EDP Renewables dispatch center. The communication is ensured by ICCP protocol;
- EDP Produção dispatch center (CTCH). The communication is ensured by ICCP protocol;
- RTU in VNIII: bilateral flow exchange of data, from VNIII. The communication protocol is IEC 101 with an IEC 104 converter;
- RTU in Alqueva: bilateral flow exchange of data, from VNIII. The communication protocol is IEC 101 with an IEC 104 converter;

In the process network, Spectrum Power 5 SCADA system is the bridge between the different systems and the VPP Controller, ensuring all the needed information is exchanged. The communication protocol used is ICCP, with an OPC UA converter on the VPP controller side.

The communication protocols being used are REST, SOAP, ICCP, OPC UA. They are standard which is favourable to deploying the VPP concept in a different host architecture. No limitation is foreseen in terms of volumetry upon scaling-up. Indeed, and increase in the number of components connected to the VPP will definitely affect runtimes of optimization algorithms, however, for operational control, this is not an issue.

No limitation has been identified in terms of bandwith, data latency or data loss to be expected when increasing the number of assets. As a matter of fact, the VPP tool is a time asynchronous system that performs algorithms based on the best available current data. A workflow engine re-triggers the failing tasks (due to missing data) within a pre-configured time interval. If the plants cannot receive the updated power setpoints from the controller, it is expected, that the RTU goes to a default power setpoint.

9.4 COMPONENT LAYER

9.4.1 HARDWARE COMPONENTS OF THE VPP DEMONSTRATOR

The resources used for the VPP demo comprise of a Variable Speed Hydro Power Plant 756 MW (2 x 378 MW), Venda Nova III, and two nearby Wind Farms (115 MW from 57 turbines & 50 MW from 25 turbines), the Alto da Coutada WF and the Falperra WF. The assets in the portfolio are in the geographical area in the north of Portugal.
The two wind farms aggregated in the VPP's portfolio are owned by EDP Renewables, have a joint capacity of 165.6 MW and the following technical characteristics:

WPP Name	Capacity [MW]	Number of WTGs	OEM	WTG Models	Controllers	Power [MW]
Alto da Coutada	115	50	Enercon	E 82	CS82	2.3
Falperra	50.6	22				

The wind farms are located near each other and have a common connection point to the grid.
Regarding VNIII, the variable speed hydro plant with storage capacity is on the Rabagão river on Cávado-Lima cascade, see Figure 24.

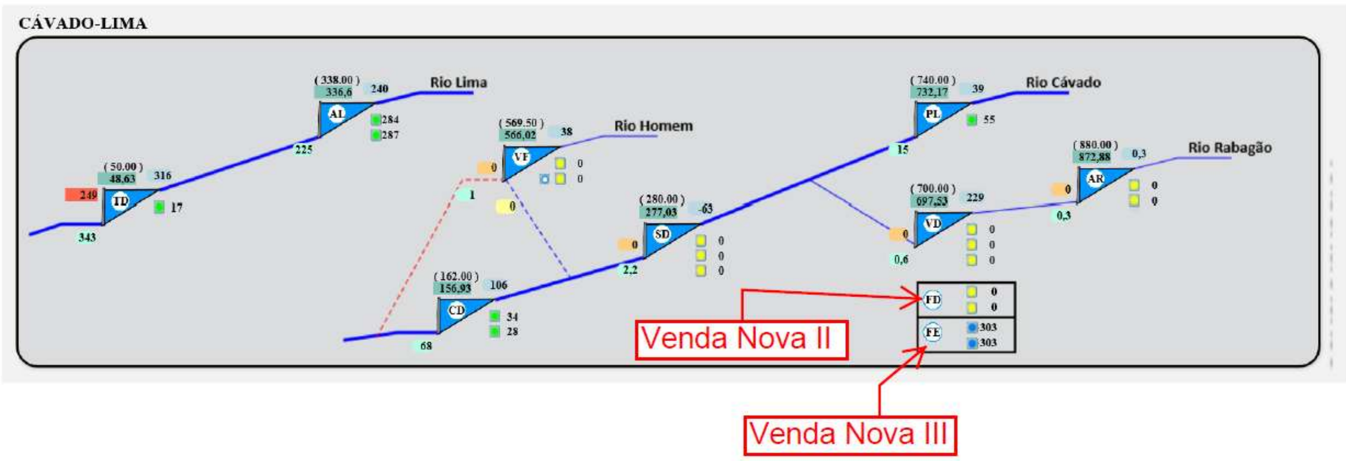


FIGURE 24: DEMO SITE 1 – CÁVADO CASCADE

9.4.2 TOOLS, SOFTWARES AND SYSTEMS IN THE VPP DEMONSTRATOR

An entire part of the work was the development of software modules for the automated & continuously integrated control of a Virtual Power Plant. The system was divided into two major parts:

1. **VPP Core**
   a. Economic dispatch optimization of the VPP on a five-minute to one-hour time scale with a 24h to 72h prediction horizon;
   b. Combined (stochastic) optimization of market participation (energy and ancillary service markets) and power dispatching based on forecast of availability of power from renewable resources and market prices;

   c. Orchestrated by a workflow engine (automated (periodic) execution of tasks, such as data retrieval, forecasting, optimization, market bidding / market clearing results, access external interfaces, etc.);
   d. Deployment into a Cloud.

2. **VPP Controller**
   a. Implementation of the dispatch power schedules of the VPP Core on a time scale of five seconds to one minute, i.e. sending power setpoints following market bids, and return information to the VPP Core (availability of generation resources, accepted bids in markets, etc.);
   b. Deviation handling: manage power imbalances, “real-time” dispatch of the hydro power plant;
   c. Technical integration with EDPs system network (communication with the power generation units and the interfaces for market trading).

The execution of the algorithms inside the VPP Core is orchestrated by a workflow engine. Moreover, there are supporting functions like data collectors & persistence, user interface, monitoring & logging. The suggested VPP control optimization approaches has been demonstrated in Portugal:

- Flexibility provided by large-scale storage and RES power plants (wind farms or WF) at the transmission level to test the optimized operation of a variable speed pumped storage power plant with capacity to provide dynamic FRR combined with wind parks,
- Demonstration of the ability of an aggregated portfolio to provide flexibility to the system, namely ancillary services. The resources used for the VPP demo will comprise a Variable Speed Hydro Power Plant 756 MW (2 x 378 MW), Venda Nova III, and two nearby Wind Farms (115 MW - 57 turbines & 50 MW - 25 turbines), the Alto da Coutada WF and the Falderal WF.

9.4.3 ICT IN THE VPP DEMONSTRATOR

Please refer to section 9.3 for the ICT details of the demo.

9.4.4 IMPACT OF COMPONENTS ON S&R

On a technical point of view, there are no barrier to S&R.
The hardware is modular and interoperable and allows easily to add new components when scaling-up:

- Set-up of component model with easy integration into optimization algorithm.
- Extension of UI for support of parameterization.

The local grid infrastructure impose minor limitations on the maximum size that can be reached by the VPP. Depending on the grid connecting the assets, congestion may become an issue, as energy flows may be hindered by grid constraints. Therefore, depending on the scale of the solution (i.e. number of assets included in the VPP) these grid constraints may be magnified.
The software tools are modular, interoperable and have no foreseen limitations when scaling-up. The programming language are not open-source: MILP solvers generally come with licenses for commercial use with seamless switch of underlying solvers (Gurobi, CPlex, Xpress, SCIP). Even “non-commercial” solvers like SCIP would require proper licensing for commercial usage. The VPP has been conceived, designed and developed to be “agnostic” in terms of

generation technologies and regulatory contexts. Adapting the concept to another environment would only require slight changes to the algorithms – adjustment of models, testing, commissioning would indeed still be needed.

The ICT architecture is modular. This easily allows the implementation of extra modules in an enlarged VPP such as data interfaces/connectors (based on the existing infrastructure of the customer / utility). The control is centralized and is done through a central work flow engine approach for VPP task execution scheduling. There is a joint optimization of all assets within the VPP. This is favourable to scalability.

9.5 SUMMARY OF THE PORTUGUESE VPP DEMO SRA: NO MEDIUM TO LONG-TERM HINDRANCES

Current regulation in several countries (incl Portugal) do not allow the implementation of a multi-technology VPP and this would is currently a major hindrance to S&R. However, the barrier is likely to wane in the near future to change and the impediment should therefore only be temporary.

Apart from regulation, the Portuguese VPP concept appears to be scalable and replicable over Europe with respect to the other dimensions of the SRA.

The main business-model envisaged (WP11) is the development and set up of the VPP as a commercial tool to be provided to utilities/asset owners to manage their portfolio of assets – on a subscription or license based agreement. The economic viability is difficult to assess at that stage without a CBA but economics seem favourable. The market is potentially large and there is an increasing competition to develop such a concept which is favourable to replicability.

The expected results from the system use cases (SUCs) vary moderately to changes in boundary conditions but this shouldn't affect replicability.

The communication protocols are standard and have no foreseen limitations. Hardware, software and ICT architecture are modular and interoperable and could easily allow the implementation of extra modules in an enlarged VPP. Besides, The local grid infrastructure impose minor limitations on the maximum size that could be reached by the VPP.

10. FRENCH VPP DEMO SRA (WP8)

10.1 SHORT DESCRIPTION OF THE FRENCH VPP DEMO

The purpose of the French demonstration of the EU-SysFlex project was to test the concept of multi-resources aggregation for multi-services provision. A decentralized multi-resources VPP containing wind and PV generation as well as a battery energy storage system (BESS) has been built at a scale of several MW and operated over a long period. The main objectives of this demonstration were:

- To demonstrate the technical feasibility to perform an optimal and coordinated control of wind turbines, PV panels and storage as a VPP to provide system services to the transmission system operator;
- To analyze the performance of the system services that can be provided by the VPP and to assess the contribution of the aggregator to the enhancement of system security and flexibility.

The main facilities and testing assets for the French demonstration are shown in Figure 26. This VPP was composed of a 12-MW wind farm, a 2-MW / 3-MWh battery storage and photovoltaic panels and is mainly implemented at EDF privately owned Concept Grid (CG), apart from the wind farm being at a remote location and connected to the French public distribution grid.

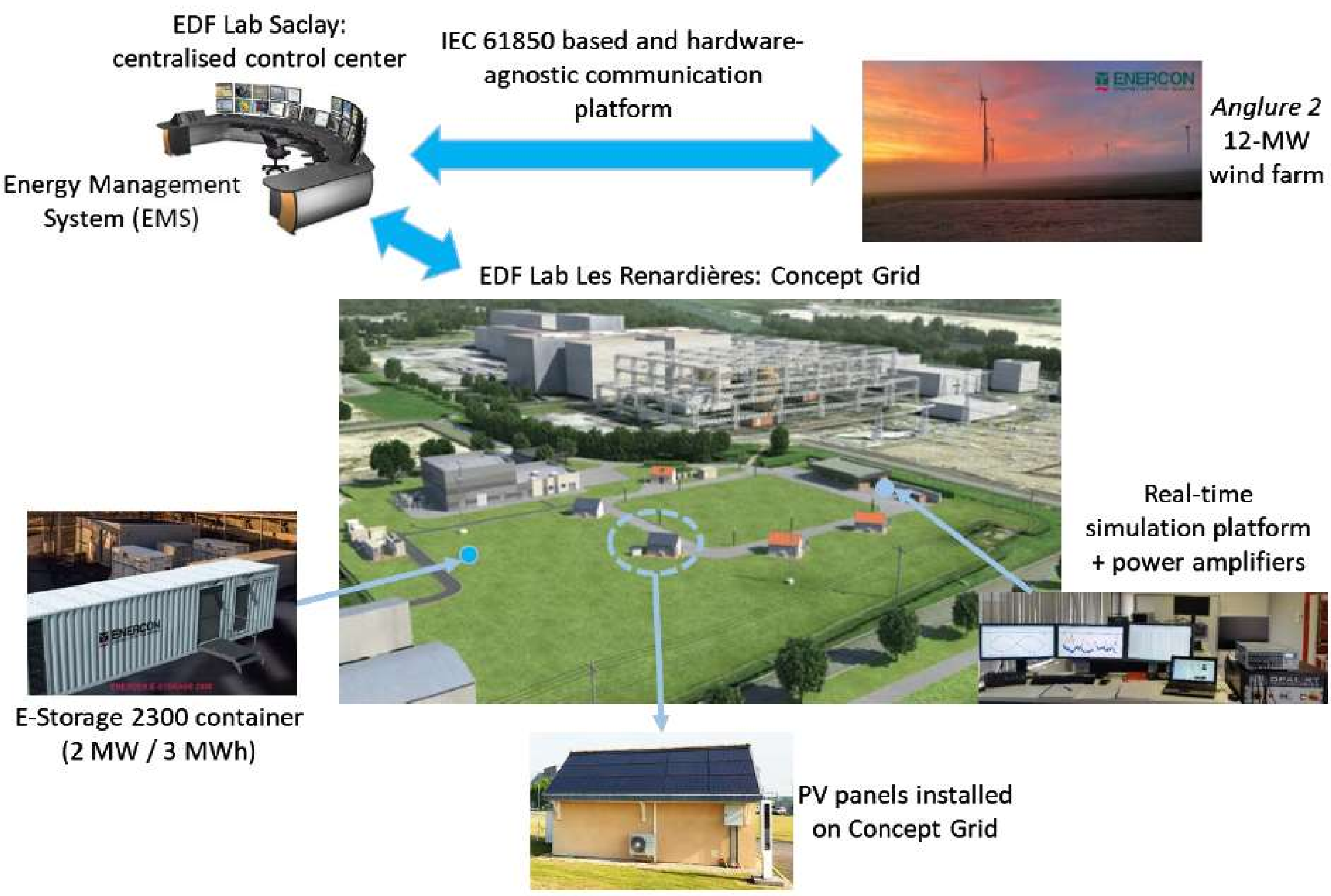


FIGURE 25: MEANS AND FACILITIES OF THE MULTI-RESOURCES MULTI-SERVICES DEMONSTRATION

10.2 COMPONENT LAYER OF THE FRENCH VPP DEMO

10.2.1 HARDWARE COMPONENTS OF THE FRENCH VPP DEMONSTRATOR

The demonstration is mainly implemented on EDF Concept Grid (CG), which is a private distribution grid dedicated to the test and validation of smart grid equipment, systems and functions.

The hardware components (Table 13) used in the French VPP comprise:

- The EDF concept grid laboratory;
- a 12-MW wind farm of 6 x 2000-KW turbine of type ENERCON E82;
- a full storage system including a 2.3-MW/1h lithium-ion battery as well as an ENERCON E-Storage 2300 power conversion system;
- photovoltaic panels installed at EDF Concept Grid.

Most of the distributed resources are installed on Concept Grid with the exception of the wind farm located in the department of “Marne” in France and connected to the public distribution grid (20 kV).

TABLE 13: HARDWARE RESOURCES OF THE FRENCH VPP DEMONSTRATION

Resources	French Demonstrator
Power system equipment	- BESS
Protection and tele-control devices	Grid Edge Devices (GED) Farm Control Unit (FCU) E-Storage Control Unit (ESCU)
Communication infrastructure	wired / wireless communication connections, routers, switches, servers
Computers	Any additional computer needed?
Software tools	- Forecasting Tools o Wind power forecasting o PV power forecasting o Simplified services prices forecasting - Centralised EMS of the aggregator o Operational planning scheduler o Short term control - Advanced Wind Farm Control o Farm Control Unit (FCU) controller o Grid Edge Device - Wind farm (GED-W) - Storage Control o E-Storage 2300 control o Grid Edge Device - Storage (GED-S) - HMI -

The generation output of the PV panels as well as of the variable load test bench of kW-size that have been installed at CG have been used to emulate the respective behaviour of a MW-size PV farm and of an industrial-size controllable load through power amplifiers.

10.2.2 TOOLS, SOFTWARES AND SYSTEMS IN THE FRENCH DEMONSTRATOR

To operate the VPP composed of multi-resources of different nature as a whole and to ensure the optimal coordination of multi-services provision, centralized control functions have been built, including:

- Renewable Generation Forecasting Tools
    - Wind power forecasting
    - PV power forecasting
- Centralised Energy Management System (EMS) of the aggregator providing both day-ahead / intraday optimized schedules and short-term program adjustment capacities
    - Operational planning scheduler
    - Short term control
- local controllers of the BESS and the wind farm (GEDs) that will autonomously manage the execution of the optimized schedule in real time. The GEDs play the role of interface between the EMS and all the distributed resources. They have been improved and upgraded for the purpose of the demonstration
- Concept grid Control
    - Concept Grid Control Center
    - Grid Edge Device – PV (GED-P)

Furthermore, to ensure the monitoring of the VPP's operation during experimental tests, a Human-Machine Interface (HMI) has been dedicatedly designed and developed. The HMI provides all the relevant information concerning the resources performance and the services participation levels. Additionally, the HMI allows the manual activation of the services and the manual definition of the global scheduling for the purpose of pre-testing and proof of concept.

10.2.3 ICT IN THE FRENCH VPP DEMONSTRATOR

Concerning the ITC infrastructure, there is a GED (Grid Edge Device) for the communication of each asset with the EMS (Energy Management System). The servers have been installed in a datacenter, directly connected to the Internet. EDF network filters communication between internal network and the Internet. Industrial protocols are not allowed to pass from one network to the other. Figure 26 shows a simplified view of the IT architecture of the demonstration.

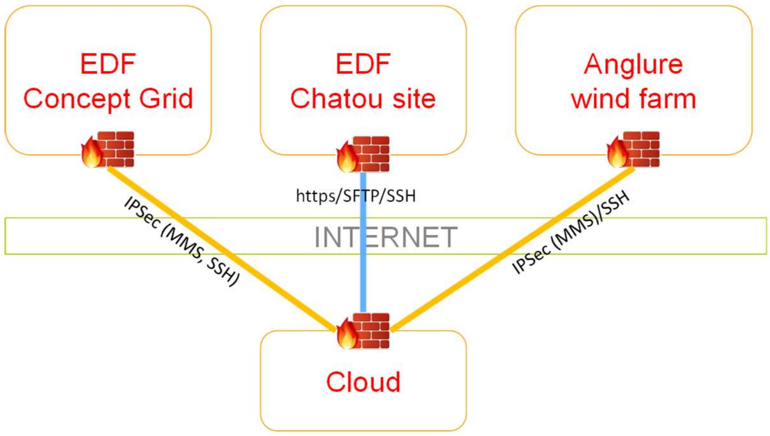


FIGURE 26: DEMONSTRATION UPDATED IT ARCHITECTURE (SIMPLIFIED VIEW)

10.2.4 IMPACT OF COMPONENTS ON S&R

10.2.4.1 HARDWARE

The hardware is modular and allows the addition of different distributed resources such as loads, storage, renewable generators or electrical vehicles provided some necessary adaptions are brought to the technical solution. These addition of extra components upon scaling-up the demo could however imply several limitations that could affect the proper operation of the VPP without a significant incidence on the scalability of the concept. These limitations could affect:

- The robustness of the communication system,
- The calculation capacity of the EMS including an optimizer,
- The complexity of the control strategy in case of unexpected events,
- The data processing capacity,
- The complexity of management of grid constraints in case of involvement of several DSOs/TSOs.

The wind farm is connected directly to the distribution grid of the Marne region. The storage system and PV panels are installed at EDF Concept Grid which is connected to the distribution grid to a 6 MVA primary substation with a dedicated feeder. In France, the maximum size allowed of an asset when it is connected to the distribution grid is 18 MW. This would limit the size of an an up-scaled VPP project even though this is not a major limitation.

10.2.4.2 SOFTWARE TOOLS

The software tools are modular and therefore allow the addition of extra components when up-scaling the design albeit with moderate limitations: i) the computational time and memory requirements would be impacted at the level of the EMS when more data need to be processed or more calculations should be performed for the upscaled VPP; ii) the application of stochastic optimization also increases the computational time, as several probabilistic scenarios based on RES generation need to be considered. The more scenarios are considered, the better the performance is, however, the more time will be required to get optimization results.

The operation of the VPP Energy Management System (composed of an operational planning scheduler and a short-term controller) is not system-specific. The designed architecture of the VPP allows an easy integration of new components / assets or the replication of the concept. However, to do this, necessary modifications of the whole platform should be considered, such as modelling in the scheduler, implementation of new forecasts and/or control algorithms, updates in communication software, etc. These are common and normal considerations and actions in case of replicability or scalability of the project, but are not sticking points.

The EMS algorithms of the VPP are encoded in open-source languages. A license agreement should be signed with EDF in order to use it. In addition, a licensed computing server has also been applied for the operational planning scheduler because of its high performance

The various software / tools of the demonstration run on Linux (which is an open-source and largely deployed operating system for industrial projects). Regarding the EMS software, porting to Windows or to other OS would be technically feasible. However, necessary adaptation work could be costly with little economic and technical interest. Regarding the communication platform software, it can only run on Linux.

The EMS software is standard compliant and based on open standards (IEC-61850). All software tools are interoperable. In the French demonstration, to operate the whole VPP for energy arbitrage and services provision, it is necessary to ensure the coordination of several tools/software/functional layers, including forecasting tools, operational planning scheduler, short-term control, communication software and local controllers of each asset. Interfaces have been carefully developed to make sure that necessary I/O data and information can be exchanged between different tools from D-1 to real time at each scheduled time window. At the level of the EMS, a script corresponding to “EMS Core” has been developed to coordinate data exchange and make sure that EMS software / algorithms work together (e.g.: writing the most recent forecasts and measures in the database of the scheduler or processing the outputs from the scheduler).

10.2.4.3 ICT

ICT is modular which favours scalability. If a new asset, that should be added in the VPP, uses a protocol/medium which is not supported by the VPP solution, a gateway could be easily integrated in the demonstrated solution. If the new asset uses a protocol which is supported by the solution, then a GED could be added to communicate with the asset.

The control is centralised. Measurement (voltage, frequency, etc.) is collected at a local level via GEDs, the setpoints of services are generated at a centralised level and then sent to each GED to be applied on each asset. Indeed, the services activation as well as the optimization process are calculated by the EMS (Energy Management System) in the French VPP.

The ICT architecture is standard compliant and it is based on voluntary standards which is favourable to replicability. A recommended ICT architecture exists in the IEC-62351 standard. This architecture is not specifically implemented but the best practices are applied in the French demonstration. Benefits are an enhanced cyber security, easier configurations, etc. The drawback is that every asset should respect the standard, which is not the case in practice.

ICT components are interoperable. The operation of the VPP needs to collect and process data which are generally available on the standard SCADAs of the managed assets. These data are not technology-dependent nor manufacturer-dependent and are processed at the centralised level by the EMS, which means that information will not be communicated among local decentralised resources. This avoids, for example, the communication problems between assets of different type of technologies or of different vendors. Furthermore, the applied communication solution is based on IEC 61850, which allows interoperability of the demonstration.

10.3 BUSINESS LAYER

10.3.1 SHORT DESCRIPTION OF THE BUSINESS LAYER OF THE FRENCH VPP DEMONSTRATOR

In the context of the French VPP Demo a Virtual Power Plant providing flexibility services has been tested. The VPP tools, provides decision support aiming at allowing the aggregator to bid in the different markets (day ahead, intraday, ancillary services) and for optimized dispatching of the units. The demonstration focused on testing at a reduced scale in EDF's laboratory distribution grid several innovative products (Fast Frequency Response, Ramp-Rate Control) or different existing services (FCR, a-FRR) but provided by "new" assets (e.g. from variable renewable generation). Some of these products do not exist in the current French ancillary services market but could be required by the future grid codes, as their procurement will help to meet future European system needs at high renewable penetration rates.

At this stage, specific processes of those services from the "market" perspective cannot be fixed yet and detailed BUC description taking into account the regulatory framework and roles of stakeholders cannot be described and should be further explored after the project execution.

Within the demonstration, the following flexibility services have been provided either simultaneously or consecutively depending on their compatibility:

- **Manage VPP active power flexibility to support FFR, FCR and a-FRR at the TSO/DSO connection point;**

In addition to the classical operating reserves (FCR and a-FRR), the Fast Frequency Response (FFR) will also be tested. This service will take action before the FCR is activated and is supposed to help the electrical system compensate the decreasing amount of inertia due to the increasing penetration of renewables. Moreover, the ability of the VPP to perform "service stacking" (also referred to as "service bundling") has also been tested. It refers to a unit ability to provide multiple services consecutively, for example delivering FCR and aFRR.

- **Manage VPP active power flexibility to perform ramp-rate control and peak shaving**;

As RES (Renewable Energy Sources) inject active power into the grid with relevant short-term variability, the power quality and the grid reliability can be affected. Hence the question of the control and limitation of the active power variation (dP/dt) is of importance; the resolution of this issue can be solved to some extent by the mean of a well calibrated storage system coupled to the RES.

Additionally, and again due to the short-term variability, in some cases local grid congestions occur when a high amount of active power is injected by RES. In such cases, the curtailment of the RES can be a solution but with the adverse consequence of wasting primary energy (wind or solar energy), except if the curtailed energy is stored on a well-designed storage system.

Both solutions, so-called “Ramp-Rate control” and “Peak shaving” have been tested within the French VPP demo.

- **Perform energy arbitrage**.

10.3.2 IMPACTS OF REGULATION ON S&R

No current national or regional regulation or market rules in Europe create barriers that could limit the size (in terms of number of assets) and scope of an up-scaled technical solution or its replicability. However, for certain innovative active power services such as Fast Frequency Response (FFR) or for most reactive power services, the market do not exist yet in most continental European countries. Regarding some existing services such as FCR, the current market rules are not always favourable to encourage the participation of new actors. Moreover, certain services tested in the French demonstration could be designed differently in other countries (FCR or FRR). This means that the replication of the solution will imply some adaptations at the technical / controller levels according to the allowed BUCs corresponding to the market and regulatory rules.

Besides, as the French VPP demonstration aggregates renewable resources, the latter could benefit from the smoothing effect when its size is scaled up. This is also encouraged by market rules as more constant and more smooth and firm power can be generated and more reliable reserves can be provided by an up-scaled VPP comprising a larger number of renewable power plants.

10.3.3 IMPACTS OF ECONOMICS ON S&R

In terms of possible business-models, one can envisage the remuneration of multi-services provision in different ancillary services and energy markets according to the energy market prices of the whole VPP generation. No CBA has been carried out and it is therefore difficult to conclude on the economic viability of the demonstration or of an industrial version. However, considering the current market prices of ancillary services and the very beneficial feed-in tariffs for renewable generation, it seems difficult to make enough profits to cover investment costs for an industrial-size VPP composed of renewables and storage.

An up-scaled VPP based on renewables and storage (like the French demo) could benefit from the smoothing effect as well as from a larger battery size, allowing to provide more reliable services and to have more potential of flexibilities (which could imply higher potential gain). However, the project costs would also increase. Intuitively, it is expected that economies of scale are globally favourable for the VPP development, further in-depth CBA should however still be performed in order to conclude on this point.

In the short to medium term, several evolutions can be foreseen that could improve the economic viability of the concept:

1/ A sustained decrease in cost of batteries and renewable resources,

2/ The reduction in financial support mechanism such as feed-in tariffs of renewable generation,

3/ More flexible or enhanced market rules in favour of the participation of renewables in ancillary services (asymmetry of the reserve products, procurement lead-time closer to real time, shorter duration commitment, regulatory and economic compatibility between system services and RES supportive remuneration such as feed-in tariffs, etc.).

Aligned with this, the market rules within the common FCR market changed very recently: since July 1st 2020, 'D-1' auctions with 4-hour products per delivery are in force (while it was in the past based on weekly auctions and weekly products). Even if the symmetry of the product remains mandatory, this evolution has already opened opportunities for RES participation.

Some similar or related concepts (but not the full solution) have been tested by other demonstration or industrial projects. We can cite, for example, the multi-services provision by a single battery (VENTEEA demonstration in France), the Enhanced Frequency Response (EFR) provision by storage (EDFR's West Burton B project in the UK), or the participation of wind farms in Spain in mFRR and aFRR services. However, It is difficult to compare the solutions at a technical level, especially when the different tested concepts are only similar or partially related (but not exactly the same). Moreover, even when the concept is similar, the business use cases behind could still be very different according to the local market where the solution is implemented

10.3.4 IMPACTS OF STAKEHOLDERS'ACCEPTANCE ON S&R

The stakeholders likely to be concerned by the scalability of the French VPP concept are mainly producers and owners of batteries. They should not pose acceptance challenges in case that the aggregation is beneficial. Their possible participation depends a lot on the market opportunities and the project profitability and this remains difficult to assess at this stage.

10.4 FUNCTIONS AND SERVICES, INFORMATION AND COMMUNICATION IN THE FRENCH VPP DEMO

The services that can be procured from the VPP are well aligned with the power system scarcities at high RES (Renewable Energy Sources) penetration rates, in terms of future needs of ancillary services, as well as additional requirements on flexibilities. These services are classified into 4 categories as summarized in Table 14.

TABLE 14: SERVICES PROVIDED BY THE FRENCH MULTI-RESOURCES VPP

Categories	Services
Frequency support services	Fast Frequency Response (FFR)
	Frequency Containment Reserve (FCR)
	Frequency Restoration Reserve (FRR)
Flexibility solutions	Ramp-rate control
	Peak shaving
Energy arbitrage as an aggregator	

Globally the SUCs of the French VPP concept will not change in boundary conditions . However, whenever several DSOs and/or TSOs could be involved in an up-scaled VPP of this type (depending on the locations of the assets managed by the VPP), the SUC of “system communications” would need to be adapted, or a new SUC related to TSO/DSO/VPP EMS coordination could be created.

Data models attributes are standard compliant which is favourable to replicability. They rely on IEC-61850 which ensures interoperability. However, data models are complex and some data required for the VPP operation are not yet included in the current standard (and have to be created using IEC-61850 semantics).

To ensure the interoperability and scalability of the proposed solutions in the present demonstration, a new full IEC 61850 based and hardware-agnostic R&D software and platform developed by EDF R&D is used. The overall communication architecture of the demonstration is presented in

Figure 27.

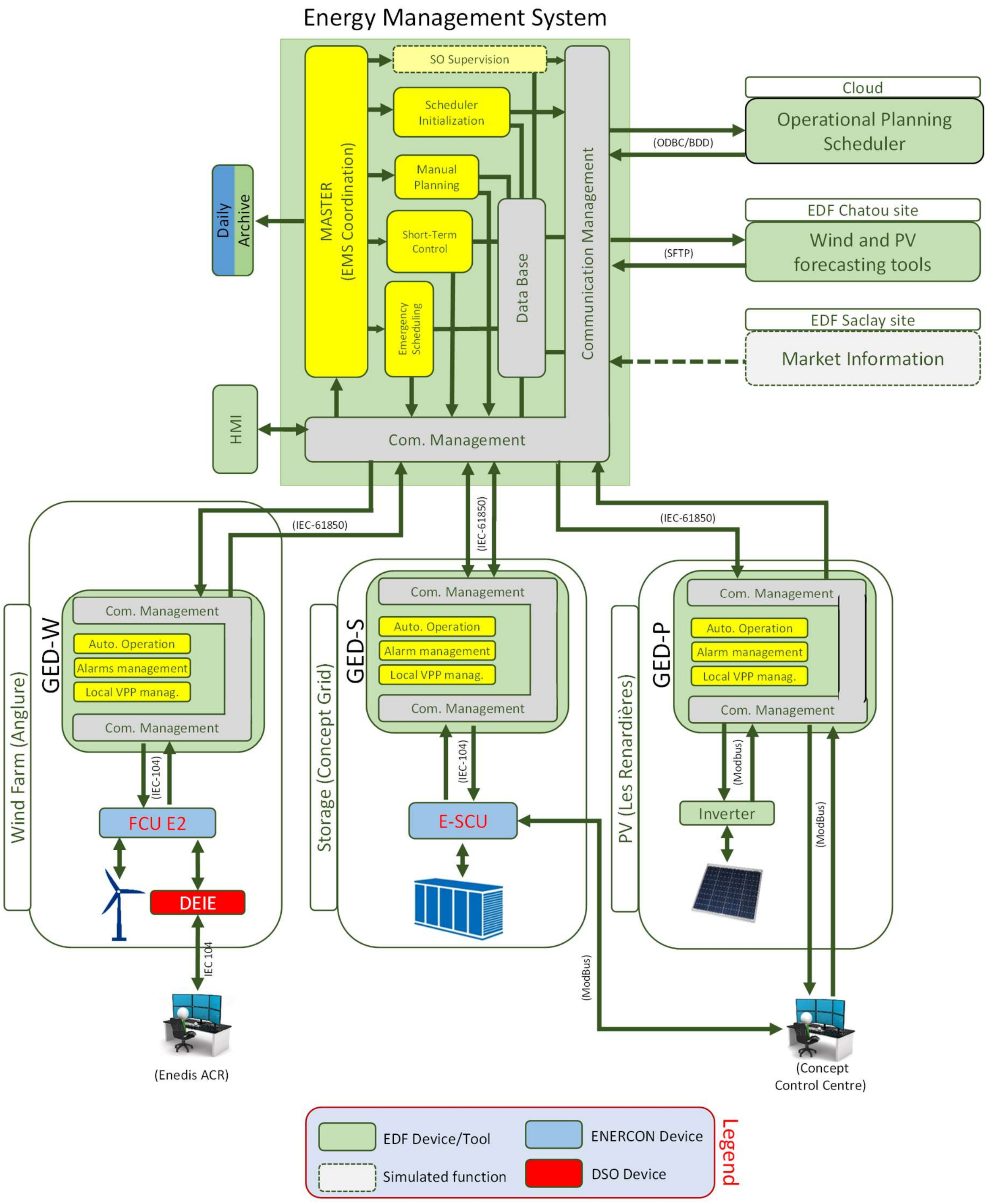

Energy Management System
SO Supervision
Scheduler Initialization
Manual Planning
Short-Term Control
Emergency Scheduling
MASTER (EMS Coordination)
Data Base
Communication Management
Daily Archive
HMI
Com. Management
Cloud
Operational Planning Scheduler
(ODBC/BDD)
EDF Chatou site
Wind and PV forecasting tools
(SFTP)
EDF Saclay site
Market Information
(IEC-61850)
(IEC-61850)
(IEC-61850)
Wind Farm (Anglure)
GED-W
Com. Management
Auto. Operation
Alarms management
Local VPP manag.
Com. Management
(IEC-104)
FCU E2
DEIE
IEC 104
(Enedis ACR)
Storage (Concept Grid)
GED-S
Com. Management
Auto. Operation
Alarm management
Local VPP manag.
Com. Management
(IEC-104)
E-SCU
(ModBus)
PV (Les Renardières)
GED-P
Com. Management
Auto. Operation
Alarm management
Local VPP manag.
Com. Management
(Modbus)
Inverter
(ModBus)
(Concept Control Centre)
EDF Device/Tool
ENERCON Device
Simulated function
DSO Device
Legend

FIGURE 27: SIMPLIFIED COMMUNICATION IN THE FRENCH DEMONSTRATOR

System 1	System 2	Protocol	Reason
EMS	GED-W	IEC-61850	
EMS	GED-S	IEC-61850	
EMS	GED-P	IEC-61850	
EMS	Operational Planning Scheduler	ODBC/BDD	
EMS	Forecast Tool	ODBC/BDD	
Concept Grid Control Centre	GED-S	ModBus	
Concept Grid Control Centre	GED-P	ModBus	
GED-W	FCU	IEC 60870-5-104	
GED-S	ESCU	IEC 60870-5-104	
GED-P	Inverter	ModBus	

TABLE 15: COMMUNICATION LAYER SUMMARY FOR THE FRENCH DEMONSTRATOR SYSTEM 1 SYSTEM 2 PROTOCOL

The proposed solution allows the interaction with a wide range of DER using different protocols. The communication between the EMS and the GEDs was made in IEC 61850. Between the GEDs and the FCU and ESCU, the communication was made using IEC 60870-5-104. The communications with the Concept Grid devices was performed using ModBus protocol.
To guarantee the expected performance of the EMS giving orders to activate and deactivate flexibility services, it is necessary to communicate with two external servers to obtain respectively the updated generation forecasts (wind and PV) and the operating program calculated by the operational planning scheduler. The communications with these two servers has been implemented using REST (REpresentational State Transfer). In the present demonstration, the markets and the system operator have only been emulated.

The communication protocols used in the demonstration (IEC-61850-8-2 MMS, IEC-60870-5-104, Modbus TCP/IP, REST) are standard and allow replicability. Possible limitations in terms of communication volumetry when up-scaling the concept are difficult to assess because the communication architecture would be different in an industrial version of the concept allowing for a much larger volume of data to be processed. Possible limitations could arise depending on the capacity of the hardware design / specification for data processing (especially the processor, the memory or other dimensions could also have impacts, etc.). That would depend also on IEC 61850 model size (number of data to be transmitted). Up to 50 simultaneous connections have been tested with ~5000 data/s (100/equipment). Tests were performed with a 8 Core CPU with 2.1 GHz, 16 GB RAM. To support more equipment, it would be possible to adapt the applied architecture.

10.5 SUMMARY OF THE FRENCH VPP DEMO SRA

The SRA of the French VPP shows that there are no hurdle to scalability and replicability with respect to technical dimensions. There are some concerns however on the economic viability related to current low remunerations of frequency services. As for the other demonstrations, no CBA has been carried out and it is therefore difficult to conclude on the economic viability of the demo or of an industrial version. However, considering the current market prices of ancillary services and the very beneficial feed-in tariffs for renewable generation, it seems difficult to make enough profits to cover investment costs for an industrial-size VPP composed of renewables and storage. Economies of scale could be foreseen as well as several evolutions that could improve the economic viability of the concept.To allow the large-scale roll out of the concept, remuneration mechanisms need to evolve as illustrated in WP2.

No current national or regional regulation or market rules in Europe create definite obstacles that could limit the size and scope of an up-scaled technical solution or its replicability.

The stakeholders (producers and owners of batteries) should not pose acceptance challenges in case that the aggregation is beneficial.

Data models attributes are standard compliant which is favourable to replicability. They rely on IEC-61850 which ensures interoperability. However, data models are complex and some data required for the VPP operation are not yet included in the current standard (and have to be created using IEC-61850 semantics).

The communication protocols used in the demonstration (IEC-61850-8-2 MMS, IEC-60870-5-104, Modbus TCP/IP, REST) are standard which allows replicability. Possible limitations in terms of communication volumetry when up-scaling the concept are difficult to assess.

The hardware is modular and allows the addition of different distributed resources such as loads, storage, renewable generators or electrical vehicles provided some necessary adaptions of the technical solutions.

The software tools are modular and therefore allow the addition of extra components when up-scaling the design albeit with moderate limitations. Their operation is not system specific. The EMS algorithms of the VPP are encoded in open-source languages. The different software / tools of the demonstration run on Linux and are portable. The EMS software is standard compliant and based on open standards (IEC-61850). All software tools are interoperable which is favourable to replicability.

11. DATA EXCHANGE DEMOS SRA (WP9)

11.1 SHORT DESCRIPTION OF THE DATA EXCHANGE DEMOS

The objective of WP9 was to test and demonstrate the data management solutions for flexibility services, developed in WP5. It focused on aspects of data management, including cross-border communication between different data exchange platforms and with different stakeholders in order to facilitate cross-border exchange of flexibility services. Two main joint demonstrations have been carried out:

- First, a joint demo, where a flexibility platform, a tool for flexibility aggregators allowing an affordable access to market by flexibility service providers (FSP), and a system operator simulator were interfaced through a data exchange platform. This allowed to define, investigate, test and demonstrate the data exchanges between different stakeholders participating in a flexibility market. The tool for flexibility aggregators (called Affordable Tool) enables an affordable access-to-market to small distributed flexibility sources. An interface between this tool and a data exchange platform has been developed.
    - The Flexibility platform allows flexibility trading market places to support TSO-DSO data exchanges for the effective supply of flexibility services from all sources connected to both the distribution grid and transmission grid. The application focusses on data exchanges between flexibility service providers (including aggregators) and flexibility users (system operators). An interface between this software and a data exchange platform has been developed.
- Second, cross-border and cross-sector communication between data exchange platforms and with different stakeholders in order to facilitate cross-border exchange of flexibility services. The aim was not to develop a single data exchange platform but ensure the interoperability of different solutions. This Cross-border exchange of data encompassed:
    - data exchange between a data exchange platform in Estonia (Elering), the ENTSO-E's platform in Brussels;
    - data exchange between Lithuanian customers located in the distribution grid of ESO and the Estonian data exchange platform Estfeed;
    - cross-sector Data Exchange between the Building sector (Building Registry: data on buidings) and the energy sector (Elering Data Hub: consumption and production data).

WP9 has tested recommendations from WP5 aiming at ensuring the scalability of data management solutions, including the requirements related to cyber security, data privacy, time constraints of data exchanges performance, procedures for handling massive flows of data, and functionalities. Functionalities are described in 16 system use cases defined in WP5.

11.2 COMPONENT LAYER

11.2.1 SHORT DESCRIPTION OF THE HARDWARE COMPONENTS OF THE DATA EXCHANGE DEMOS

Components of data exchange demos include:

- TSOs and one DSO with their data hubs and customer portals
- Operational data platform ECCo SP (Communication & Connectivity Service Platform) from ENTSO-E

- Flexibility platform used by flexibility service provider.
- Affordable tool for flexibility offering.
- Building Registry system
- Estfeed secure adapters to enable international data exchange through secure channels and in accordance with authorizations from data owner

An overview of the components and interactions is shown in Figure 28.

While the **Affordable Tool** and the **Flexibility Platform** were major new components that have been developed in WP9, Data Hub, Customer Portal and Data Exchange Platform were existing components of Elering to be used in demos. However, Elering's DEP needed to be upgraded in order to facilitate cross-border data exchange.

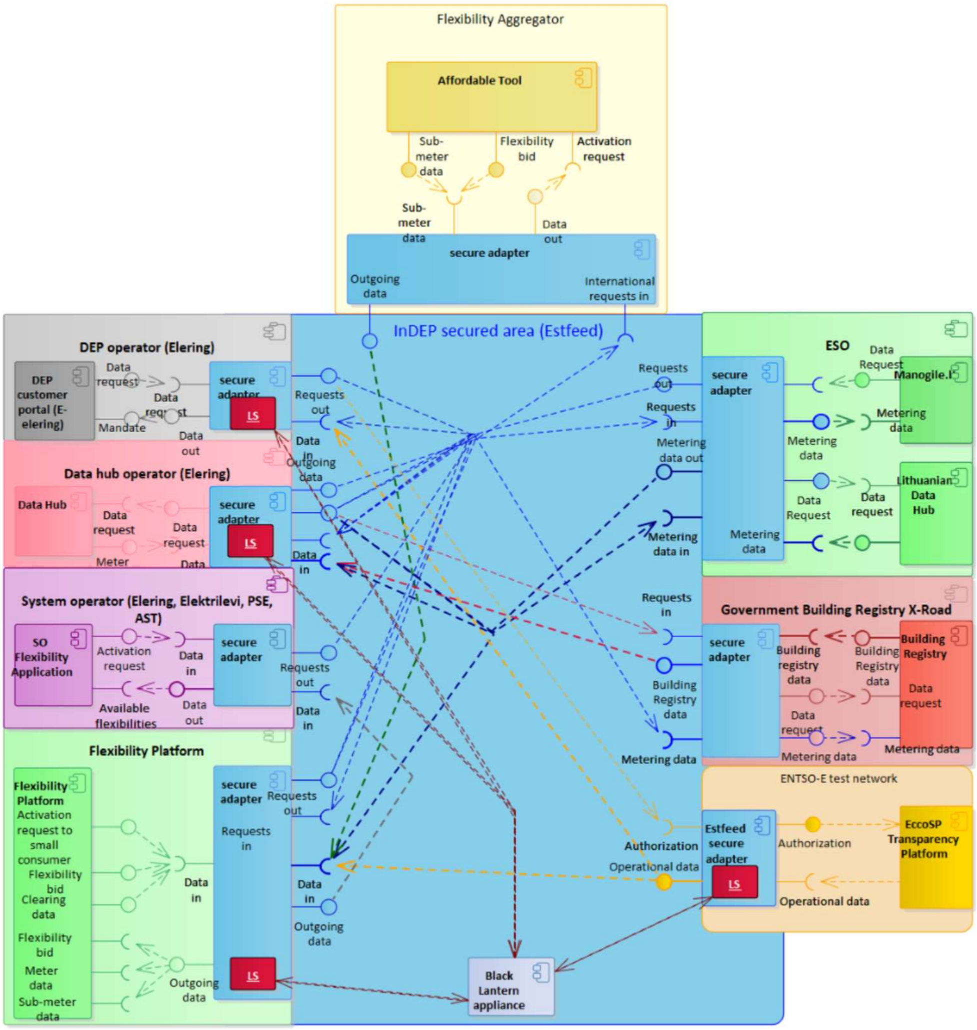


FIGURE 28: COMPONENTS INVOLVED IN CROSS-BORDER DATA EXCHANGE [EU-SYSFLEX DELIVERABLE 9.3]

The affordable tool ensures data exchange through the secure Estfeed adapter that has been developed based on the documentation and guidelines provided by Elering. The adapter provides an interface to the Estfeed system.

Each system communicating over Estfeed system is connected to its adapter that relays the Estfeed messages to other adapters using the Estfeed protocol secured with TLS. The data exchange involves three components:

i) The application information system,
ii) The Estfeed platform;
iii) the data source information system as shown in Figure 29.

The adapter communicates with the X-Road security server. The Estfeed secure adapter enables international data exchange over secured channels and in accordance with authorizations from data owners.

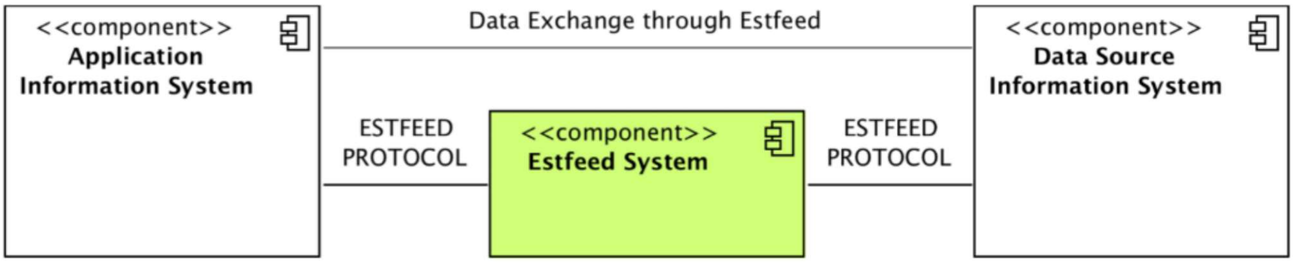


FIGURE 29: ESTFEED PROTOCOL OVERVIEW [CYBERNETICA]

The aggregator application's architecture was developed focusing on the required interfaces needed. The architecture is shown in the Figure 30 below:

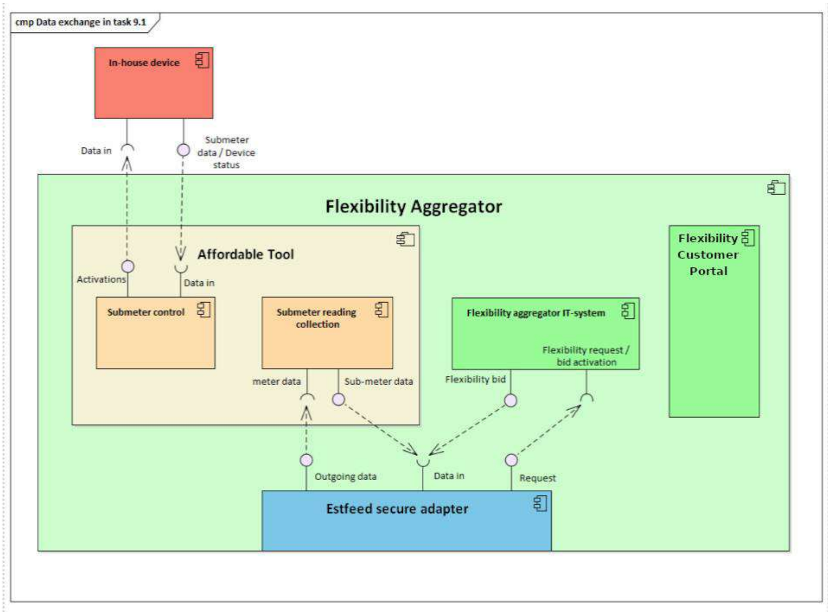


FIGURE 30: HIGH-LEVEL ARCHITECTURE OF THE AFFORDABLE TOOL DEMO

Component description from Figure 30:

- Estfeed secure adapter: enables international data exchange over secured channels and in accordance with authorizations from data owner;
- Submeter Control: communicates with in-house devices, including receiving sub-meter data, device status and flexibility activations;

- Submeter reading collection: stores meter and sub-meter data, aggregates meter-data and exposes interface for reading/sending of sub-meter / meter data;
- Flexibility aggregator IT-system: Makes bids and receives activations;
- Flexibility customer portal: gives the small consumers/participants in the aggregated flexibility a GUI to view and administrate their flexibility contribution.

11.2.2 SHORT DESCRIPTION OF THE SOFTWARE COMPONENTS

The Flexibility Platform itself is a software application developed in order to investigate and demonstrate data exchanges between different stakeholders participating in flexibility market (SOs as flexibility buyers, FSPs, flexibility platform operators). An interface between the Affordable Tool and a data exchange platform was developed to verify the usefulness of such a tool. Large consumers and suppliers are easy to identify and to handle with Flexibility Platform, however, significant amount of energy volume is found in the high number of small DSR units (households and other small consumers/prosumers. Therefore, in addition to the physical units, applications and algorithms were developed to combine the small units efficiently and effectively to the grid.
The demonstration covers the integration of the ESTFEED DEP with the “Flexibility Platform“ to enable exchange of flexibility information and metering data. ESTFEED provides security mechanisms and standardized data exchanges for example through REST APIs.
As part of the “Flexibility Platform” demonstrator the need was identified to develop a SO system simulator to enable the end-to-end data exchanges between some SOs, the Flexibility Platform and aggregators.
For the development of the Flexibility Platform, open source tools and common development languages or frameworks such as Django, mongoDB, Vue.js, ANGULAR, python or java scripts have been used.
With respect to cross-border and cross-sector data exchange, an “SO Application” was developed to demonstrate the interface between SO and the Flexibility Platform for any relevant processes using DEP as intermediary – e.g. grid qualification, launching of flexibility call for tenders, submission of flexibility activation requests.

11.2.3 SHORT DESCRIPTION OF THE ICT COMPONENTS

Hardware ICT components were not explicitly the focus of WP9 demonstrators. Existing hardware components were used, which was expecially true and relevant in “Big Data” demonstrator.

11.2.4 IMPACT OF COMPONENTS ON S&R

Scalability:
Software tools are modular and would easily allow the addition of new functionalities with minor change.
As a matter of fact, any data type as a new service can be added to the DEP and that would require upgrading the capabilities of DEP.
In terms of short to medium term evolutions, Big data is becoming reality and will be increasingly used facilitating scalability. Though massive amounts of data were not explicitly tested in WP9 demonstrators, a big data framework was provided in D5.3. The big data components used in the “Big Data” demo are themselves scalable (this is one of the reasons why they have been selected) and the designed demo architecture is scalable as well

due to the usage of commodity hardware and cloud solution. An example: the Kafka component of the big data demo is also used by Linkedin to handle bursting of millions of messages per second.

In case of scaling-up, most of the limitations could be exogenous to the system itself, for example the network connection to access the big data system or other systems which might be connected to this one. Another limitation could come from regulations when the scalability leads to transnational implications. Some limitation could come also from a cost perspective (see result of costing sub-task in D5.3).

Some technological improvements or breakthroughs can be foreseen in the short to medium term and could further facilitate scalability. In particular, as DEPs will be more widely used, the more interoperable they will be by providing standardised APIs. This would facilitate the data exchange on more global scale.

Replicability:

While ICT providers Cybernetica and Guardtime took the chance to demonstrate their proprietary tools, many other tools, components, libraries and programming languages are open source (e.g. used in Estfeed DEP and in 'Flexibility Platform' and 'Big Data' demonstrators) which facilitates replicability. As such, many of the results are being considered as open source.

In terms of portability, the Flexibility Platform and the Big Data Platform are portable especially if containerization approaches are applied facilitating replicability. Indeed, both systems are composed of different components and applications which can be easily packaged in containers, such as Docker or CoreOs. Then, these containers can be deployed on a large number of operating systems allowing the Flexibilty Platform and the Big Data Platform to run independently from them.

All software tools are interoperable. All data sources and data users are integrated to DEP using standardised APIs (adapter server installed at each source and user) and security level (security server installed at each source and user) for the communication.

11.3 BUSINESS LAYER

11.3.1 SHORT DESCRIPTION OF THE BUCs OF THE DATA EXCHANGE DEMOS

The BUCs of the WP9 demonstrations are dealing with aspects of data management, including aggregation of consumer loads in a single flexibility marketplace for TSO-DSO flexibility data exchange, cross-border and cross-sectoral communication between different data exchange platforms and with different stakeholders in order to facilitate cross-border exchange of flexibility services:

Affordable tool for small demand-side resources (DSR) units with the following objectives:

- offer consumer loads as flexibility for bidding,
- added options for automatic response to events,
- real-time metrics,
- ensure users'privacy is protected (GDPR)

Operation of single flexibility marketplace for TSO-DSO flexibility data exchange: Detailing a flexibility market platform as well as the related data exchange between the different involved stakeholders and systems. Within this BUC, features regarding the process of massive data are considered out of scope.

Operation of cross-border and cross-sector data exchange model/network:

i) between a data exchange platform in Estonia (Elering), the ENTSO-E's platform in Brussels,

ii) between Lithuanian customers located in the distribution grid of ESO and the Estonian data exchange platform Estfeed,

iii) cross-sector: between the Building sector (Building Registry: data on buidings) and the energy sector (Elering Data Hub: consumption and production data).

Table 16 shows how the system roles have been implemented in relation to the BUCs and by which systems. It shows also that some roles have not been used in the demo such as the grid validation system.

TABLE 16: IMPLEMENTATION OF THE SYSTEM ROLES IN THE WP9 DEMOS

System Roles	Task 9.1 Affordable Tool for smaller DSR units	Task 9.2 Application for TSO-DSO flexibility data exchange	Task 9.3 Cross-border data exchange
Data Exchange Platform	Elering's Esfeed	Elering's Esfeed	Elering's Esfeed / ENTSO-E's ECCo SP
Data Hub	Affordable Tool	Elenng's data hub	Elering's Data Hub
Grid Validation System			
Flexibility Platform		Flexibility Platform	
System Operator SCADA		TSO/DSO IT System (SO Simulator)	
Aggregator SCADA	Affordable tool	Affordable tool (FSP Simulator)	
Automation Controller	Affordable tool		
Customer Portal	Customer interface of Affordable Tool		e-Elering
Foreign Customer Portal			
In House Device	in-house devices used by Affordable Tool		
Meter Data Collection Tool	Affordable Too)		
Sub-Meter Data Collection Tool	Affordable Tool		
External Data Source			Estonian Building Registry / Cybernetica's sharemind (providing baselines)

11.3.2 IMPACTS OF REGULATION ON S&R

There is no lasting impediment to scalability and replicability from the point of view of regulation.

Scalability:

Current regulation as such in Estonia does not hinder scaling up the solution. However, further regulation could further facilitate this, e.g. by defining the flexibility products, roles of aggregator and market operator, usage of sub-meter data, etc.

Replicability :

Data exchange relies on the concept of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process. These elements are not available yet in all EU countries which is a temporary impediment to replicability. However, DEP and central data hub are preconditions as long as private data can be easily accessed and shared by data owners through other means and made interoperable with the solutions of other countries in order to ensure cross-border data exchange. An easier (i.e. more efficient) access to data will be available to aggregators and other energy service providers (ESCOs) if rules and conditions are similar in different countries and data can be easily exchanged between countries and sectors.

Regarding cross-border data exchange, critical aspects are related to authentication of data users and data access permissions (consents) given to data users of other countries. However, future EU regulation (eIDAS, Data Governance Act, Data Interoperability Implementing Act) is expected to address these points. Beside regulation further standardisation could facilitate further interoperability which is key for cross-border and cross-sector data exchanges – e.g. defining the roles and data semantics. Therefore, the impediment to replicability is here also temporary.

11.3.3 IMPACTS OF ECONOMICS ON S&R

The Business Opportunity Analysis and Business Model Development studied in WP11 suggested the creation of a secure European Data Exchange Platform (DEP), as proposed by the Data Bridge Alliance and led by Elering. This secure DEP would connect two types of Customer Segments: (1) Data Hubs (T-1 independent and T-2 regulated) and (2) App owners. One or both Customer Segments would pay a fee to access the platform.
In the EU-SysFlex project, no cost-benefit analysis (CBA) of the demonstrations was carried out.

Scalability :

The current proposed services are considered as economically viable. Smooth and well structured data management solutions can be repeated elsewhere, thus reducing global investment costs and facilitating scalability. Moreover, if DEPs and Data Hubs, or even some component of these like consent management solutions, were specified in the same or similar way in different domains/regions/countries then the economies of scale would make initial investment costs relatively lower and thus contribute to further facilitate scalability while interoperability would be achieved faster.

Changes in regulation could also have a positive effect on the cost-benefit ratio of an upscaled concept. As a matter of fact, the European Commission’s initiative Smart Grid Task Force is developing first set of data interoperability implementing acts as mandated by the electricity market directive. The first acts will establish a ‘reference model’ and use cases for smart meter data exchanges. Other important EC’s target is to set up ‘European Energy Data Space’. Early 2021 the BRIDGE Initiative has proposed a European energy data exchange reference architecture aiming at further interoperability between countries and sectors.

Replicability :

Data management solutions should be agnostic to specific business processes. Therefore the EU-SysFlex proposal is (to a large extent) exactly fit to be replicated in different countries regardless of the market design. However, while there are many positive developments in individual countries for accessing to and sharing of (some) private energy data, it seems that on more global level accessing to and sharing of these data is still not easily possible and this is currently a hindrance to replicability even though a temporary one..

There is no competition per se among data sharing solutions. Ideally as much as possible the latter could coexist and they should not be considered as competitors. Rather the common aim should be interoperability of these solutions

11.3.4 IMPACTS OF STAKEHOLDERS'ACCEPTANCE ON S&R

The stakeholders likely to be concerned (that could be barriers) by the scalability of the concept are data owners and data providers. This risk is, however, of moderate importance for scaling-up the concept and replicate it and dosen't pose any challenge since the solution implemented respects privacy:

- From the data owners'perspective they may hesitate to share their data:
  - Data owners like households may fear that their privacy is not protected.
  - Data owners like system operators fear that making available the grid and system data could risk the system security.
- From the data providers'perspective some stakeholders (like system operators, energy service providers) who have access to their customers data may try to set restrictions to sharing these data with third parties because of the market competition reasons.

Some groups of stakeholders (if any) might have a strong interest in participating to the large-scale deployment of the concept and this is favourable to replicability:

- Many data owners are willing to access their own data in order to better understand their own behaviour and to make corrections if necessary (e.g. consumption data).
- Many data owners are willing to share their data in order to gain from energy services provided to them based on these data.
- Many service providers are looking for access to data in order to develop new innovative business models based on these data.
- Technology providers can develop new secure and privacy-respecting solutions for data sharing.

11.4 FUNCTIONS AND SERVICES LAYERS

11.4.1 SHORT DESCRIPTION OF THE FUNCTIONS AND SERVICES OF THE DATA EXCHANGE DEMOS

Given flexibility data exchanged in EU-SysFlex demonstrators,

- provide recommendations for **data management** in flexibility services when applied on a large scale (on an IT perspective),

- estimate the volume of data exchanges,
- work on the guidelines and requirements (cybersecurity, privacy, time constraints, handling massive flows of data, etc.)
- and provide recommendations at each level in order to ensure the **scalability of flexibility services**

Identification, description and analysis of **data exchange system use cases** are necessary for business processes. WP5 focused on data exchange System Use Cases useful for demonstrations that could impact the feasibility of **scaling up** flexibility services (on an IT perspective). The SUCs designed for the “Flexibility Platform” address the issue of homogeneous and secure data management and data interoperability through the concept of Data Exchange Platform. Some SUCs are related to flexibility data and others to more general data including private data (aggregate energy data). Proper data management contributes to the participation of stakeholders across the geographical borders and of any asset.
Table 17 shows how the SUCs have been implemented in the WP9 demonstrations.

TABLE 17: SUCS OF THE WP9 DEMONSTRATIONS (FROM MILESTONE 17 REPORT)

	BUCs DEMOs	Affordable tool for smaller DSR units (task 9.1)	Operation of single flexibility marketplace (task 9.2)	Operation of cross-border data exchange model (task 9.3)	
				"ESO"	"ENTSO-E"
SYSTEM USE CASES	Aggregate energy data	y	y	y	y
	Anonymize energy data			y	y
	Authenticate data users	y	y	y	y
	Calculate flexibility baseline	y	y		
	Collect energy data	y	y	y	y
	Detect data breaches	y	y	y	y
	Erase and rectify personal data	y	y	y	y
	Exchange data between DER and SCADA	y	y		
	Integrate new application	y	y		y
	Integrate new data source		y	y	
	Manage authorizations (permissions)	y	y	y	y
	Manage flexibility activations	y	y		
	Manage flexibility bids	y	y		
	Manage security logs	y	y	y	y
	Manage sub-meter data	y	y		
	Manage users' requests	y	y	y	y
	Notify customers	y	Y	y	y
	Predict flexibility availability	y	y		
	Process massive data	?	?	?	?
	Provide list of suppliers and ESCOs		y	y	y
	Transfer energy data	y	y	y	y
	Verify and settle activated flexibilities	y	y		

Green means that the high-level description for the respective SUC has been provided

ESO - demo with ESO's data hub and Elering's DEP

ENTSO-E - demo with ENTSO-E's and Elering's DEPs

11.4.2 IMPACTS ON S&R

The results from the system use cases (SUCs) will vary to changes in boundary conditions with minor change and this doesn't affect the replicability. As a matter of fact, the data exchange SUCs are agnostic to specific business processes in general. For example, the consent management use case should work for any process and for any data. However, some flexibility market related data SUCs were elaborated, and making some assumptions from the market design perspective had to be made. For example, it was assumed that the 'Flexibility Platform' (i.e. Market Operator) selects flexibility bids, not the System Operator (alternative SUC was developed to address the latter case).

11.5 INFORMATION LAYER

11.5.1 SHORT DESCRIPTION OF THE INFORMATION LAYER OF THE DATA EXCHANGE DEMOS

The diagram hereafter (Figure 31) provides an overview of the data model of the Flexibility Platform from a business user perspective.

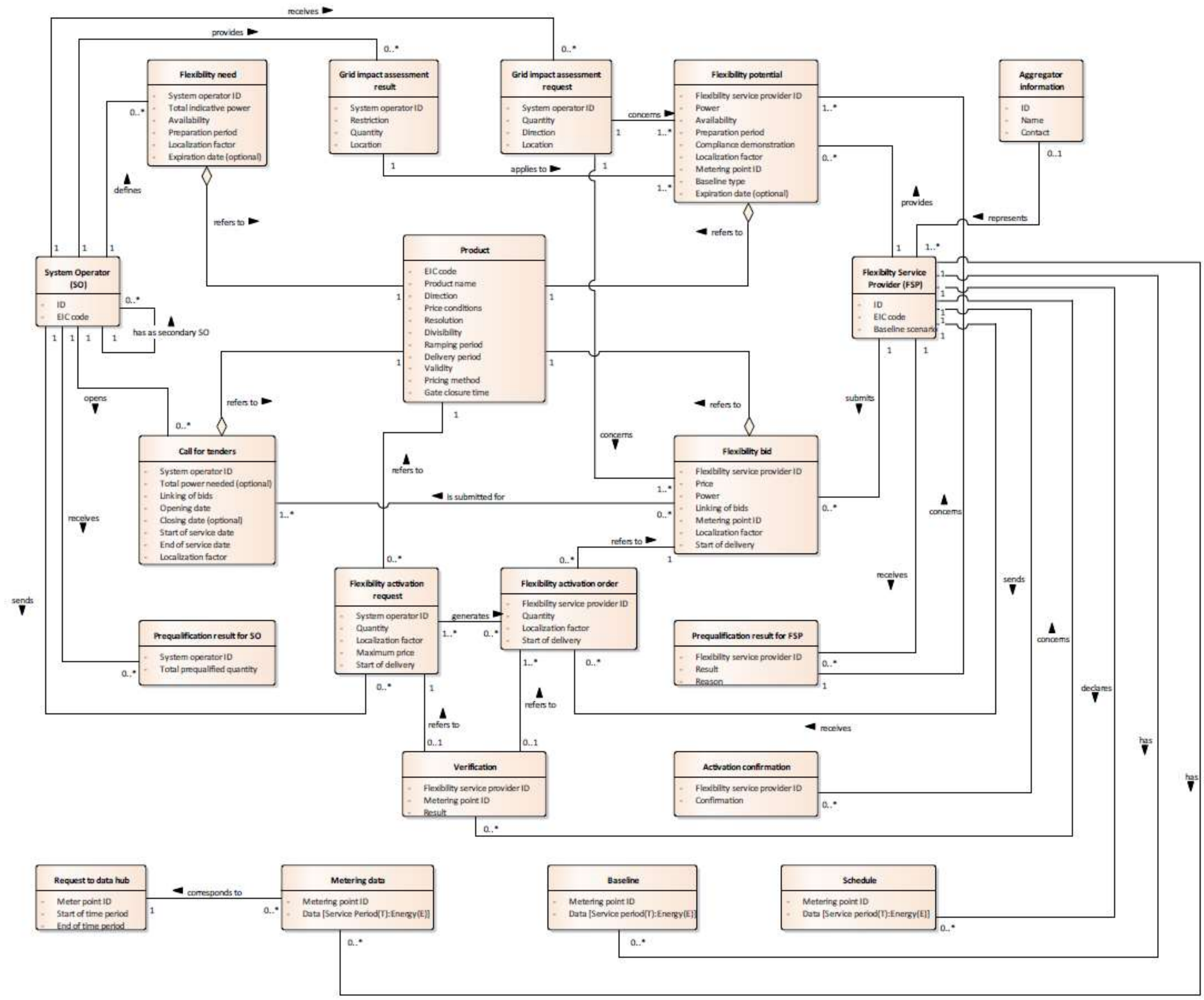


FIGURE 31: DATA MODEL OF THE FLEXIBILITY PLATFORM (FROM DELIVERABLE D9.2)

There are increasing needs for private (incl. personal) data management (in order to bring end-customers to the market), big-data management and multilateral data management (in order to enable 'joint procurement' of flexibilities, value-stacking, grid qualification).

11.5.2 IMPACT OF INFORMATION ON S&R

Information attributes are standard compliant.

In the interest of not losing focus from the core objectives of demonstrators (multilateral data exchange using the concept of DEP) proprietary standards for modelling were used. Either because they already existed (for Estfeed DEP) or there was no certainty whether appropriate open standards already existed (for 'Flexibility Platform').

In a next step, the transformation from these proprietary standards to open standards (CIM) was tried for a couple of Business Objects. For one ('Flexibility Bid') it appeared that current CIM profile addresses the need, while for the other ('Customer Consent') extensions to the CIM would be needed.

11.6 COMMUNICATION LAYER

11.6.1 SHORT DESCRIPTION OF THE COMMUNICATION LAYER OF THE DATA EXCHANGE DEMO

All data exchange between actors use standards for data formats and communication. The standards are:

- MQTT, ISO/IEC PRF 20922
- JSON, RFC8259/ECMA404
- TSL, RFC6176

These standards are assumed based on industry practices. Especially MQTT and JSON are becoming widespread standards within IoT. TSL (HTTPS) communication is a requirement for security when exchanging data.

Estfeed DEP protocol is based on SOAP and REST. Estfeed information systems (applications and data sources) communicate with Estfeed adapters using HTTPS protocol.
The Big data platform is based on MQTT, REST, TLS, HTPP
For the flexibility platform (FP):

- externally to the FP: HTPP, REST, TLS,
- internally to the FP: WebSocket, MQTT, AMQP, WGSI

11.6.2 IMPACT OF COMMUNICATION ON S&R

The protocols used are standard which is favourable to replicability.
Assessing limitations in terms of communication volumetry when scaling-up is difficult at this stage. This would require to undertake some thorough tests. Limitations such as the use of bandwidth, data latency or data loss have not been addressed in WP9.

11.7 SUMMARY OF THE DATA EXCHANGE DEMOS SRA

Most of the limitations related to scalability of components could either be exogenous to the system itself or come from regulation when the there are transnational implications. Some limitations could also come also from an economic perspective.
Software tools are modular and would easily allow the addition of new functionalities with minor change.
As a matter of fact, any data type as a new service can be added to the DEP and that would require upgrading the capabilities of DEP.
In terms of short to medium term evolutions, Big data is becoming reality and will be increasingly used facilitating scalability. Though massive amounts of data were not explicitly tested in WP9 demonstrators, a big data framework was provided in D5.3.

Data exchange relies on the concept of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process. These elements are not available yet in all EU countries which is a temporary impediment to replicability.

While ICT providers Cybernetica and Guardtime took the chance to demonstrate their proprietary tools, many other tools, components, libraries and programming languages are open source (e.g. used in Estfeed DEP and in 'Flexibility Platform' and 'Big Data' demonstrators) which facilitates replicability.

The Flexibility Platform and the Big Data Platform are portable especially if containerization approaches are applied facilitating replicability.

All software tools are interoperable. All data sources and data users are integrated to DEP using standardised APIs (adapter server installed at each source and user) and security level (security server installed at each source and user) for the communication.

There are currently some hurdles with respect to regulation but there is no lasting impediment:

- Current regulation as such in Estonia does not hinder scaling up the solution.
- Regarding cross-border data exchange, critical aspects are related to authentication of data users and data access permissions (consents) given to data users of other countries. However, future EU regulation (eIDAS, Data Governance Act, Data Interoperability Implementing Act) is expected to address these points.

The Business Opportunity Analysis and Business Model Development studied in WP11 suggested the creation of a secure European Data Exchange Platform (DEP), as proposed by the Data Bridge Alliance and led by Elering. No cost-benefit analysis (CBA) of the demonstrations was carried out, but the current proposed services can be considered as economically viable. Foreseen economies of scale could make initial investment costs relatively lower and thus contribute to further facilitate scalability while interoperability would be achieved faster.

Data management solutions are designed to be agnostic to specific business processes. Therefore the EU-SysFlex proposal is (to a large extent) exactly fit to be replicated in different countries regardless of the market design. However, on global level accessing to and sharing of private energy data is still not easily possible and this is currently a hindrance to replicability even though a temporary one.

There is no competition per se among data sharing solutions. Ideally as much as possible the latter could coexist and they should not be considered as competitors. Rather the common aim should be interoperability of these solutions.

The stakeholders likely to be concerned (that could be barriers) by the scalability of the concept are data owners and data providers. There acceptance don't pose any challenge since the solution implemented respects privacy.

Information attributes are standard compliant. Proprietary standards for modelling were used either because they already existed (for Estfeed DEP) or because there was no certainty whether appropriate open standards already existed (for 'Flexibility Platform'). In a next step, the transformation from these proprietary standards to open standards (CIM) was tried for a couple of Business Objects.

The protocols used are standard which is favourable to replicability. Assessing limitations in terms of communication volumetry when scaling-up is difficult at this stage. This would require to undertake some thorough tests. Limitations such as the use of bandwidth, data latency or data loss have not been addressed in WP9.

12. CONCLUSIONS OF THE SRA

12.1 SCALABILITY AND REPLICABILITY OF THE VARIOUS EU-SYSFLEX DEMONSTRATIONS

This section provides an overview of the main conclusions regarding the scalability and replicability of the various EU-SysFlex demonstrations. Particular attention is paid to the identified potential barriers to scalability and replicability and their importance as seen by the demonstrations. Table 18 provides a summary of the potential impediments and relates them to the identified SRA dimensions

Reg: Regulation
Eco: Economic
Com: Communication
Soft: Software
ITC: IT Communication Architecture

The barriers in red font are those which are considered as long-lasting impediments. Positive changes might occur but they are to be expected in the long-run.

TABLE 18: SUMMARY OF BARRIERS AND CHALLENGES FOR EACH EU-SYSFLEX DEMONSTRATION

Demonstration	Scalability	Replicability
Finland (WP6)	Eco: price of components (BESS) still expensive, (so far) low price of electricity and low volatility. Reg: adaptations of frequency regulation rules would be beneficial (lower bid limits and larger fast response time required for FCR-D). Reg: no DSO reactive power market at the moment in Finland and elsewhere (BUC FI-RP).	Eco: Market not fully ready (EVs infrastructure, no DSO Q-market). Reg: Frequency regulation services are different in other EU countries but rely on similar principles. Reg: no DSO reactive power market at the moment in Finland and elsewhere.
Germany (WP6)		Soft: dependance of software on the grid topology.
Italy (WP6)	Reg, Eco: Absence of remuneration mechanism in Italy. Reg: current prohibition for the Italian DSO to own and manage storage ITC: communication architecture might meet limitations with an increase in data volumetry	Reg: current prohibition for the DSOs in EU member states to own and manage storage
Portugal (WP7): Flexhub	Reg: no DSO reactive power market at the moment in EU countries	Reg: no DSO reactive power market at the moment in EU countries (PT-FXH-RP)

	Soft: software limitations due to grid size (in terms of computation time) ITC: communication architecture might meet limitations with an increase in data volumetry	Reg: only few countries allow distributed resources to provide flexibility (PT-FXH-AP)
Portugal-VPP (WP7): VPP	Reg: implementation of a multi-technology VPP not allowed yet in Portugal	Reg: implementation of a multi-technology VPP not allowed yet in most EU countries
France (WP8): VPP	Reg, Eco: Low market prices for frequency regulation services	Reg: only few countries allow distributed resources to provide flexibility (PT-FXH-AP)
Data Exchange (WP9)		Reg: the concepts of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process, are not available yet in all EU countries Reg (cross-border): current EU regulation do not address authentication of data users and data access permissions (consents) given to data users of other countries

12.1.1 FINLAND: LONG-LASTING POTENTIAL HINDRANCES RELATED TO REGULATION AND ECONOMICS

The Finnish demonstration is technically scalable and replicable. The potential hurdles are related to the regulation and economic dimensions of the SRA.

- Among the frequency regulation services proposed by the demonstration, FCR-N, FCR-D and mFRR markets apply only in Finland (BUC **FI-AP1**: Manage active power flexibility to support FCR-N and BUC **FI-AP2**: Manage active power flexibility to support mFRR/RR). Some adaptations of the rules related to the provisions of this services would be beneficial to facilitate the aggregation of a large number of assets: lower bid limits and a larger fast response time required for FCR-D which is currently seen as difficult to fulfill. In other countries, though slightly different, frequency regulation services rely on similar principles and therefore only minor adaptations would be needed to adapt them to another setting.
- In contrast, there is currently no DSO reactive power market in Finland and elsewhere and thus no rules. This means that changes in regulation/market rules could support this development towards local markets to allow the scale-up of the related BUC (FI-RP: Manage reactive power flexibility to support voltage control at the TSO/DSO connection points). This is a hurdle that could be long-lasting as compared to the limitations previously mentioned for frequency regulation services. The EU-SysFlex demonstration results will contribute to define and propose appropriate rules

Regarding economic viability, no definite conclusion can be drawn. BESS are still expensive in small (< 100 kW) and mid-scale (< 1000 kW) and that could put the profitability of the related BUC at risk on the short term (FI-AP1 and FI-AP2). Moreover, electricity and power has been cheap and there has not been enough volatility and thus the income from the markets has had its limits. Added costs from transmission and taxes might also affect negatively the viability. In the short to medium term, there are however some favourable factors: prices of BESS are expected to decrease sharply due to the development of electrical mobility. Moreover, economies of scale are foreseen in a scaled-up concept and could contribute to improve the economics.

The market is not fully ready yet for the wide-scale deployment of such solutions: there is the need of additional infrastructure for EVs, and of the establishment of a DSO reactive power market.

12.1.2 GERMANY: NO SPECIFIC BARRIER TO SCALABILITY AND REPLICABILITY

The German demonstration is already at industrial-scale and therefore the main focus was replication of the concept in a different host environment and not the increase in size.

No hindrance has been identified with respect to replicability apart from a slight dependance on the grid topology that could imply some modifications to adapt the software to a new setting.

12.1.3 ITALY: LONG-LASTING POTENTIAL HINDRANCES RELATED TO REGULATION AND ECONOMICS

The technical solution implemented in the Italian demonstration is considered as effective, scalable and replicable from a technical point of view. There is however a strong and long-lasting impediment from the regulation standpoint related to the current prohibition for the DSO to own and manage storage. Furthermore there is, in Italy, an absence of remunation mechanism of network and market services provided by DER and resources in general to the distribution networks. To be able to replicate the concept, there is then the need for new rules to be enacted by Regulators regarding remuneration, roles and responsibilities for DSOs, Owners of DERs of DGs and finally (eventually) BSP.

As far as the economic viability is concerned, the absence of remuneration mechanism and the incomplete knowledge about price levels of local flexibility services in real conditions does not allow to do a comprehensive cost / benefit analysis. The market is not ready yet since current regulation rules don't allow the deployment of such a concept.

It is needed to point out that the RES involvement during the automated process of flexibility provision from the DSO to the TSO is widely affected from PV production seasonality and the physical limits of capability curves while performing reactive power regulation. This suggests that is needed to scale up the number of participants to flexibility services and to define a wider flexibility service portfolio, integrating new technologies promoted by Italian Electrotechnical Committee which meet the most recent regulatory guidelines from Italian local authority ARERA.

12.1.4 PORTUGUESE FLEXHUB: MAIN POTENTIAL BARRIER RELATED TO REGULATION

The Portuguese Flexhub demonstration is scalable and replicable with respect to technical aspects (SUCs, Data, communication and components). However, potential regulatory barriers to scalability and replicability have been identified.

- Currently, few countries allow distributed resources to provide flexibility. BUC PT-FXH-AP (provision of mFRR/RR type reserves) could be easily applicable if regulation evolves towards a better integration of DER in system services. This should evolve in the short to medium term.

- Reactive power markets (BUC PT-FXH-RP) are not considered yet in Portugal and elsewhere. This BUC is still far from being implemented commercially and this is to be considered as a lasting impediment to the roll-out of this BUC.

Minor limitations are foreseen in terms of communication volumetry when upscaling, however communication with the field assets in the demonstration is rather for demonstration purposes. The limitations could be easily mitigated by appropriately sizing the ICT infrastructure that supports the FlexHub and therefore shouldn't have a negative impact on scalability.

A minor OPF software limitation (PT-FXH-RP and PT-FXH-AP BUCs) with respect to computation time could occur with large grids with large number of resources.

12.1.5 PORTUGUESE VPP: A TEMPORARY BARRIER ON REGULATION

Apart from regulation, the Portuguese VPP concept appears to be scalable and replicable over Europe with respect to all other dimensions of the SRA.

Current regulation in several countries (incl Portugal) do not allow the implementation of a multi-technology VPP and this is a hurdle to S&R. However, the barrier is likely to wane in the near future and the impediment should therefore only be temporary.

12.1.6 FRANCE: SOME CONCERNS ON THE ECONOMIC VIABILITY DUE TO INSUFFICIENT REMUNERATIONS

The SRA of the French VPP shows that there are no hurdle to scalability and replicability with respect to technical dimensions. There are some concerns however on the economic viability related to low remunerations. As for the other demonstrations, no CBA has been carried out and it is therefore difficult to conclude on the economic viability of the demo or of an industrial-size version. However, considering the current market prices of ancillary services and the very beneficial feed-in tariffs for renewable generation, it seems difficult to make enough profits to cover investment costs for an up-scaled VPP composed of renewables and storage for the purpose of ancillary services provision. Economies of scale could be foreseen as well as several evolutions that could improve the economic viability of the concept.To allow the large-scale roll out of the concept, remuneration mechanisms need to evolve.

12.1.7 DATA EXCHANGE: NO SPECIFIC BARRIER TO SCALABILITY AND REPLICABILITY

Data exchange relies on the concept of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process. These elements are not available yet in all EU countries which is a temporary impediment to replicability that should be solved on the short to medium term.

There are currently some hurdles with respect to regulation but there is no lasting impediment.Regarding cross-border data exchange, critical aspects are related to authentication of data users and data access permissions (consents) given to data users of other countries. However, future EU regulation (eIDAS, Data Governance Act, Data Interoperability Implementing Act) is expected to address these points.

12.2 MAIN TAKE-AWAYS FROM THE SRA

This section provides a cross-analysis view of the results. They are presented here per SRA dimension. Most of the difficulties arise from the fact that overcoming the barriers often depends on exogenous factors which are not part of the demonstrations and with limited influence of the latter to make things evolve. The aggregated results highlight that:

- The various demonstrations have a rather strong focus on the technical level of their solution/application.
- The main possible problems pointed out in the analyses may arise from the regulation or market design dimension either because rules may not allow the envisaged services or because the remuneration is currently low or nil.
- The economic barriers were difficult to address properly since no Cost Benefit Analysis (CBA) was carried at the demonstration level. Therefore, the economic viability was rather assessed through experts'opinions and foreseen economies of scale and changes in market rules that could be favourable to S&R.
- Stakeholders acceptance and possible involvement don't pose any challenge even if they are crucial in some cases (e.g. in Finland, for aggregating customers'assets).
- Some limitations regarding the component-related dimensions have been identified and are likely to arise upon up-scaling. However, the demonstrations are rather to be considered as prototypes and components and architecture will change in industrial-scale versions thereby solving the potential problems.

The detailed results presented in the previous sections highlighted specific limitations and challenges that could hamper the scalability and replicability dimensions of the EU-SysFlex demonstrations. Table 19 summarizes these limitations and challenges and indicates whether these impediments are temporary or long-lasting :

(green)	Short-Term impediment
(pink)	Long-Term impediment
(yellow)	Intermediate

Dimensions that do create hurdles or challenges and that do not hamper the potential industrialisation and wide-scale roll-out of the demonstrations are not further described in this section.

TABLE 19: LIMITATIONS AND CHALLENGES IN THE EU-SYSFLEX DEMONSTRATIONS

Barriers	Scalability		Replicability	
Component-related	**Software**	PT-FlexHub: software limitations due to grid size (in terms of computation time)	**Software**	DE: slight dependance of software on the grid topology
	Communication	PT-FlexHub: communication architecture might meet		

		limitations with an increase in data volumetry		
Economics	**Profitability**	All: Viability difficult to assess (no cost-benefit analysis at demo level in the EU-SysFlex project)	**Business-Model**	FI: Market not fully ready (EVs infrastructure, no DSO Q-market)
		FI: price of components (BESS) still expensive and so far low electricity prices		
		IT: Absence of remuneration mechanism		
		FR: Low market prices for frequency regulation services		
Regulation and market rules	**Regional / National**	FI, PT-FlexHub: no DSO reactive power market at the moment in Finland and elsewhere	**National / Intl.**	FI, PT-FlexHub: no DSO reactive power market at the moment in EU countries
		FI: adaptations of frequency regulation rules would be beneficial (lower bid limits and larger fast response time required for FCR-D)		FI: Frequency regulation services are different in other EU countries but rely on similar principles
		IT: current prohibition for the Italian DSO to own and manage storage		IT: current prohibition for DSOs to own and manage storage in EU countries
		IT: absence of remunation mechanism in Italy.		FR, PT-FlexHub: only few countries allow distributed resources to provide flexibility
		PT-VPP: implementation of a multi-technology VPP not allowed yet in Portugal		PT-VPP: implementation of a multi-technology VPP not allowed yet in most EU countries
		FR: Low market prices for frequency regulation services		Data exchange: the concepts of Data Exchange Platform (DEP), meter data storage in central data hub and clearly defined consent management process, are not available yet in all EU countries.
				Data Exchange (cross-border): current EU regulation do not address authentication of data users and data access permissions (consents) given to data users of other countries

12.2.1 REGULATION AND MARKET-DESIGN BARRIERS

The regulation and market design dimensions are the most important factors in this analysis since the main barriers and challenges stem from them. Actual impediments arise from i) the absence of appropriate regulation framework at national level as regards scalability or in other member states with respect to replicability and ii) lack of remuneration rules or low market prices. The latter could put at risk the economic viability of the concepts whereas the former could hamper the roll-out to an industrial-scale version of the concept and its deployment in other EU member states. These limitations have causes which stand outside of the project boundaries. They stress the need for evolutions in terms of regulation and market-design at the EU level and in some cases these changes are already expected which makes the hurdle only temporary. These changes are rather to be expected in the medium to long term.

12.2.2 ECONOMIC BARRIERS

The economic dimension is also of high importance. As mentioned earlier, there was no Cost-Benefit Analysis at the demonstration level and thus the economic viability of the concepts has not been studied per se in the EU-SysFlex project. The demonstrations had a strong focus on the technical feasibility and the economic aspects were not the priority. The analysis carried out has thus relied on experts'opinions and on factors that could be either favourable or detrimental such as the foreseen economies of scale or foreseen changes in remuneration schemes. The main barriers that have been identified come from i) components which are still expensive (e.g. BESS) and whose expected decrease in cost could ease the potential economic constraint, ii) low remuneration or no remuneration at all which ties the economic dimension to the market design and iii) the insufficient readiness of the market. The SRA showed that the demonstrations sometimes use proprietary standards or other types of standards (mandatory, open). Use of non-proprietary standards has a positive impact on cost since multiple vendors can provide offers. The recommendation from the analysis of the economic dimension of the concepts developed in EU-SysFlex is to complete the studies carried out during the project by a cost-benefit analysis of a larger scale solution and especially in a different setting.

12.2.3 COMPONENT-RELATED BARRIERS

Limitations can arise also from components (hardware, software, ITC architecture). Some limitations have been identified related to i) the computation time of softwares when dealing with larger grids or a larger number of assets, ii) the dependence of softwares on the grid topology, and iii) the increase in data volumetry when up-scaling. None of these potential limitations are considered as real impediments mainly because the EU-SysFlex demonstrations are to be considered as prototypes and medium to major changes to the solution/application are to be expected for most of them with the roll-out to an industrial-scale or within different boundary conditions. Therefore technologies and design are likely to change and be adapted.

13. ANNEX 1: QUESTIONNAIRE EU-SYSFLEX

13.1 METHODOLOGY

The structure of the Smart Grids Architecture Model is used as the backbone for defining the scope of the SRA. Scalability and Replicability may be defined as assessing the implementation potential of a given technology/solution/application/business model at a larger scale or in a different context. The specific scope and corresponding methodology selected to perform a scalability and replicability analysis (SRA) may vary significantly depending on the type of questions that each project wants to answer as well as the characteristics of the project itself. In particular, questions may address different layers of the SGAM (Smart Grids Architecture Model), illustrated by the Figure 32.

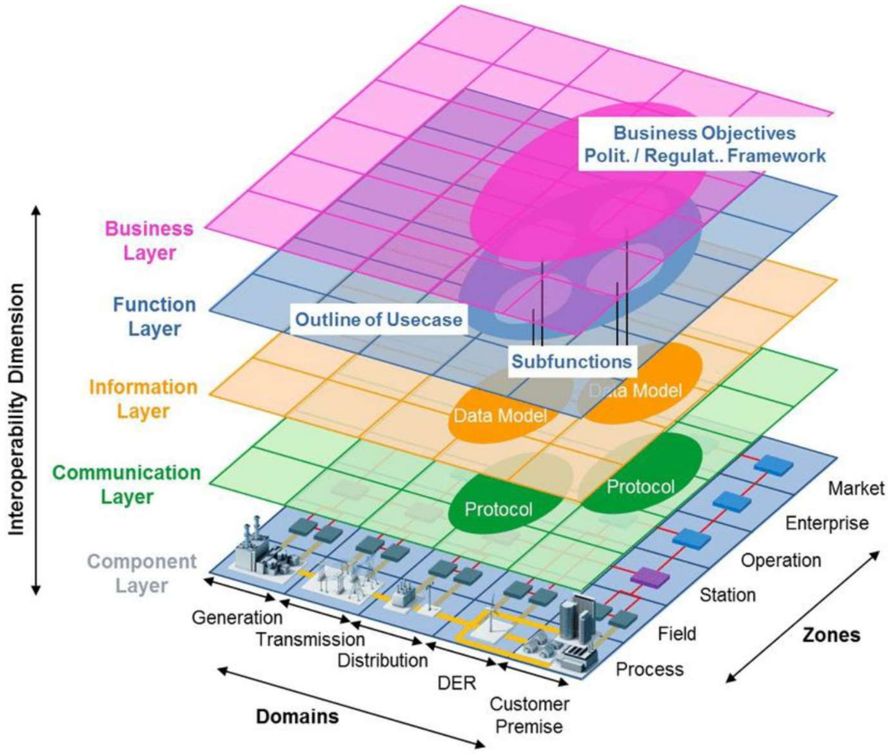


FIGURE 32: SGAM FRAMEWORK

The draft steps to perform a SRA of a smart grid project proposed by the BRIDGE Task Force Replicability & Scalability Analysis can be broken down into four stages, each of them comprising several steps.

1. **Define the scope of the SRA**: firstly, the SGAM layers to be considered in the SRA have to be selected as well as the SRA dimension(s) that will be assessed within each SGAM layer. In order to deploy a solution such as those proposed in the EU-SysFlex project, the scalability and replicability analysis must be guaranteed from the perspectives of four main focus areas, this includes the functional, business (economic and regulatory), functions and services, information and communications (ICT) and hardware component domains. Each of the analysis areas provides individual SRA analysis based on each of their respective objectives and methodologies:

2. **Perform the SRA for each dimension selected**: a data collection, based on a questionnaire is organised in order to perform qualitative analyses.
3. **Draw conclusions and deliver the SRA rules/roadmap**: the last stage consists in analysing the results obtained in the SRA, first for each dimension individually and subsequently trying to relate among them the results for the different dimensions when relevant.

SGAM Layer	*SRA Dimension*
Business	Regulatory analysis
	Economic analysis
	Business model aspects: market preparedness, market maturity, competition level, ease of doing business
	Stakeholders' perspectives
Functions	SUCs scalability
Information	Standardization of attributes (replicability)
Communication	Communication protocols for data exchange (standardization), communication volumetry, bandwidth, data latency, data loss
Component	Hardware (modularity, standardization, plug and play)
	Software (open- source, libraries, etc.)
	ICT (modularity, standardization, use of open protocols, etc.)

13.2 SHORT DESCRIPTION OF THE DEMO

To be filled in by Task-Leader

13.3 BUSINESS LAYER (B)

The *business layer* represents the business view on the information exchange related to smart grids. It covers regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer.

Four dimensions will be discussed:

1. Regulation/market rules: Could current regulation or market rules create barriers to the new solutions?
2. Economics: Is your solution viably scalable?
3. Business-Models: What is the market readiness/maturity for a given solution? What is the current competition level?
4. Stakeholders' perspectives: Are the different groups of stakeholders ready to embrace an enlarged project? What would be their willingness to participate in the innovative solution?

13.3.1 SHORT DESCRIPTION OF THE BUCS OF THE DEMO

To be filled in by Task-Leader

13.3.2 QUESTIONNAIRE #1: BUSINESS SRA

13.3.2.1 REGULATORY ANALYSIS: DOES THE REGULATORY FRAMEWORK ALLOW SCALING UP OR REPLICATION?

With respect to scalability, regulation is understood in terms of its impact on size and scope of the demonstration. Usually, the rules and requirements to provide certain services mostly affect scalability.

With respect to replicability, the regulatory analysis is based on the investigation of the regulatory drivers and barriers which may be imposed within various countries in order to highlight the compatibility of these regulations with the deployment of scaled-up solutions.

B1 – Did you harmonize the role models of your demo?

The Role Models have been developed in order to facilitate dialogue between the market participants from different countries through the designation of a single name for each role and domain that are prevalent within the electricity market. Its focus is essentially to enable a common terminology for IT development. The question related to scalability and replicability is related to the use of the Harmonised Electricity Market Role Model by ENTSO-E.

☐	Yes
☐	No

If not, describe the possible barriers that could affect scalability and replicability (S&R) of your demo:

Your answer

B2 - Could current national or regional regulation or market rules create barriers that could limit the size and scope of an up-scaled technical solution?

☐	Yes and it is a lasting impediment to scalability
☐	Yes but it is a temporary impediment to scalability
☐	Neutral value to scalability
☐	No and it is Favourable to scalability
☐	No and it is a strong case for immediate scalability

Describe the barriers and how they could affect scalability:

Your answer

B3 – Does your technical solution rely on elements of current national/regional regulation or market rules that are specific to your country/region and that could prevent replication elsewhere?

(e.g.: in some countries, DSOs are not allowed to act as aggregators; ownership of BESS by DSOs that may not be allowed in other countries' regulatory framework).

☐	Yes and it is a lasting impediment to replicability
☐	Yes but it is a temporary impediment to replicability
☐	Neutral value to replicability
☐	No and this is Favourable to replicability
☐	No and this a strong case for immediate replicability

Describe the barriers and how they could affect replicability:

Your answer

B4 – Are you aware of regulatory barriers or market rules (in other regions of the same country, in other countries) that could prevent replication of your technical solution in another location?

(e.g. provision of FCR-N is specific to the Finnish regulatory framework).

(e.g.: in some countries, DSOs are not allowed to act as aggregators).

(e.g. congestions management are not regulated/remunerated in the current Italian regulatory framework).

(e.g. FFR is not regulated/remunerated in most continental Europe regulatory frameworks).

☐	Yes and it is a lasting impediment to replicability
☐	Yes but it is a temporary impediment to replicability
☐	Neutral value to replicability
☐	No and this is Favourable to replicability
☐	No and this a strong case for immediate replicability

Describe the barriers and how they could affect replicability. What regulation or market rules should be put in place in order to replicate the solution:

Your answer

13.3.2.2 ECONOMIC ANALYSIS (CBA): ARE SCALING-UP AND REPLICATION ECONOMICALLY VIABLE?

In the EU-SysFlex project, no cost-benefit analysis (CBA) of the demonstrations was carried out. The questions related to economic analysis provide, whenever possible, indications of the viability of the implementation of scaled-up solutions based on technology improvements and economies of scale.

B5 –Are the current proposed services economically viable? (is the cost-benefit ratio greater than 1?)

☐	Very true
☐	Rather true
☐	Rather false
☐	False
☐	No clue
☐	Not applicable to the demo

What is the main reason for the benefits being larger than the costs (summarize briefly)?
If not, why aren't the services economically viable?

Your answer

B6 – When considering an enlarged project, do you foresee economies of scale?
(e.g.: If the number of BESS deployed is multiplied by 5, the incurred costs are multiplied by less then 5; the system savings increase with respect to the current system costs).

☐	No and it is a lasting impediment to scalability

☐	No but it is a moderate impediment to scalability
☐	Neutral value to scalability
☐	Yes and it is Favourable to scalability
☐	Yes and it is a strong case for immediate scalability
☐	Not applicable to the demo

Explain:

Your answer

B7 –Do you foresee evolutions (regulation or market rules changes, technical breakthroughs, …) in the short to medium term which could have a positive effect on the cost-benefit ratio of an up-scaled project?

(e.g.: decrease in cost of electrochemical batteries, more afordable IoT and big data, foreseen increase in remuneration of a flexibility service).

☐	No and it is a lasting impediment to scalability
☐	No but it is a moderate impediment to scalability
☐	Neutral value to scalability
☐	Yes and it is favourable to scalability
☐	Yes and it is a strong case for immediate scalability
☐	Not applicable to the demo

If yes, describe the foreseen evolutions:

Your answer

B8 –Could an industrial solution be replicated under different markets (e.g. other EU member states) and still be economically viable(have a cost-benefit ratio greater than 1)?

(e.g.: i) flexibility service could be less remunerated in some places than in others, ii) demand response might be limited by regulations or market rules at the moment because of security of supply concerns).

☐	No and it is a lasting impediment to replicability
☐	No but it is a temporary impediment to replicability
☐	Neutral value to replicability
☐	Yes and this is favourable to replicability
☐	Yes and this a strong case for immediate replicability

Explain what the barriers are:

Your answer

13.3.2.3 BUSINESS-MODELS

What are the identified business opportunities for your demo?

Your answer

B9 –Is the market ready/mature for an up-scaled industrial solution? (assuming that revenues are high enough)

☐	No and it is a lasting impediment to scalability
☐	No but it is a moderate impediment to scalability
☐	Neutral value to scalability
☐	Yes and it is favourable to scalability
☐	Yes and it is a strong case for immediate scalability
☐	Not applicable to the demo

Comment (optional):

Your answer

B10 – Have similar solutions been already implemented or at least tested by another entity up to now (utility/grid operator, Agregator, …)?

e.g.: No, the demo is an innovative solution and we are not aware of an application elsewhere

e.g.: Yes, the suppliers of the solution are aware of a similar solution being tested in …

☐	Yes
☐	No
☐	Partially
☐	No clue

Describe why and how, if not, why not?

Your answer

How critical is it to replicability?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

B11 –How would you describe the competition level? your position as compared to other similar solutions?

☐	Major competition
☐	Average competition
☐	Minor competition
☐	No competition
☐	Not applicable to the demo

Explain

Your answer

How critical is it to replicability?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

B12 –Are there any barriers with respect to availability and accessibility of the data needed to your solution?

Move to Business Layers

e.g. Data not collected (on large scale) or not accessible due to privacy issues).

☐	Yes, major barriers
☐	Yes, moderate barriers
☐	Yes, minor barriers
☐	No

Describe which ones and how they affect the demonstration's solution:

Your answer

Do you consider this important for your demonstration?

☐	Yes
☐	No

13.3.2.4 STAKEHOLDERS' ACCEPTANCE

Stakeholders' acceptance mostly affects the scalability of the demonstrations: would the different groups of stakeholders be ready to embrace a scaled-up project? what would be the willingness of different groups of stakeholders to participate in the innovative solution?

Who are the stakeholders likely to be concerned (that could be barriers) by the scalability of your technical solution?

Your answer

B13 –Is social? consumers? stakeholders' acceptance important for the scale-up of your technical solution?

☐	Yes, of major importance
☐	Yes, of moderate importance
☐	Yes, of minor importance
☐	No

If yes, explain which stakeholders why:

Your answer

B14 –Do you foresee any challenges with respect to stakeholders' readiness to embrace an enlarged technical solution?

Challenges might come from:

a) the environmental impact of the scaled-up project? (e.g.: some stakeholders might not be ready to embrace a new project involving a large-footprint).
b) the amount of investment implied? (e.g.: residential consumers could be reluctant to invest in smart house appliances).
c) the necessary stakeholders'involvement? (e.g.: residential consumers could be reluctant to participate to a demand-response programme).
d) …

☐	Yes and it is a lasting impediment to scalability
☐	Yes but it is a temporary impediment to scalability
☐	Neutral value to scalability
☐	No and this is favourable to scalability
☐	No and this a strong case for immediate scalability

Describe the potential challenges with specific stakeholders and how they could be overcome:

Your answer

B15 - Do you foresee stakeholders'acceptance problems upon deploying your technical solution in other countries?

☐	Yes, major problems
☐	Yes, moderate problems
☐	Yes, minor problems
☐	No
	Difficult to answer (IT)

If "Yes", describe what could be the acceptance problems:

Your answer

How critical is this to replicability?

☐	Lasting impediment to replicability
☐	Moderate/Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

B16 - Do you foresee a willingness of different groups of stakeholders to participate in the industrialisation of your innovative solution?

☐	Yes, a strong willingness
☐	Yes, a moderate willingness
☐	Yes, a minor willingness
☐	No

☐	No clue

Describe which groups of stakeholders (if any) might be interested in participating and why:

Your answer

How critical is this to replicability?

☐	Lasting impediment to replicability
☐	Moderate/Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

13.4 FUNCTION LAYER

The function layer describes **functions and services including their relationships** from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components.

Here, the analysis focuses on the main functions developed within the project and their interrelation (exchanged information) and aims at assessing the SUCs scalability and replicability. It is based on the qualitative analysis of the set of system use cases (SUCs) of each demo, as well as SUCs interaction in order to identify potential barriers/constraints or drivers.

13.4.1 SHORT DESCRIPTION OF THE FUNCTION AND SERVICES OF YOUR DEMO

To be filled in by Task-Leader

13.4.2 QUESTIONNAIRE #2: FUNCTIONS AND SERVICES SRA

FS1 - Do the expected results from your system use cases (SUCs) vary to changes in boundary conditions?
(e.g.: changes in the characteristics of the distribution grid on which they are implemented, the load profiles of consumers, etc.)

☐	Yes, with major change
☐	Yes, with moderate change
☐	Yes, with minor change
☐	No
☐	No, not considered yet

Describe which boundary conditions would have an impact on your SUCs:

Your answer

How critical is it to the replicability of your demonstration?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

13.5 INFORMATION LAYER

The information layer describes the information that is being used and exchanged between functions, services, and components. It contains **information objects** and the **underlying canonical data models**. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.

The main question related to SRA is dealing with the exchange of attributes.

13.5.1 SHORT DESCRIPTION OF THE INFORMATION LAYER OF THE DEMO

To be filled in by Task-Leader

13.5.2 QUESTIONNAIRE #3: INFORMATION SRA

I1 – Are attributes standard compliant?

Semantics : A is exchanged. Attribute A has to be understood in the same way on both sides (e.g.: Compliance with proprietary standards will usually not enhance replicability when the solution is applied to another utility).

☐	Yes, mandatory standards
☐	Yes, voluntary standards
☐	Yes, open standards
☐	Yes, proprietary standards
☐	No

Could you mention the benefits and/or challenges you expect for being your system/solution compliant with the contemplated standards?

which standards (mandatory, voluntary, open or proprietary)?	Benefits	Challenges
Your answer	Your answer	Your answer

How critical is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability

☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

13.6 COMMUNICATION LAYER

The emphasis of the communication layer is to describe **protocols and mechanisms for the interoperable exchange of information between components** in the context of the underlying use case, function or service and related information objects or data models.

Therefore, the main questions deal with communication protocols for data exchange (within an area or point-to-point). They are summarized as follows:

- Which protocols are being used (MQTT, REST, SOAP, …) ? are they open protocols? are they standard ?
- Are there foreseen limitations upon scaling-up the solution in terms of communication volumetry?
- Are there foreseen limitations upon scaling-up the solution that could affect the use of bandwidth, data latency or data loss?

13.6.1 SHORT DESCRIPTION OF THE COMMUNICATION LAYER OF YOUR DEMO

To be filled in by Task-Leader

13.6.2 QUESTIONNAIRE #4: COMMUNICATION SRA

C1 – Which communication protocols are being used (MQTT, REST, SOAP, …) ? Are they standard ?

Communication protocols being used:

Your answer

☐	Yes, they are standard
☐	No

How does it affect replicability?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

What is the maximum number of simultaneous accesses (e.g. users connected to a portal)

What is the maximum number of connected equipment

What is the expected maximum response time (volumetry : a unit communication has a given volume that should be multiplied by the number of connected equipment)

C2 – Could you foresee limitations in terms of communication volumetry when scaling-up your solution?
(volumetry : a unit communication has a given volume that should be multiplied by the number of connected equipment)

What is the maximum number of simultaneous accesses (e.g. users connected to a portal)?

What is the maximum number of connected equipment?

Your answer

☐	Yes, major limitations
☐	Yes, moderate limitations
☐	Yes, minor limitations
☐	No

Explain what the limitations might be (maximum number of simultaneous accesses (e.g. users connected to a portal), maximum number of connected equipment):

Your answer

How critical are these limitations to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

C3 – Could you foresee limitations that could affect communication such as the use of bandwidth, data latency or data loss, when scaling-up your solution?
Latency is the amount of time it takes for data to travel from one point to another.

Bandwidth is the rate of data transfer for a fixed period of time.

Your answer

☐	Yes, major limitations

☐	Yes, moderate limitations
☐	Yes, minor limitations
☐	No

Explain what the limitations might be:

Your answer

How critical are these limitations to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

13.7 COMPONENT LAYER

The component layer includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired/wireless communication connections, routers, switches, servers) and any kind of computers. The emphasis of the component layer is the physical distribution of all participating components (hardware, softwares, ICT components).
The main questions related to scalability are dealing with modularity and compatibility of components with other manufacturers' technologies. Regarding replicability, the main question is the compliance with existing standards?

The main questions dealing with the scalability of components are their modularity, the complexity of interface design (foreseen increase in interaction among components with scale-up) and the expected technology evolutions that could facilitate a scale-up of the project.
Regarding replicability, the main aspects that could hinder replicability are the interoperability of the components, their compliance with existing standards, and the possible dependence of the demo on the local resources – solar, wind - and infrastructures.

The evaluation of the scalability consists in assessing the modularity of the components with respect to system integration and system reliability. By system integration, one refers to the evaluation of the complexity of integrating additional systems or components. Concerning the system reliability, the scalability analysis will aim at assessing the effect of scaling the system on the performances and security.

Replicability is mainly ensured through the implementation of standards and interoperability of devices providing an almost plug and play solution. The SRA will then deal with:

- Accessibility of components to any interested party and avoidance of possible vendor lock.
- Interoperability of services and devices (interfaces and connections used among different actors). Standardization is a key enabler for interoperability. If devices, protocols and data formats are standards, they will ease the replication process.
- interchangeability (exchange of certain devices/components of the demo without compromising the performance or functionality supported)

13.7.1 HARDWARE COMPONENTS

13.7.1.1 SHORT DESCRIPTION OF THE HARDWARE COMPONENTS OF YOUR DEMO

To be filled in by Task-Leader

13.7.1.2 QUESTIONNAIRE #5: HARDWARE SRA

H1 - Does the modularity of your hardware components allow you to easily add extra components to increase the size of your technical solution and your ability to provide an enhanced flexibility to the electrical system? (e.g.: a VPP in which additional vRES, loads and storage capacity can be easily integrated into without any technical difficulty/limitation and at a low extra cost)

☐	Yes, with minor change
☐	Yes, with moderate change
☐	Yes, with major change
☐	No, not considered yet

Describe briefly which extra components could be added and how, or why not:

Your answer

How important is modularity to your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

H2 - Can you foresee limitations that could affect the proper operation of your technical solution when adding extra components to enlarge your technical solution?
(e.g.: a data concentrator can manage a certain number of data sources. If the number of data sources increases to an extent the data concentrator is not able to cope with, an upgrade is needed, implying increased fixed costs).

☐	Yes, major limitations
☐	Yes, moderate limitations
☐	Yes, minor limitations
☐	No

Explain what the limitations might be:

Your answer

How critical are these limitations to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

H3 - Does the local grid infrastructure in which your technical solution is inserted, impose any limitation on the maximum size that can be reached by the latter?

e.g.:

- limitation due to the rating of a substation transformer,
- insufficient number of parallel transformers in a substation, that could limit the power supplied
- possible congestions on the grid,
- …

☐	Yes, major limits
☐	Yes, moderate limits
☐	Yes, minor limits
☐	No

If yes, what are these external limitations and can they be easily overcome?

Your answer

How critical is it to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

H4 - Do you foresee technological improvements or breakthroughs in the short to medium term that could facilitate the scale-up of your project?

e.g.:

- The use of IEC 61850 (if not already done) could make it easier to add components into an existing facility;
- Replacing a data concentrator which only reads meters by a new data concentrator with automation capabilities (reading meters, automate secondary substations, control switches, etc.).

☐	Yes

☐	No

Describe which breakthroughs/improvements and their possible impact (optional):

Your answer

How critical is it to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

H5 - Is the operation of your technical solution dependent on the location characteristics of your demo?

Possible aspects:

- Local RE resource: wind/solar resource
- Terrain conditions (mountains vs. lowlands / forest vs. desert),
- local generation mix,
- demographics (urban vs. rural population),
- size of the given area and distances,
- etc.).

☐	Yes, major dependence
☐	Yes, moderate dependence
☐	Yes, minor dependence
☐	No dependence

If yes, which aspects could have an impact? Do they have a positive or negative impact?

Your answer

How critical is it to replicability?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

H6 - Is the hardware standard compliant? If yes, with which standards (mandatory, voluntary, open or proprietary)? Could you mention the benefits and/or challenges you expect for being your system/solution compliant with the contemplated standards?

(e.g.: Compliance with proprietary standards will usually not enhance replicability when the solution is applied to another utility).

☐	Yes, mandatory standards
☐	Yes, voluntary standards
☐	Yes, open standards
☐	Yes, proprietary standards
☐	No
☐	Not relevant to the demo

Could you mention the benefits and/or challenges you expect for being your hardware compliant with the contemplated standards?

Standards	Benefits	Challenges
Your answer	Your answer	Your answer

How critical is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

H7 - Could the solution be easily made compliant (economically and technically) with a defined different set of standards? If yes, describe how? If not, explain why not?

(e.g.: convert or adapt your proprietary standard to an open standard)

☐	Yes, major change
☐	Yes, moderate change
☐	Yes, minor change
☐	No
	Not relevant to the demo

Describe how:

Your answer

H8 - Are all components of your solution interoperable, i.e. able to adapt their operation and interactions to a different setting?

Interoperability can be described as the ability of two or more devices from the same vendor, or different vendors, to exchange information and use that information for correct cooperation [IEC61850-2010].

☐	Yes, all units are interoperable
☐	Yes, a majority of units are interoperable
☐	Yes, moderate units are interoperable
☐	Yes, a minority of units are interoperable
☐	No

If not, which ones are not interoperable? If yes, why and how has the interoperability been obtained?

Your answer

How important is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

H9 - Can a component currently provided by manufacturer A be substituted by a component provided by manufacturer B, at no extra cost (time/investment)?

☐	Yes, with major investment
☐	Yes, with moderate investment
☐	Yes, with minor investment
☐	No

Describe how or why not:

Your answer

How important is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

13.7.2 SOFTWARE COMPONENTS

13.7.2.1 SHORT DESCRIPTION OF THE SOFTWARE COMPONENTS OF YOUR DEMO

To be filled in by Task-Leader

13.7.2.2 QUESTIONNAIRE #5: SOFTWARE SRA

S1 - Does the modularity of your software tool allow you to easily add extra functionalities to scale-up your solution (and your ability to provide enhanced services)?

e.g. can you integrate new modules to the existing software; are there standard I/O functions and format which allow interfacing with other softwares?

☐	Yes, with major change
☐	Yes, with moderate change
☐	Yes, with minor change
☐	No, not considered yet

Describe which functionalities could be added and how, or why not:

Your answer

How important is software modularity to the scale-up of your demonstration?

☐	Lasting impediment to scalability

☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

S2 - Can you foresee limitations that could affect the proper operation (e.g. memory requirements, computational time, etc.) of the software tool when adding extra functionalities to enlarge your solution?
e.g.: changing the character of the optimization from a linear problem to a mixed integer problem; adding more detailed models of the elements of the Grid.

☐	Yes, major limits
☐	Yes, moderate limits
☐	Yes, minor limits
☐	No

Explain what the limitations might be:

Your answer

How critical are these limitations to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

S3 - Does the current computer architecture (memory size, CPU time, data storage), apart from the software tool itself, impose any limitation on the maximum size of the system?
(e.g. a more powerful computer is needed to process a much larger volume of data and keep computational times manageable).

☐	Yes, major limits
☐	Yes, moderate limits
☐	Yes, minor limits
☐	No

If yes, what are these external limitations and can they be easily overcome?

Your answer

How critical is it to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

S4 - Do you foresee breakthroughs/improvements (input data, solvers, etc.) in the short to medium term that could enhance the application of your software tool?

This question does not address the computational power of your computer.

e.g.: i) a new type of solver that could reduce computational time; ii) a new type of smart meter that could make available the needed data more easily; …

☐	Yes
☐	No
☐	Not of importance

Describe which breakthroughs/improvements and their possible impact (optional):

Your answer

How critical is it to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

S5 - Is the tool system-specific? (Does the operation of the software tool depend on the specific infrastructure of the system your demo is modelling?)

e.g. different input data, such as grid topologies or system elements; some tools cannot model all elements such as FACTS, ICT models, etc.

☐	Yes, major dependence

☐	Yes, moderate dependence
☐	Yes, minor dependence
☐	No

On which aspects? (optional):

Your answer

How critical is it to replicability?

☐	Lasting impediment to replicability
☐	Moderate impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

S6 - Is the programming language free, open source?

e.g.: The licensed solvers are currently more powerful than the free alternatives.

☐	Yes
☐	No

If not, for what specific reasons did you select a licensed tool? (optional):

Your answer

How critical is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

S7 - Are there any limitations in terms of portability?

e.g.: Dependence on operation systems (Windows, Linux, Unix, Apple, …).

☐	Yes, major limitations
☐	Yes, moderate limitations

☐	Yes, minor limitations
☐	No

Describe the limitations and their impact:

Your answer

How critical is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

S8 - Is the solution standard compliant? If yes, with which standards (mandatory, voluntary, open or proprietary)? (e.g.: Compliance with proprietary standards will usually not enhance replicability when the solution is applied to another utility).

☐	Yes, mandatory standards
☐	Yes, voluntary standards
☐	Yes, open standards
☐	Yes, proprietary standards
☐	No

Could you mention the benefits and/or challenges you expect for being your system/solution compliant with the contemplated standards?

Standards	Benefits	Challenges
Your answer	Your answer	Your answer

How critical is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

S9 - Could the software tools be easily made compliant (economically and technically) with a defined different set of standards?

(e.g.: convert or adapt your proprietary standard to an open standard)

☐	Yes, major change
☐	Yes, moderate change
☐	Yes, minor change
☐	No

If yes, describe how? If not, explain why not?

Your answer

S10 - Are all software tools interoperable?

Interoperability can be described as the ability of two or more devices from the same vendor, or different vendors, to exchange information and use that information for correct cooperation [IEC61850-2010]. Interoperability of software tools refers to the functionality of different programs to perform cooperatively a specific function by using information exchanged, sharing files and using the same protocols.

☐	Yes, all software tools are interoperable
☐	Yes, a majority of software tools are interoperable
☐	Yes, certain software tools are interoperable
☐	Yes, a minority of software tools are interoperable
☐	No

If not, which ones are not interoperable? If yes, why and how has the interoperability been obtained? (optional)

Your answer

How important is it for the replicability of your project?

☐	Lasting impediment to replicability
☐	Temporary impediment to replicability
☐	Neutral value to replicability
☐	Favourable to replicability
☐	Strong case for immediate replicability

13.7.3 ICT COMPONENTS

The analysis focuses on the information and communication architecture. The qualitative analysis carried out here identifies potential network architecture bottlenecks.

13.7.3.1 SHORT DESCRIPTION OF THE ICT COMPONENTS OF YOUR DEMO

To be filled in by Task-Leader

13.7.3.2 QUESTIONNAIRE #5: ICT SRA

ICT1 - Does the modularity of your ICT architecture allow you to easily scale-up your solution?

☐	Yes, with minor change
☐	Yes, with moderate change
☐	Yes, with major change
☐	No, not considered yet
☐	Not applicable. Demo is already at an industrial scale

Describe briefly which extra modules could be added and how, or why not:

Your answer

How important is ICT modularity to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

ICT2 - Can you foresee limitations that could affect the proper operation of the ICT when scaling-up your solution?

Is it a useful question?

☐	Yes, major limits
☐	Yes, moderate limits
☐	Yes, minor limits

☐	No

Explain what the limitations might be:

Your answer

How critical are these limitations to the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

ICT3 - How is the interaction between the components controlled? (is the control centralized of decentralized?)

☐	Centralized
☐	Decentralized

N.B.: decentralized controls: when control actions are taken based on the signals detected locally (voltage, frequency deviation) as well as the control logic at each device

If the control is organized centrally, describe how this is done and indicate at which level centralized control is needed/optimal: at national/regional/local level?

Your answer

How critical is the complexity of interface design (foreseen increase in interaction among components with scale-up) for the scale-up of your demonstration?

☐	Lasting impediment to scalability
☐	Moderate impediment to scalability
☐	Neutral value to scalability
☐	Favourable to scalability
☐	Strong case for immediate scalability

ICT4 - Is the ICT architecture standard compliant? If yes, with which standards (mandatory, voluntary, open or proprietary)?

(e.g.: Compliance with proprietary standards will usually not enhance replicability when the solution is applied to another utility).

☐	Yes, mandatory standards
☐	Yes, voluntary standards
☐	Yes, open standards
☐	Yes, proprietary standards
☐	No

Could you mention the benefits and/or challenges you expect for being your system/solution compliant with the contemplated standards?

Standards	Benefits	Challenges
Your answer	Your answer	Your answer

ICT5 - Could the ICT architecture be easily made compliant (economically and technically) with a defined different set of standards?

(e.g.: convert or adapt your proprietary standard to an open standard)

☐	Yes, major change
☐	Yes, moderate change
☐	Yes, minor change
☐	No

If yes, describe how? If not, explain why not?

Your answer

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