Platone

PLATFORM FOR OPERATION
OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D7.2 v1.0

Methodology for SRA

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Abstract

D7.2 further develops the methodology for scalability and replicability analysis (SRA) of D7.1, including some updates that come from the analysis of the deliverables published in Platone's second. SRA is needed to estimate the increase of social welfare that can be enabled by the large scale deployment of the Platone solutions. Additionally, D7.2 describes the main concepts of the Platone SRA methodology, explains how the proposed approach is in line with the SRA guidelines proposed by BRIDGE, provides more details of the SRA methodology for the most relevant use cases identified in D7.1, describes the representative networks and the data that will be used for the SRA. It is a common theme that in order to quantify most of the benefits coming from the Platone solutions, fully deployed solutions should be compared to Business-as-Usual/baseline scenarios. Furthermore, costs of assets in different time scales should be projected.

Thanks to the work done in the first 18 months, the process of defining representative networks for baseline scenarios has started based on the data collection process accomplished according to the circulated questionnaire in Annex A. The next steps of WP7 will encompass the following activities:

- identification of the nodes in the network where to install new Distributed Energy Sources that will be used to meet the target set by the National Climate and Energy Plans;
- estimation of the foreseen evolution of loads based on historical trends;
- estimation of the evolution of EV and charging infrastructure;
- definition of load and generation profiles:
- network simulations considering different level of grid flexibility.

Keyword list

Scalability and Replicability Analysis, Use Cases,

Executive Summary

"Innovation for the customers, innovation for the grid" is the vision of project Platone - Platform for Operation of distribution Networks. Within the H2020 programme "A single, smart European electricity grid", Platone addresses the topic "Flexibility and retail market options for the distribution grid". Modern power grids are moving away from centralised, infrastructure-heavy transmission system operators (TSOs) towards distribution system operators (DSOs) that are flexible and more capable of managing diverse renewable energy sources. DSOs require new ways of managing the increased number of producers, end users and more volatile power distribution systems of the future. Platone is using blockchain technology to build the Platone Open Framework to meet the needs of modern DSO power systems, including data management. The Platone Open Framework aims to create an open, flexible and secure system that enables distribution grid flexibility/congestion management mechanisms, through innovative energy market models involving all the possible actors at many levels (DSOs, TSOs, customers, aggregators). It is an open source framework based on blockchain technology that enables a secure and shared data management system, allows standard and flexible integration of external solutions (e.g. legacy solutions), and is open to integration of external services through standardized open application program interfaces (APIs). It is built with existing regulations in mind and will allow small power producers to be easily certified so that they can sell excess energy back to the grid. The Platone Open Framework will also incorporate an open-market system to link with traditional TSOs. The Platone Open Framework will be tested in three European demos and within the Canadian Distributed Energy Management Initiative (DEMI).

D7.2 aims at complementing the methodology for scalability and replicability analysis that was illustrated in D7.1, including some updates that come from the analysis of the deliverables published in the second year of the Platone project. D7.1 provides more details about the methodology for scalability and replicability analysis proposed by the Platone consortium. Chapter 2 motivates the need for scalability and replicability analysis to estimate the increase of social welfare that can be enabled by the large scale deployment of the Platone solutions. Additionally, it describes the main concepts of the Platone methodology and explains how the proposed approach is in line with the guidelines for scalability and replicability analysis proposed by the BRIDGE task forces.

Chapter 3 provides more details regarding the methodologies for the scalability and replicability analysis of the most relevant use cases identified in D7.1.

Chapter 4 describes the representative networks that will be used for the Scalability and Replicability Analysis.

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Authors and Reviewers

Main responsible		
Partner	**Name**	**E-mail**
RSE		
	Ilaria Losa	Ilaria.losa@rse-web.it

Author(s)/contributor(s)	
Partner	**Name**
RWTH	
	Mirko Ginocchi
Avacon	
	Benjamin Petters
HEDNO	
	Eleni Daridou
areti	
	Gabriele Fedele

Reviewer(s)	
Partner	**Name**
areti	
	Antonio Vito Mantineo
Avacon	
	Benjamin Petters

Approver(s)	
Partner	**Name**
RWTH	
	Padraic McKeever

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1 Introduction

The project “PLATform for Operation of distribution Networks – Platone” aims to develop an architecture for testing and implementing a data acquisition system based on a two-layer Blockchain approach: an “Access Layer” to connect customers to the Distribution System Operator (DSO) and a “Service Layer” to link customers and DSO to the Flexibility Market environment (Market Place, Aggregators, …). The two layers are linked by a Shared Customer Database, containing all the data certified by Blockchain and made available to all the relevant stakeholders of the two layers. This Platone Open Framework architecture allows a greater stakeholder involvement and enables an efficient and smart network management. The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, transmission system operators (TSOs), Market, customers and aggregators. In particular, the DSOs will invest in a standard, open, non-discriminatory, blockchain-based, economic dispute settlement infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will allow the DSO to acquire a new role as a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone strongly contributes to aims to removing technical and economic barriers to the achievement of a carbon-free society by 2050 [1], creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in three European demos (Greece, Germany and Italy) and within the Distributed Energy Management Initiative (DEMI) in Canada. The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme “A single, smart European electricity grid” Platone addresses the topic “Flexibility and retail market options for the distribution grid”.

The scalability and replicability analysis is used to estimate the increase of social welfare that can be enabled by the large-scale deployment of the Platone solutions. Here, the social welfare of the system due to a measure being implemented is defined as the sum of the total benefits to the consumer and revenues of the producer due to the measure. The producer’s revenues, in a competitive market can be approximated by the cost function of real power generation. The measures could be things like a more efficient exploitation of the network assets and/or an increase of network flexibility. The measures can trigger benefits like reduction of network congestions, avoided over voltage and over frequency events, increase of hosting capacity, etc. The benefits brought by the measures foreseen in Platone will be analysed and quantified in the technical SRA to be performed in WP7.

In particular D7.2 builds on the main findings of D7.1 [2] and describes in more detail the methodology for scalability and replicability analysis (SRA) that will be used for the analysis of the three demos included in the Platone project.

The methodology proposed in Platone was developed taking into consideration the different methodologies that have been proposed by other projects that have tackled this type of analysis However this document updates the overview of the existing methodologies and includes also the “Draft methodological guidelines to perform a scalability and replicability analysis” [3] prepared by the BRIDGE task force on scalability and replicability. This deliverable describes also the representative networks that will be used in the later stage of the Platone project for SRA.

1.1 Task 7.2.1

Task 7.2.1 develops a methodology for SRA. Scalability is defined as the ability of a system, network or process to increase its size/scope/range in order to adequately meet a growth in demand. Replicability is defined as the ability of a system, network or process to be duplicated in another location or time [2]. The scope of this activity is to estimate how the KPIs calculated in the demos might change when boundary conditions will change (replicability analysis) or when the project will be deployed at a larger scale. It is important to identify the effect of these boundary conditions to be able to determine how to scale up the results provided that the same boundary conditions remain and to define the domain of validity for replication. The approach for the analysis of the boundary conditions and subsequent development of scaling up and replication rules will focus on three main aspects:

- technical and economic analysis,

- regulatory framework;
- stakeholder acceptance.

The BRIDGE task force aims to define a methodology that allows to understand how technical boundary conditions affect the effects of the use cases observed in the demonstrators, to study their scalability and replicability using simulation tools and models specifically adapted for that purpose and to assess the impacts of the regulatory, economic and stakeholder acceptance parameters on the results of the technical SRA by means of a qualitative analysis.

1.2 Objectives of the Work Reported in this Deliverable

The present deliverable aims at complementing the methodologies that have been already introduced in D 7.1 [2] by providing more details about the algorithm and the scenarios that will be used in the next steps of WP7 to perform these analyses. Moreover, the present deliverable describes in more detail the mathematical approach that will be used to perform the simulations. In particular, the present deliverable aims:

- To describe in a more detailed manner the algorithms to be used within the three demos and respective UCs and the scenarios to be used within the SRA simulations
- To analyse the available representative networks (e.g., from JRC) with the demo networks
- To present the next steps to set up the simulations

1.3 Outline of the Deliverable

Chapter 2 motivates the need for scalability and replicability to estimate the increase of social welfare that can be enabled by the large-scale deployment of the Platone solutions. Moreover, it describes the main concepts of the Platone methodology and explains how the proposed approach is in line with the guidelines for SRA proposed by the BRIDGE task forces. Chapter 3 provides more details regarding the methodologies for SRA of the most relevant use cases identified in D7.1. Chapter 4 describes the representative networks that will be used for SRA. Finally, Chapter 5 presents the conclusions and the next steps.

1.4 How to Read this Document

D7.2 complements the methodology for scalability and replicability analysis proposed in D7.1 [2]. More details about the use cases that will be analysed in the SRA have been reported in the related deliverables D3.6 [4], D4.1 [5], D5.2 [6] for the Italian, Greek and German demos.

D7.2 provides more input for the definitions of future deliverables of WP7 (in particular the analysis of Scalability and Replicability and Cost Benefit Analysis that will be performed in D7.4.

2 Conceptual framework

The decarbonisation process of energy systems, underway both at European and national level, is substantially affecting the electricity system. In the future, the distribution networks will have to be able to integrate a greater share of distributed generation (DG), to guarantee at the same time the participation of resources connected to the distribution network in dispatching services and for local flexibility services. In fact, the European Directive EU 2019/944 regarding the creation of the internal energy market (IEM) [10], states that "the development plans of the distribution networks that DSOs must publish every two years must include the use of demand flexibility, energy efficiency and storage systems as alternatives to the network expansion".

The study of possible future development scenarios and of the impact of new control techniques are needed for the planning and operation of future distribution networks. In fact these studies represent the first step of the network planning analysis and aim at identifying the potential problems that may arise in the next years in the observed networks due to increase of load demand, local generation and penetration of innovative technologies like storage units, EV charging stations etc.

In this work we intend to develop methodologies for analysing the large-scale evolution scenario with local detail, taking into account the co-presence of different sources of grid flexibility. This report presents the preliminary analyses which will form the basis for the successive detailed studies. In particular, the possible schemes for the participation of distributed resources in local regulation services of the distribution network are described. Furthermore, the main characteristics of the energy networks in the areas under study will be described, with a particular focus on the electricity distribution networks.

2.1.1 Planning and operation procedures for grid management: an overview of alternative options for grid upgrading with respect to business as usual solutions (grid reinforcements)

The DSOs can update their own networks using three alternative options: grid reinforcements, control solutions that employ DSOs' assets and control solutions that use assets belonging to third parties connected to distribution grids. These different alternatives are characterized by different costs and performance, therefore specific analyses shall be performed in each case in order to identify the optimal solutions in each case.

The use cases that the three demos implement in Platone in order to update their own networks can be implemented thanks to the development of control systems that monitor the assets owned by the DSOs or by third parties. These control systems are integrated in the different layers of the Platone platform. In fact, thanks to an improved visibility of the assets connected to the network, the DSO can operate its own assets (e.g. the OLTC – On Load Tap Changer) more efficiently. Moreover, in order to cope with the targets set by the regulation EC 2019/944 [10], the current regulatory and market frameworks of existing European energy market will change and consequently the DSOs will also be able to integrate in their daily operations the contributions provided by the local distributed resources. The studies performed in the next steps of SRA (tasks 7.3.2 and 7.4) will aim at assessing the contributions that the control systems embedded in the Platone platform will make to support the DSO in enhancing the participation of local resources in the management of the grid and the contributions that these sources can provide in terms of deferring the need for additional grid investments.

The possible alternatives are characterized by different costs and performance, therefore it is difficult to establish a priori the most suitable solution to solve each network problem. A particularly significant difference is that the costs of network reinforcement substantially affect investments (CAPEX), while the costs of control solutions affect operating costs or OPEX (management costs of IT equipment, remuneration of resources that assist in regulation, etc.). The best choice among the possible solutions can therefore only be obtained through a cost-benefit analysis. Some advantages of the control systems, especially the simpler ones that involve only the DSO, are however evident and in fact the DSOs are installing these solutions within their SCADA systems. The improved knowledge of the network status, enabled by the advanced monitoring, allows systems to operate more efficiently and allows the DSO to integrate the forecast contribution of distributed renewable sources and of demand flexibility. The Scalability and Replicability Analyses also have the aim of establishing, at least to a first approximation, the contribution that can be provided to the system efficiency by the participation of final customers. In fact, the activation of local resources of flexibility can support the DSO in the management of the grid and thus it can reduce the need for reinforcement of the infrastructure, as summarized in Figure 1.

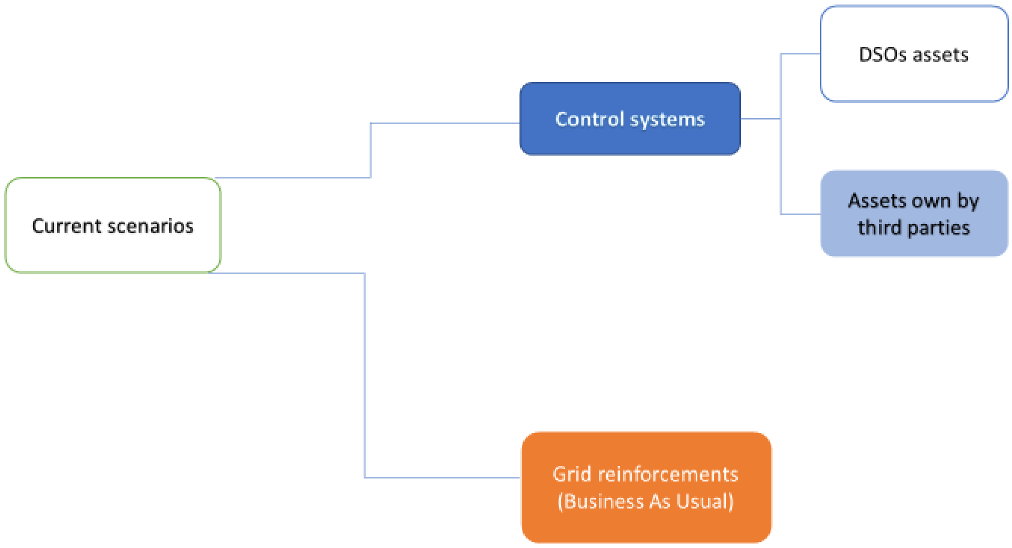


Figure 1 – Different alternatives for upgrading the existing grids

The SRA will estimate these contributions considering initially the boundaries of the Platone demos and evaluate these contributions when the solution is deployed in different boundary conditions (replicability) and at a larger scale (scalability).

The difficulties in defining the local services that can be provided by local sources of flexibilities are not only technical, but also economic and regulatory and are linked to the specific characteristics of the distribution networks. It should be noted that in the case of distribution networks the network control needs are, of their nature, based on local needs. Two interrelated considerations arise from this observation: (i) it is unlikely that there will be many resources that can offer flexibility in the point desired and (ii) the creation of local markets require a significant amount of liquidity and this can be difficult to achieve in a restricted area managed by the local DSO. For these reasons, the three pilots included in the Platone project will explore different alternatives for the procurement of local flexibility services: local markets (Italian demo); dynamic tariffs (Greek demo) and bilateral contracts (German demo).

In order to set up the schemes related to dynamic tariffs and bilateral contracts, it is necessary to determine the range of prices and modulated energy that can be remunerated. These price ranges can be assessed by means of cost-benefit analysis in order to compare curtailment, or innovative solutions in general, to conventional solutions (e.g. grid reinforcement) in order to determine in which cases they are to be favoured. These analyses are however complex because the costs of future solutions are uncertain and, together with the benefits, they depend strongly from the considered scenarios. Regarding the solution that foresees the creation of a local market, a necessary step to achieve this goal consists in the definition of the rules for participation. A subsequent step requires the creation of a liquid market and that allows the participation of numerous resources, as in the transmission sector, which is characterized by a larger perimeter with respect to the distribution control area.

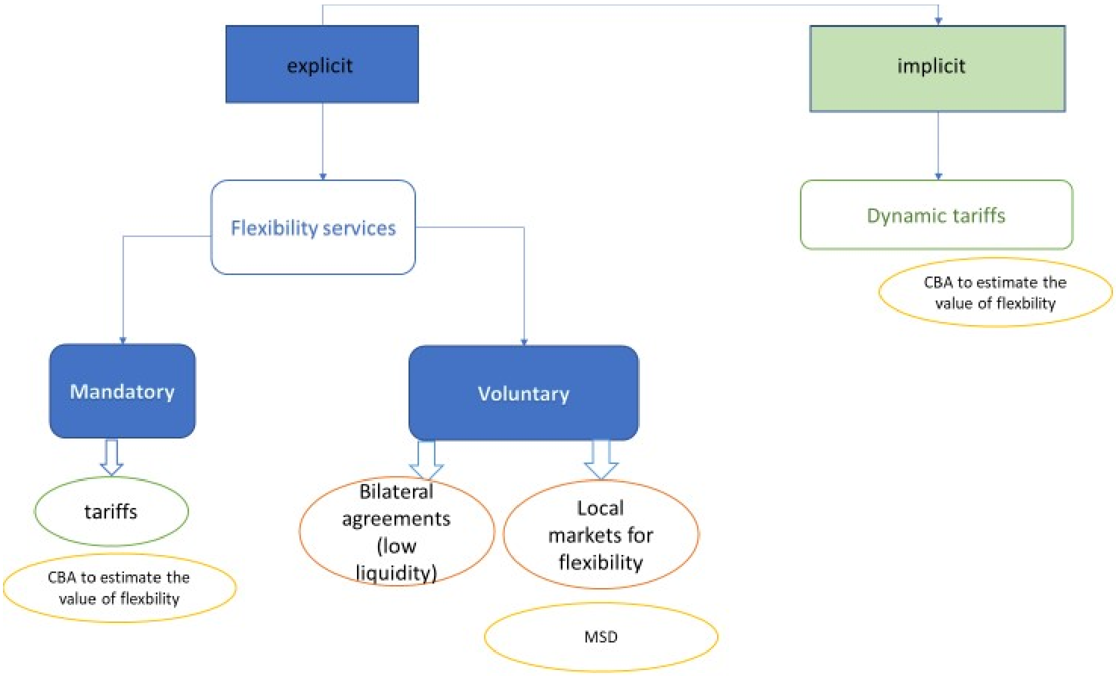


Figure 2 – Summary of the possible remuneration schemes for ancillary services

Figure 2 summarizes the main remuneration schemes for local ancillary services. The first scheme is represented by the "implicit" approach based on dynamic network tariffs: the quantification of these tariff components should be carried out through a CBA: moreover technical aspects like the procedure for service activation and timing of the services to be provided and the perimeter of application (city, regions, country, etc.) shall be assessed based on ad hoc calculations and studies that can assess the optimal level of penetration of flexibility services that can maximize the increase of total welfare. These analyses will be performed in WP7 and will tackle both economic aspects (CBA) and the other above-mentioned aspects (SRA).

The explicit mechanisms consist in different procedures for activation of local flexibility services in terms of technical requirements: the participation of the local sources of flexibility would be voluntary. However, in some cases, all network users might be required to provide certain services. These services can be then remunerated by means of a dynamic tariff that foresees a low energy price when those flexibility services will be needed (the price reduction can be estimated by means of a social CBA).

The voluntary mechanism can be based on a remuneration type bilateral agreement, based for example on auctions, or in the most general case through a true local market, when the market liquidity is adequate. In case of bilateral agreements or local markets, the prices for the different flexibility services shall be assessed through a comparison of the costs of these services in case those services would be purchased on the Ancillary Service Markets (ASM) or Dispatching Services Market (Italian Mercato dei Servizi di Dispacciamento, MSD)

2.1.2 Scalability

The analysis of scalability aims at answering the question "what to expect if the use case were to be implemented at a larger scale under the same boundary conditions?" The implementation of a use case at a larger scale could mean the implementation of a higher degree of smartness, a larger area of action, the engagement of a larger number of consumers, the penetration of higher volumes of distributed resources, etc. In this regard, scaling-up may be classified according to the two main dimensions

- Scalability in **density**: This analysis includes the evaluation of the effects of the increased penetration of a given solution within the same area that hosts the demo: e.g.: higher penetration degree of distributed generation in the network, higher degree of flexibility of consumers, higher degree of network automation, etc.
- Scalability in **size**: This analysis includes the evaluation of the effects of the deployment of a given solution at a larger scale involving different types of areas within a region or country.

In order to analyse scalability, sensitivity to different aspects involved in a larger-scale implementation (e.g., related to technical, economic, regulatory and stakeholder considerations) must be studied.

- Technical aspects include technical parameters such as: size of the network, number and size of consumers, peak demand, number size and location of distributed resources, etc. Additional technical aspects to take into account could include saturation effects for network hosting capacity, overloading of lines and transformers, simultaneity factors, saturation of the potential for load shifting, etc.
- Economic aspects would mainly comprise the economic signals received by different agents.
- Stakeholder acceptance aspects address the potential of acceptance of the solution by key stakeholders in another context.

2.1.3 Replicability

The analysis of replicability aims at answering the question "what to expect if the use case were to be implemented at a different location, where different boundary conditions can be found?" In order to analyse replicability, different scenarios must be considered and sensitivity to the main parameters that constitute the boundary conditions of the demonstrator has to be assessed. Replicability analysis has two main dimensions:

- Intra-national replication: it addresses the analysis of the replication of the same solution in the same country that hosts the demo but in situations in which technical boundary conditions may differ, but the same economic and regulatory boundary conditions prevail and the different stakeholders have similar points of view. Variations in the penetration degree of distributed resources, degree of automation in the network, impact of demand side management, etc. will be also studied, to account for the effect of changes in the regulatory and stakeholder related boundary conditions
- International replication: it addresses the analysis of the replication of the same solution when all types of boundary conditions may differ from those in the demo site due to different regulation schemes and incentives, different economic situations, different strategies from policy makers and distribution companies, different types of networks, different social concerns, etc.

The impact of different boundary conditions will also be assessed, thus identifying the best-practices or more-friendly boundary conditions. Figure 3 summarizes the definition of the general methodology for SRA.

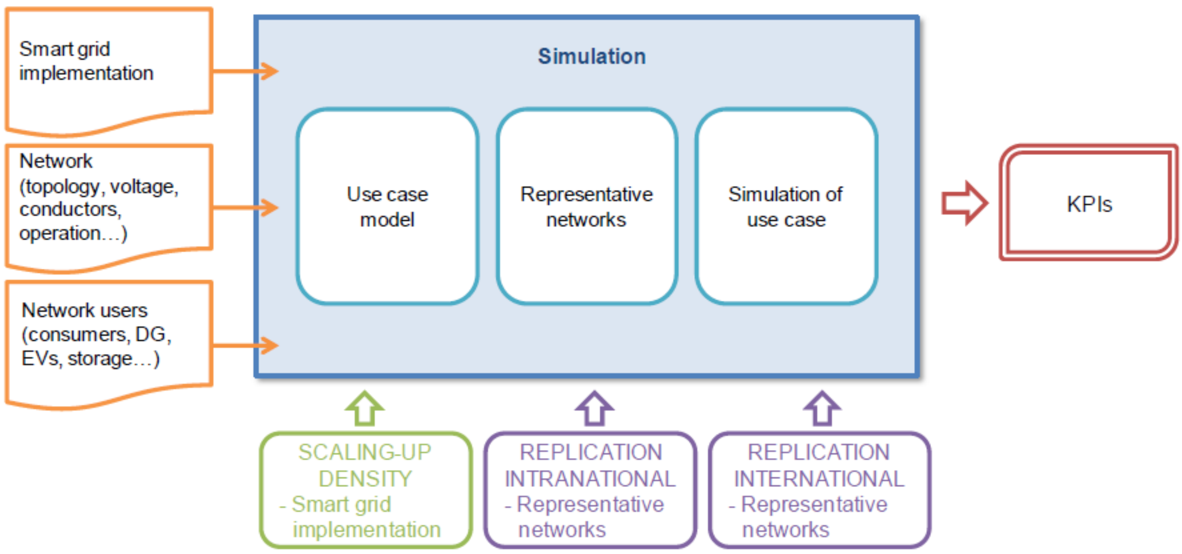


Figure 3 – Methodology for technical SRA of smart grid use cases

2.2 Comparison between the Platone approach and the BRIDGE methodology

BRIDGE is a European Commission initiative which unites Horizon 2020 Smart Grid and Energy Storage Projects to create a structured view of cross-cutting issues which are encountered in the demonstration projects and may constitute an obstacle to innovation. As a result of the 2019 General Assembly (GA) of the BRIDGE initiative [11] a number of task forces (TF) where created to address topics that could be horizontal to more than one of the above-mentioned working groups. In this way, a specific TF on Scalability and Replicability was launched to investigate how the different projects were tackling the SRA of the different project results. The objectives of the TF were: (i) to develop common guidelines to perform SRAs; and (ii) to develop ideas on how to define the scope and implementation of a toolbox/repository of past experiences, best-practices and necessary data. In 2019 the task force published a report [3] that identifies common guidelines for the scalability and replicability analysis that the projects referring to BRIDGE initiative shall adopt. Figure 4 summarizes the different steps proposed by the BRIDGE methodology.

In deliverable D7.1 the first 3 steps of the methodologies have been analysed and implemented. In particular, regarding:

- Step 1: select SGAM layer: the Platone approach chose to focus the SRA on a set of selected use cases instead of adopting the SGAM layers to perform the analysis. In particular, in D 7.1, the UCs proposed by the demos have been analysed and the most suitable use cases for the SRA were selected. For each of the selected use cases, D7.1 and the relevant deliverables prepared by demo leaders describe the Component, Communication, Information and Function SGAM layers that are included in the analysis.
- Step 2: Select SRA dimensions. In D 7.1, the Platone consortium identified the dimensions that would have an impact in order to consider them in the replicability and scalability task. These dimensions are technical and economic analysis, regulatory framework and stakeholder acceptance.
- Step 3: Define methodology for each SRA dimension. This step requires defining the methodology for each selected SRA dimension. These methodologies consist of a set of general steps. In order to make informed decisions at each one of these steps, it is recommended to rely on best practices from previous projects. SRA developers need to consider that, when developing quantitative analyses, it is key to properly define the relevant KPIs and simulation scenarios, focusing on the most critical parameters affecting the scalability and replicability within a given dimension. In addition to the scenarios, an early definition of the input data required as well as potential data sources that enables an early start of the data collection is essential to prevent delays in the execution of the SRA. Step 3 is composed by the following sub steps:
    - Step 3.1: joint analysis with other dimension or not. This step was performed in D7.1: for each of the relevant use cases, D7.1 identified the technical, economic and regulatory factors that might have an impact on the scalability and replicability of the demos. This analysis has been updated in the present deliverable considering the developments obtained in the second year of the Platone project. The updates are described in Chapters 3.1.1, 3.2.1 and 3.3.1
    - Step 3.2: Select the geographical scope: the Platone project decided to perform a quantitative SRA that aims at assessing how the project KPIs will change when the solutions will be replicated or scaled up in broader areas or in different networks. In order to perform these analyses on standardized and open source networks that are also representatives of the characteristics of the European distribution network, the Platone consortium will use in the simulations the representative networks generated by the EC JRC [12]. The Platone consortium compared the characteristics of the demo networks with the characteristics of the JRC representative networks in order to identify the most relevant networks that will be used for the SRA of each demo. This analysis is described in Chapter 4.
    - Step 3.3: decide a quantitative, qualitative or mixed approach. The Platone consortium proposed in D 7.1 a quantitative approach based on the estimation of the variation of project KPIs when the proposed solutions are deployed at a larger scale or under different boundary conditions. This methodology is also summarized in Figure 3. The

outcomes of the quantitative analysis will be then complemented with a qualitative analysis aimed at identifying possible regulatory or stakeholder acceptance barriers that might arise from the deployment of the Platone solutions in different regulatory contexts and with different types of consumers. The input for the quantitative analysis will be provided by WP1 and WP8 analysis [7],[8],[9].
  - Step 3.4 Develop detailed methodologies. In D 7.1 the Platone consortium proposed some preliminary methodologies for the analysis of the relevant use cases. These proposals have been updated in the present deliverable considering the progress achieved by each demo during the second year of the project. The updated methodologies are described in Chapter 3.
- Step 4: perform the SRA for each scenario. This step will be performed in the second part of the Platone project, however, in the first half of the project few actions were already performed. In particular:
  - Step 4.1 data collection was already performed; in fact, in D7.1 the list of the categories of data that will be used in the analysis was reported and approved by demo leaders
  - Step 4.2 perform the analysis for the defined scenarios. The analysis will be performed in the future tasks of WP7, however D7.2 anticipates few data and information that describe the scenarios that will be used for the SRA (in Chapters 3.1.2, 3.2.2 and 3.3.2).

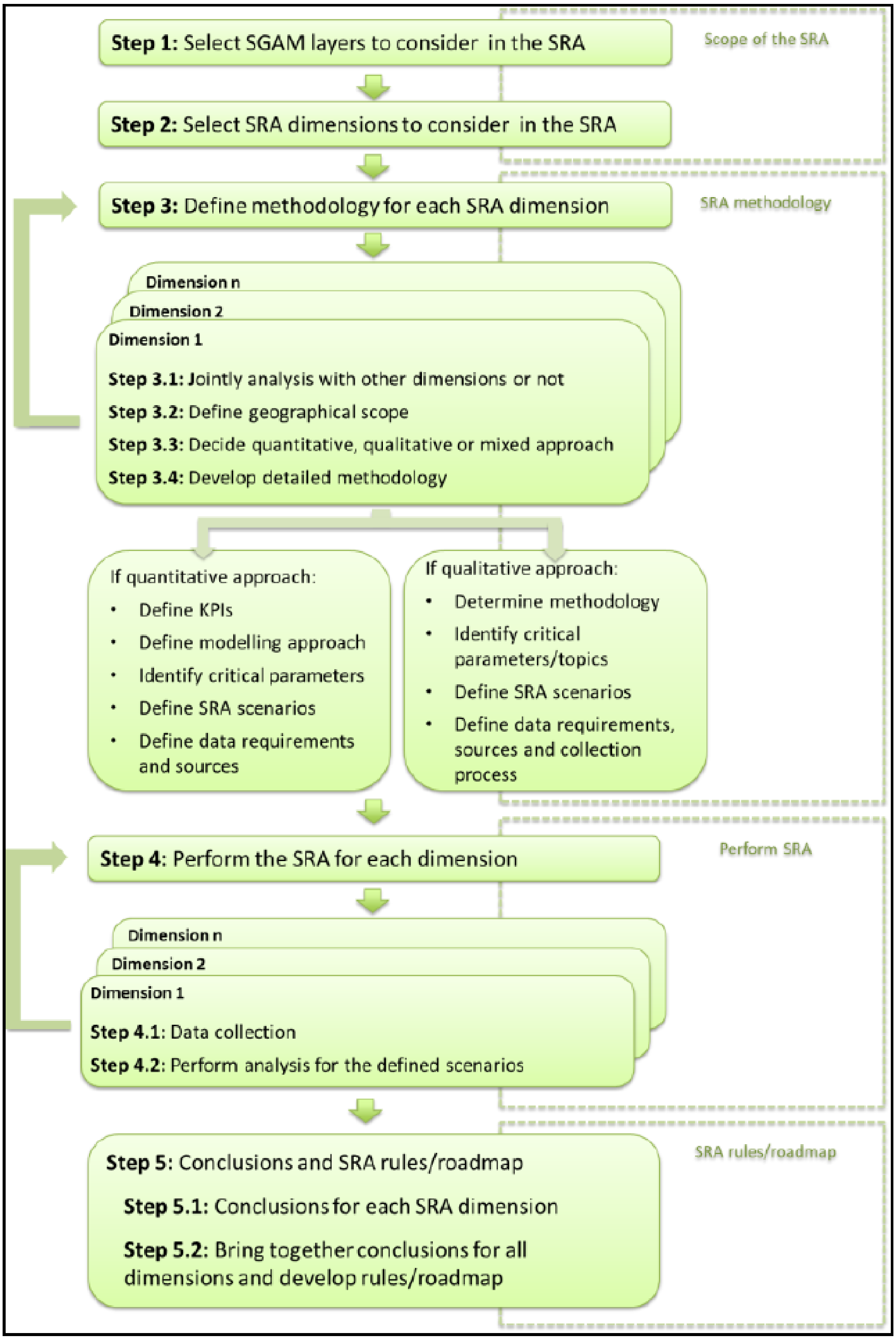


Figure 4 - Guidelines for Scalability and Replicability analysis proposed by BRIDGE TF (source: [3])

3 Application of SRA methodology to the three Platone demos

3.1 German demo

The UC "Islanding" of an energy community aims to balance generation and demand of a local energy community in such a way that the load flow across the connecting MV/LV transformer is reduced to a minimum. The balancing is enabled by an EMS (ALF-C). The ALF-C monitors the power flow across the transformer and controls a Community Battery Energy Storage (CBES) connected directly to the LV-terminal of the substation. Generated energy surplus will be stored in the CBES and released at times of a generation deficit. Private households equipped with domestic batteries and controllable electric heaters can be dispatched to increase the degree of self-sufficiency further. In the context of the German field test trial of Platone, Avacon will upgrade a rural LV grid with all assets required to operate a local energy community (see Figure 5).

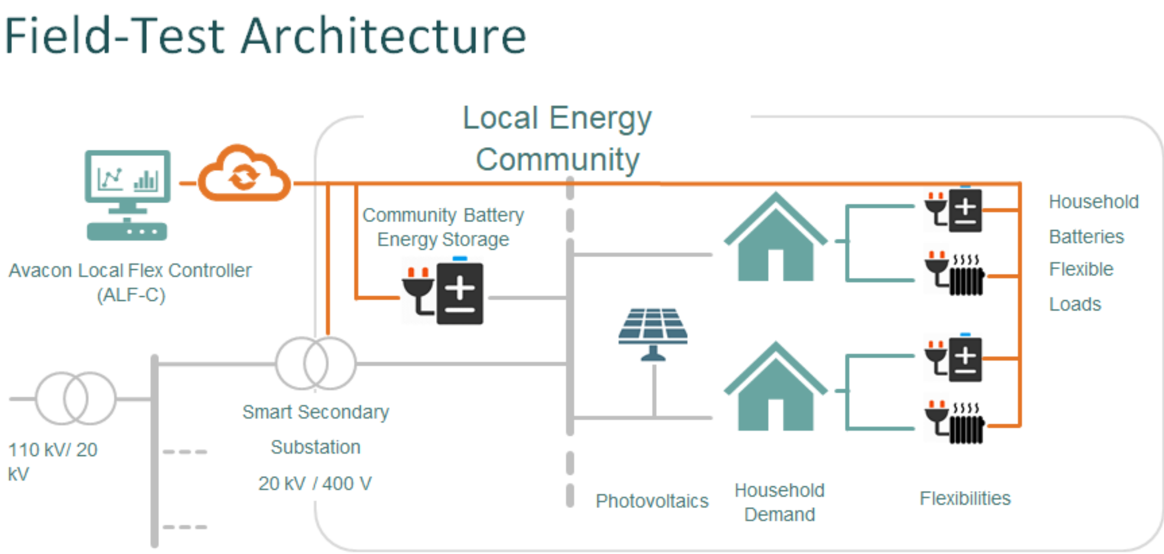


Figure 5 – Field test architecture of the German demo

The core of the demo will be a newly developed energy management system (EMS) which takes charge of monitoring and controlling the power flows within the community and between the community and the MV-feeder. There are four UCs:

- UC 1 – Islanding is focussed on the demonstrator's ability to operate domestic storages of households as a local energy community (LEC) practicing collective self-consumption.
- UC 2 - Flexibility Provision explores the ability of energy communities to adhere to a fixed setpoint of power exchange with the distribution grid at the DSO's request or in response to market signals.
- UC 3 and 4 - Bulk energy supply/export are grounded in the realization that energy communities will remain very likely to require some degree of interaction with the distribution grid, either to export surplus energy during times of high local generation or to import energy to cover a deficit likely to arise during the winter semester. These UCs will investigate the degree to which the import and export can be organized in bulk packages, by assigning fixed windows of grid access to energy communities.

Within the frame of the field test demo, the DSO will be the main actor in the UCs. The Avacon Local Flex Controller (ALF-C) will be the central Energy Management System (EMS) to be developed jointly by Avacon and RWTH to monitor the LEC's generation, demand and available flexibility and send setpoints to local storages and flexible loads to fulfill requests set by the user. The ALF-C will be integrated in the Platone framework and connected to systems located in the field, such as sensors in customer households and the secondary substation providing measurement data. CEC participating in the project may provide additional flexibility from flexible loads and household energy storage systems. A large-scale battery energy storage will be implemented in the field to provide additional storage capacity and controllable load in order to ensure a successful application of the use cases. Key Performance Indicators (KPI) will measure the data and results collected during the field test phase. The results evaluate the potential of the UCs and their possible impact on future operation. For now, it is expected that the future application of the UCs will contribute to more efficient and reliable distribution networks.

3.1.1 Description of demo UCs under SRA perspective

3.1.1.1 SRA UC1 - Virtual Islanding

UC1 aims at enabling a community (located in a bounded LV-grid section) to maximize consumption of self-generated energy (Simulation of practicing Energy Sharing) by making use of flexible load and storages and analysis of the effect on the MV/LV-grid connection point. The balancing is enabled by an EMS (ALF-C). The ALF-C monitors the power flow across the transformer and controls a CBES connected directly to the LV-terminal of the substation. Generated energy surplus will be stored in the CBES and released at times of a generation deficit. Private households equipped with domestic batteries and controllable electric heaters can be dispatched to increase the degree of self-sufficiency further. The application of UC 1 will be triggered by an operator from Avacon via a user interface. When local generation exceeds local demand, surplus energy will automatically be stored in local storages. When local consumption exceeds local generation, stored electrical energy in local batteries will be discharged. The optimization of self-consumption targets minimizing the load exchange with the MV grid along the MV/LV grid connection point up to a level at which the community is virtually islanded. In cases in which generation and demand cannot be balanced due to a lack of available storage capacity or flexibility, the residual load will be supplied by imported power from the MV grid. A sensor located at the grid connection will measure the power exchange of all 3 phases between the medium voltage and the low voltage grid. The measured values indicate the real time flow of power along the feeder. Measurement data by sensors are transferred to the EMS. Based on the provided information the EMS will increase or decrease the load demand of individual storages or flexible loads in order to balance the grid. Additionally, customer households provide flexible load and storage capacities for control. Flexible assets in the field are equipped with sensors and controllers to increase or decrease demand and to command charging or discharging of the local large CBES and private customer household storages. Flexible assets located in the field provide an interface for data exchange with the EMS, along which measurement data and control signals will be exchanged. Further, the interface of domestic storages provides data for determination of the state of charge. Historical measurement data and weather data provided by external service providers enable the EMS to predict total energy generation, consumption and residual energy demand to maximize self-sufficiency. Controllers in the field are able to switch on or off flexible loads and trigger charging or discharging of batteries in order to decrease the feed of energy into the grid. Flexible loads may be provided by storage heaters. Storage capacities will be provided by a local CBES and domestic battery storages located in households. In order to avoid customers sacrificing comfort due to a decrease of room heating, control of loads will be limited.

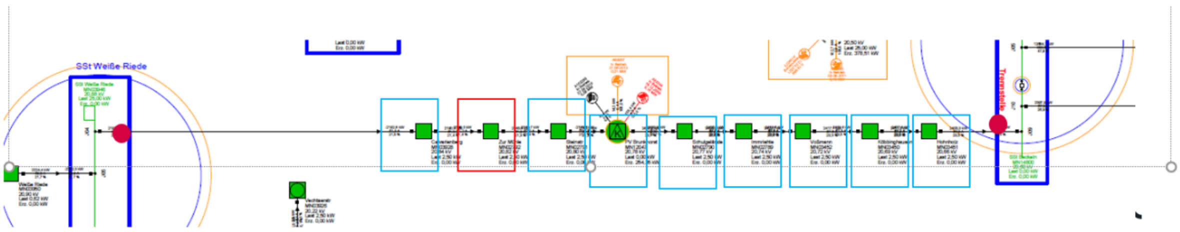


Figure 6 – Area of the German demo within the Avacon Grid

The demo area consists of a secondary substation connected to the LV network (see Figure 6). This network feeds a small village characterized by residential loads. The sources of flexibility are represented by households' batteries, community energy batteries and PV plants (as illustrated in Figure 5).

The KPIs assessed by AVACON to monitor the performances of UC1 are the followings:

1.) Reduction of Energy Demand Exchange at MV/LV feeder – $|E_{+-}|$ [kWh]

2.) Reduction of Active Power Load Peaks - $|P_{+-}|$ [kW]

3.) Increase of Self-Consumption – E_{export} [kWh]

4.) Maximization of Islanding (Duration (t); P < 5 kW)

The analysis of the "Scalability in density" aims at assessing how the above-mentioned KPIs will change when the number of customers that participate to the demo (and consequently the number and the capacity of controllable loads) increases. The baseline scenario consists of a scenario in which no flexibility of loads and DG production is available in the observed grids. In the scalability in density analysis the area investigated in the simulation will be maintained equal to the demo areas but several scenarios will be considered with growing penetration of flexible loads and generation units (Expressed in terms of percentage of the contracted power for the loads; number of small scale batteries and percentage of controllable PV production). These percentages will be in line with the targets of penetration of distributed generation and flexible demand considered in the German energy and climate plan [13] and in the Avacon scenarios for grid development.

The replicability analysis at intra national level will estimate the impact of the deployment of the UC1 when different types of loads and generators are connected to the grid. In particular, for the analysis of the German Use demo, we can consider that, in the same demo area we will connect different type of loads (e.g.: industrial loads) or flexible loads that allows to be interrupted for a limited number of times and duration (the characteristics of these loads are reported in [14]). The KPIs will be estimated considering a different reference network, with different characteristics and topology, as described in chapter 4.

The next step of the analysis is represented by the scalability in size. In this step we can simulate the impact on use cases KPI when the dimension of the local energy community increase. The aim of this analysis shall be to identify the maximum size of a LEC that can be sustained in a virtual islanding mode considering the expected penetration of renewables and flexible loads foreseen by Avacon for future grid scenarios. Moreover, this analysis might quantify the impacts on the primary substation and on the MV grid in a scenario in which more than one community along a MV-line practices collective self-consumption (virtual islanding) (see Figure 5).

Finally, replicability at international level will estimate the impact on the UC KPIs when this solution is deployed in a different and larger network (see Table 7). This analysis will consider also different regulatory boundary conditions that can have an impact on the German UC: for example different levels of voltage limits allowed by the national regulatory schemes will be considered and different target values and indicators for the indices that monitor the continuity of supply will be considered as input for the analysis for the international replicability.

3.1.1.2 SRA UC2 - Flexibility provision

The future distribution grid, as stated by the European Directive for the Creation of the Internal Energy market [10], shall integrate innovative flexibility solutions that will enable the system operators at transmission and distribution level to better exploit the existing infrastructures, to maintain overarching system stability, to secure system performance and maintain efficient operation of distribution networks. The ALF-C will be able to balance a bounded lower voltage grid section (the Local Energy Community) and treats the LEC as a single source of flexibility. An integrated scheduler will enable the coordination of flexibility requests sent by third parties such as DSO, TSO, aggregators or other market participants. The active request is subsequently disaggregated into individual control commands for available flexibility sources in a given local energy community with the goal of maintaining an externally defined non-zero setpoint for the power exchange at the MV/LV point of grid connection. UC2 aims at testing the capability of the Platone German demo to optimize the energy consumption on community level and estimates the effects of this optimization on load flows at grid connection point. The activation of local flexibility resources is coordinated with the centralised mechanism that manages both flexibility requests and the operation of the grid. The goal of this use case is to ensure the coordination of simultaneous requests for flexibility activation by third parties (DSO, TSO, market participants, aggregator).

The KPIs assessed by AVACON to monitor the performances of UC2 are the following:

1.) Accuracy of the achievement and of a given setpoint (△P [kW]] (e.g. during a typical daily operation, how many times and for how many kW the power exchange at the MV/LV interface has deviated from the given setpoint?)
2.) Responsiveness: Speed of the execution of a flexibility request (setpoint) after sending the trigger signal.
3.) the reduction of the number and amount of feed-in curtailments in distribution networks

The analysis of the “scalability in density” aims at assessing how the above mentioned KPIs will change when the number of customers that participate in the demo (and consequently the number and the capacity of controllable loads) increases. The baseline scenario consists of a scenario in which no flexibility of loads and DG production is available in the observed grids. In the scalability in density analysis, the area investigated in the simulation will be maintained equal to the demo area but several scenarios will be considered with growing penetration of flexible loads and generation units. These percentages will be in line with the targets of penetration of distributed generation and flexible demand considered in the National Climate and Energy Plans published by the National Governments.

The replicability analysis at intra national level will estimate the impact of the deployment of the UC2 when different types of loads and generators are connected to the grid. In particular, for the analysis of the German Use demo, we can consider that, in the same demo area we will connect different type of loads (e.g. industrial loads) or flexible loads that allows to be interrupted for a limited number of times and duration (the characteristics of these loads are reported in [14]). The KPIs will be estimated considering a different reference network, with different characteristics and topology, as described in chapter 4.

The next step of the analysis is represented by the scalability in size. In this step we can simulate the impact on use cases’ KPIs when the more than one LEC is connected to the MV/LV feeder that is investigated in the UC2. The aim of this analysis is to quantify the impacts on the primary substation and on the MV grid in a scenario in which more than a single virtual island is connected to the MV feeder.

Finally, replicability at international level will estimate the impact on the UC KPIs when this solution is deployed in a different and larger network (see Table 7). This analysis will consider also different regulatory boundary conditions that can have an impact on the German use case.

3.1.1.3 Use Cases 3 and 4 - Bulk import/export

Use Cases 3 and 4 aim at addressing some of the main challenges that DSOs face when dealing with networks characterized by high shares of DER:

- how to deal with the stochastic nature of a network demand that is modulated by local production that increases the difficulties to plan and design networks efficiently? Uncertainty in the planning process leads to over dimensioning of assets to account for the risk of unexpected load configurations.
- how to deal with the expected increase of peak loads in local low voltage grids arising from the increasing number of heat pumps, charging points for electric vehicles or other sector coupling technologies. New strategies for the increase of hosting capacity of existing grids are needed in order to enable the integration of these technologies in future.

In order to deal with these uncertainties, the DSO shall be allowed to leverage flexibility solutions that enables the DSO to uncouple the LV grids from its MV-feeder by employing a package-based approach for energy supply. The residual demand of a network after local production can be forecasted and delivered to the network in bulk in advance. The energy can be stored in local batteries from which customers can withdraw energy as they please without affecting the MV-feeder. UCs 3 and 4, “Bulk import/export”, focus on importing and exporting energy to and from the local network in bulks within fixed time slots. The concept bases on an interaction between centralised and decentralised grid management. The centralised grid management is responsible for an efficient and reliable energy supply in distribution grid. It monitors HV and MV grids and ensures that the grid is operated within the technical limits.

In UC 3 and 4, a forecast of generation, consumption will be done for all communities along a MV-voltage line for up to 24 h (t + 24) for each community (virtually). Then, energy (kWh) deficits (UC3 – winter) or surplus (UC 4 – summer) will determined for all communities. Based on the outcomes of these forecasts, for each community a time slot (t_{Start} – t_{End}) and active power setpoint P [kW]) will be determined by a higher level grid management that targets to reduce power peaks in MV- network. The outcome of this calculation is represented by the schedule that the flexibility sources connected to the grids shall follow for the next 24hours. In these UCs, the power exchanged at MV/LV grid connection point must be compliant with a daily (24h) profile that is calculated on the day ahead taking the forecasts for generation and consumption as input. The KPIs that AVACON assesses to monitor the performance of UC2 are the followings:

1.) Number of successful applied bulk-based energy supply/export.
2.) Forecast of total energy demand and generation.
3.) The reduction of the number and amount of feed-in curtailments in distribution networks.

The analysis of the "Scalability in density" aims at assessing how the above mentioned KPIs will change when the number of customers that participate to the demo (and consequently the number and the capacity of controllable loads) increases. The baseline and the deployment scenarios will be the same scenarios described for UC1 and UC2.

The replicability analysis at intra national level will estimate the impact of the deployment of the UC3 and UC4 when different types of loads and generators are connected to the grid. The same considerations used to develop the scenarios of UC1 and UC2 will be applied.

The next step of the analysis is represented by the scalability in size. In this step we can simulate the impact on use cases' KPIs when the number of households with a roof-top photovoltaic system and domestic battery storage increases. Moreover, this analysis shall quantify the impacts on the primary substation and on the MV grid in a future scenario (that is not included in the scope of the German demo) in which more than on communities along a MV line practice UC 3 and UC4.

Finally, replicability at international level will estimate the impact on the UC KPIs when this solution is deployed in a different and larger network (see Table 3). This analysis will consider also different regulatory boundary conditions that can have an impact on the German Use case.

3.1.2 Brief description of the scenarios considered for analyzing the expected penetration of flexibility sources

In order to perform the simulations described in Chapter 3.1.1, Avacon provided the load profiles reported in Figure 7. These load profiles represent the energy demand seen by the HV/MV feeder of the Avacon grid during 2020.

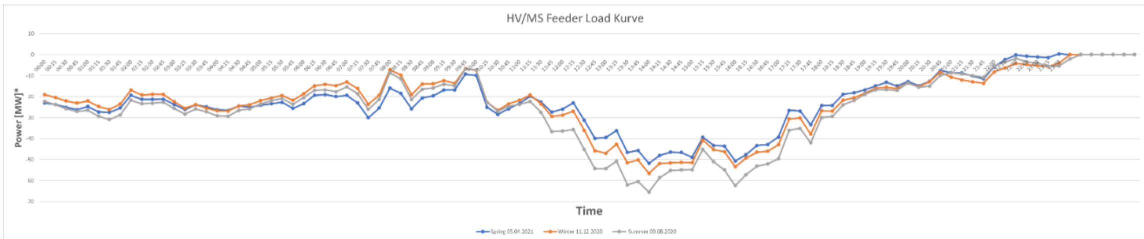


Figure 7 – load curve in 2020 in the German demo area (source: Avacon data)

In order to elaborate the load curves expected by 2030, we need to add to the curves displayed in Figure 7 the following elements: the expected energy demand for the charging of Electric Vehicles (EV) in 2030; the expected growth of energy demand caused by expected growth of consumption (based on historical trends); the expected demand curve that is needed to feed the consumption of households and industries, including heat pumps. This information will be obtained thanks to the analysis of the Avacon scenarios and to the goals defined by the German Federal Ministry of Economic Affairs and Energy [13]. Table 1 summarizes the characteristics of the loads and generators connected to the Avacon Grid in 2020.

3.1.2.1 Target for distributed renewable energy sources

The German Federal Government has set a goal of achieving a 65% share of renewable energies in electrical energy consumption by 2030. In 2018, the share of renewable energies in gross electricity consumption was approx. 38%. The expansion of renewable energies in power generation will be substantially supported and regulated by the Renewable Energy Sources Act. The following goals are currently laid down in the Renewable Energy Sources Act:

- 40 to 45% by 2025
- up to 65% by 2030 and
- greenhouse gas neutral power generation by 2050.

The share of renewable energies in gross electricity consumption is heavily dependent on the development of electricity consumption (inter alia efficiency and sectoral coupling), as are the expansion trajectories. As outlined in the Climate Protection Program, further measures are planned in relation to the expansion of renewable energies to a 65% share in gross electricity consumption by 2030

3.1.2.2 Avacon Scenarios

Avacon, taking into account the different scenarios and input mentioned above, suggested to consider for the Platone SRA analysis the trends reported in Table 1 and Table 2.

Table 1 – Characteristics of the loads and generation in Avacon 2020 grid (source: Avacon data)

		2020 Situation		
		Installed Capacity	**Number of assets**	**Comment**
Household and Industry	[MW]	*14,04*		
Heat Pump	[MW]	*unknown*	*unknown*	currently not taken into account, no estimations available
V2G	[MW]		*unknown*	
Home charging	[MW]		*unknown*	
Fast charger	[MW]		*unknown*	
Ultrafast charger	[MW]		*unknown*	
Domestic Storages (PV-self-consumption)	[MW]	*2,6*	*2663*	
Renewable Generation				
Wind	[MW]	45,7		
PV (MV)	[MW]	12,2		48
PV (LV)	[MW]	33,8		372 (iONS)
Biomass (MV)	[MW]	23,6		67
Storage	[MW]	*unknown*		
Sum Renewable Generation	**[MW]**	**112**		

Table 2 – Characteristics of the loads and generation in Avacon 2030 grid (source: Avacon data)

		2030 Situation		
		Installed Capacity	Number of assets	Comment
Household and Industry	[MW]	14,04		
Heat Pump	[MW]	+7,6	*n.a.*	
V2G	[MW]	+16,7	1015	*92.78 MW in case of 100% electric mobility (Marked oriented control). Calculation: =0,18*92.78*
Home charging	[MW]	+9,9	900	
Fast charger	[MW]	+5,2	104	
Ultrafast charger	[MW]	+1,56	13	
Domestic Storages (PV-self-consumption)	[MW]	*No Forecast Available*	*2663*	
Renewable Generation				
Wind	[MW]	45,7		
PV (MV)	[MW]	43		48
PV (LV)	[MW]	33,8		372
Biomass (MV)	[MW]	23,6		67
Storage	[MW]	unknown		
Total Renewable Generation	**[MW]**	**112**		

Table 2 summarizes the characteristics of the loads and generators connected to the Avacon Grid in 2030.

3.2 Italian demo

The Italian Demo aims to enable network users to participate in the grid optimized management (using services such peak shaving, energy shifting etc.) through the flexibility mechanism. Thanks to the coordination of *a*reti and the cooperation of all the partners involved in WP3, the Italian Demo will develop an innovative system, i.e. “a complete end-to-end local flexibility market TSO-DSO coordinated”, enabling distributed resources connected in medium and low voltage grids to provide grid services, allowing the inclusion of all the stakeholders. The solution proposed will allow the development of a new model of cooperation between citizenship and municipality, bringing multiple benefits.

The trial will involve several areas of the city of Rome where specific portions of the electricity distribution network managed by *a*reti have been identified and selected as representative location for the project activities.

To develop the flexibility market, the Italian demo has designed an innovative, dedicated architecture, which is able to manage different information flows generating the possibility for an open and liquid market share. An overview of the components of the System Architecture, is highlighted below:

- Market Platform, a blockchain-based platform that enables the management of flexibility requests from System Operators (SOs) and flexibility offers from Aggregators. In detail, it collects requests and offers and then match them according to predefined rules and priorities;
- Aggregator Platform, an operational platform that facilitates Aggregator to manage the flexibility assets. Here, several tools are able to analyse data coming from different distributed energy resources (DERs), evaluate and aggregate available flexibility from several points of delivery (PoDs);
- DSO Technical Platform, an innovative platform that allows DSOs to improve reliability and aspects of service by exploiting flexibility made available from DERs connected to their grids. It is also able to predict grid congestions and voltage violations;
- Access Layer, a structure composed by three main components Light Node, Blockchain Access Layer and Shared Customer Database. The Light Node and the Blockchain Access Layer compose a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture. The Shared Customer Database instead is a repository system where all data related to flexible PoD are collected and available to all the stakeholders involved in the process.

3.2.1 Description of demo UCs under SRA perspective

The Italian UC describes the main steps to prevent congestion issues in transmission and distribution systems by exploiting flexibility resources, contemplating all the phases concerned (procurement, activation and settlement) in the day-ahead and real time flexibility market. The DSO can use flexible resources connected to the distribution system and the TSO can use flexible resources connected to distribution systems under the DSO’s approval. The state estimation is assessed and monitored by the DSO in order to keep the electrical quantities within admissible ranges. In the day ahead market, the FR Owner sends to Aggregator Platform the list of the resources available for the day after. The list is subsequently transmitted by the Aggregator Platform to the Shared Customer Database (SCD). For each Point of delivery (PODs), the SCD collects quarterly measures and data useful for flexibility and sends them to the DSO Technical Platform, the TSO simulator and the Aggregator Platform.

Other three processes take place in parallel:

- Forecast of congestion issues on the distribution grid by the DSO Technical Platform and definition of local flexibility requests, in the event the issue cannot be solved through its own solutions.
- Definition of congestion issues on the transmission network by the TSO simulator and request of flexibility to solve them in HV grid;
- Gathering by the Aggregator Platform of flexibility offers from customers in LV and MV and offering to the Market.

At gate closure, all day ahead requests and offers are stored in the Market Platform, which matches first the offers with the DSO’s requests, and orders them economically; then, it repeats the same procedure with the TSO requests.

The list of awarded offers is sent to DSOTP for evaluating the grid constraints violations. Finally, the market platform receives the list of offers compliant with local grid constraints and sends it to all the stakeholders.

The same steps are also followed in the Real Time sessions. Indeed, in these Market sessions, the offers to be matched with DSO and TSO Real Time requests are the ones still valid because not matched in previous market sessions.

The Market Platform sends the order to the aggregator platform which then forward it to DSOTP, which divides it for every POD and dispatches the set point to the Light Nodes. The Light Nodes make available the set points to the customers' systems (e.g. EMS, storage systems etc.) and measures the electrical quantities to be sent to the SCD for evaluate the energy flexibility.

For the settlement phase, the Market Platform acquires data from the SCD and calculates the difference between market baseline, provided by aggregator (acting as BRP), and electrical quantities measured in the same time frame, uploaded in the SCD by Light Nodes. The Market Platform runs the settlement algorithm and finds the outcomes. Settlement outcomes are transmitted to the Aggregator Platform, the DSO and the TSO Simulator.

Finally, the DSO pays the flexibility to the Aggregator, who can pay the fee to the FR Owner.

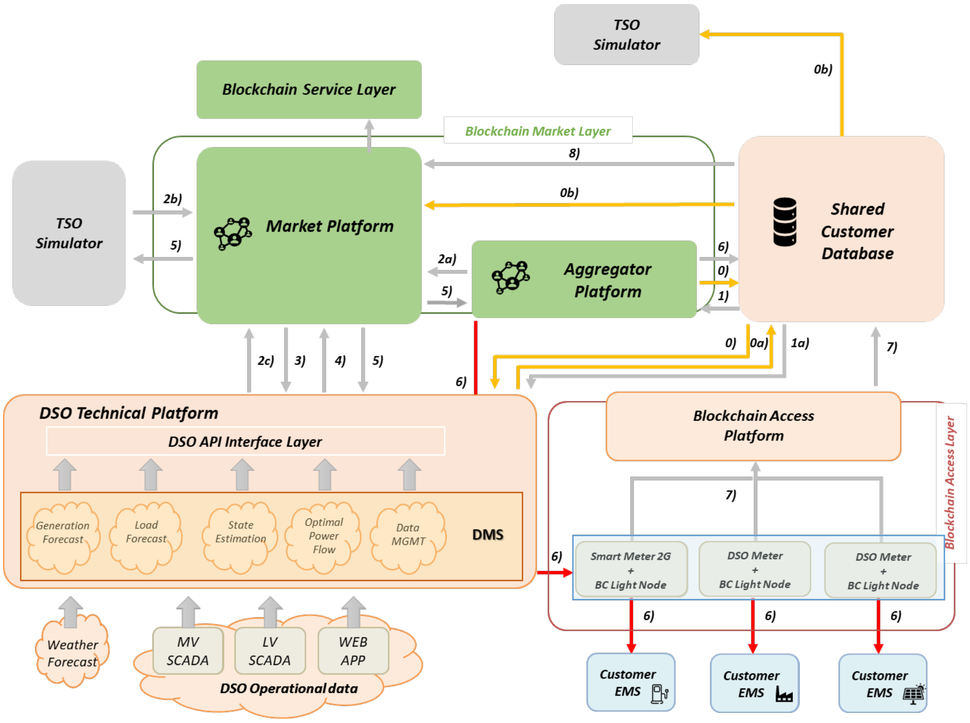


Figure 8 – Architecture of the Italian demo

The KPIs that will be monitored in the different stages of the SRA are:

1.) Reduction of Active Power Load Peaks - $|P_{+-}|$ [kW]
2.) Reduction of overloads of lines and transforms

The Italian demo is testing its task on a small number of domestic and industrial clients (an industrial CHP and Acea smart park).

The Scalability in density analysis assesses how the analysed KPIs (e.g. reduction of local congestions) vary when the number of flexible loads and distribution generation units is increased within the same area considered in the demo. Different scenarios will be implemented to focus on different technology roles, in particular to evaluate the different impact of domestic flexibility solutions and the foreseen penetration of EV and the difference between flexible load and flexible generation effects on the grid. Figure 9 describes the characteristics of the area that will be analysed in the scalability in density analysis.

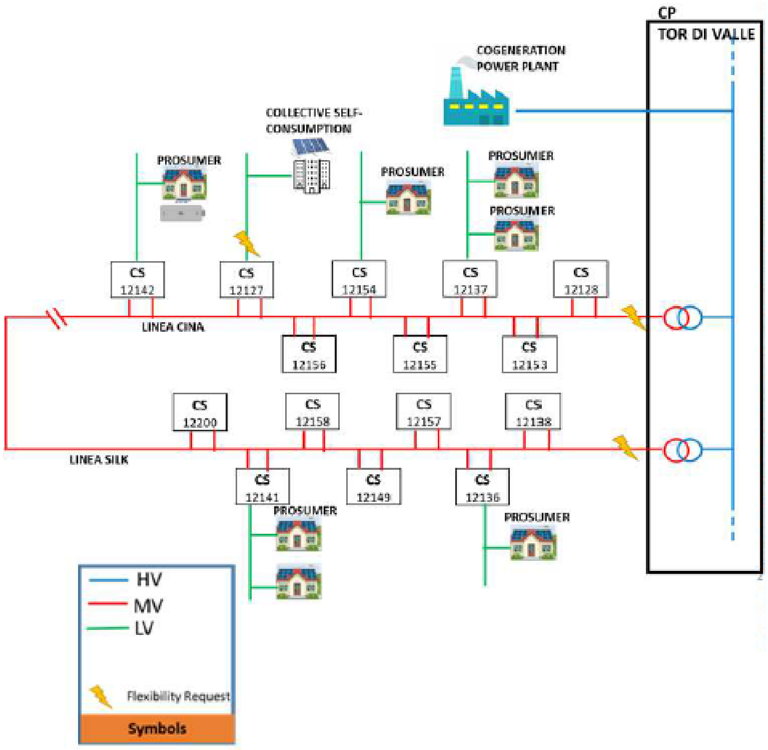


Figure 9 – Area of the Italian demo that will be investigated in the SRA density

Replicability at intra-national level aims at assessing how the selected KPIs will change when the solution is deployed in a network that has similar dimensions but different characteristics: e.g. semi urban network, rural network. Another type of analysis will assess how the selected KPIs will change when the flexibility service will be provided by a large industrial unit like the Tor di Valle CHP unit. Moreover, in this analysis we can estimate the impact of different solutions to connect residential customers (e.g. the possibility to connect residential customers to the distribution grid with three phase connections. This solution allows the customers to get access to a larger installed capacity with respect to conventional solutions deployed in the Italian grids; consequently, the DSO can increase the amount of flexibility that can be provided by each residential customers). Replicability at international level will estimate the impact on the UC KPIs when this solution is deployed in a different and larger network. This analysis will consider also different regulatory boundary conditions that can have an impact on the Italian use cases: for example different levels of voltage limits allowed by the national regulatory schemes will be considered and different target values and indicators for the indices that monitor the continuity of supply will be considered as input for the analysis for the international replicability. Figure 9 describes the characteristics of the part of the Italian demo that will be subjected to the scalability and replicability analysis in density.

3.2.2 SRA scenarios

The following chapter summarizes the main factors that have an impact on the foreseen evolution of the *a*reti grid and their impact on the distribution network. This paragraph includes also the information taken by the Development plan prepared by ACEA: in particular the following aspects are described: the expected growth of conventional load; the expected penetration of Electric Vehicles and of the installed capacity of renewable power plants in the distribution networks.

*a*reti, in the grid development plan [15], foresees to increase the hosting capacity of the distribution grid and to increase the quality of services. These targets can be enabled thanks to an optimized redistribution of the current and foreseen loads among the existing substations, but they can also be achieved thanks to the increase of flexibility of the assets connected to the grid. The grid development plan considers the following factors as main causes for the expected growth of winter (invernale) and summer (estivo) loads: historical trends of load growth [15]; (3% per year); foreseen requests for new connections (both MV and LV) and the expected load growth caused by the future demand for cooling services and heat pumps (see Figure 10). areti estimates that, by 2030 the penetration of heat pumps for heating and cooling services will cover the 54.6% of the total demand for heating and cooling energy demand [15].

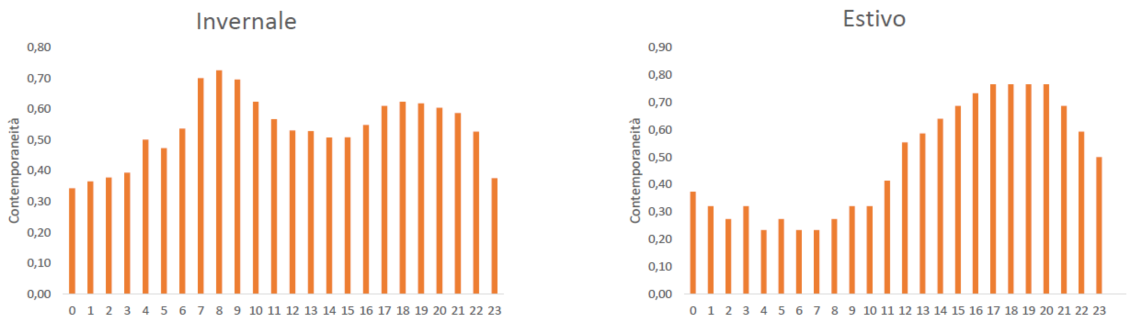


Figure 10 – Expected energy demand for heating and cooling services in 2030 in *areti* network in winter (left) and summer (right) scenario [15].

The development plan mentions other drivers like the effect of electrification of public and private transport, as well as a more thrust penetration of electricity in thermal uses (winter heating, electric ovens, etc.).

The impact of the penetration of EV charging stations on the distribution grid depends on the type of EV charging infrastructure that is installed in the network. In particular, three types of EV charging stations are available: slow charging (that are characterized by a capacity equal to 11 kW or lower); fast charging station (whose capacity is 22 kW) and finally ultrafast charging stations (whose capacity is equal or greater than 50 kW and are fed by DC). Moreover, the charging stations can be used to multiple users (e.g. dedicated to feed a company fleet or installed in a public parking) or used for multiple functions (e.g. combined with other application in some condos, etc.). The second aspect that determines its impact on networks concerns the factors of overall use and simultaneous usage, specific to each type of user served by the columns. Three particular user configurations are more likely: EV charging stations installed in private homes, charging stations for national fleets, and fast charging points (e.g. at filling stations or car parks). Private homes generally are equipped with charging stations characterized by low indices of simultaneous and overall usage. EV are usually charged mainly in the evening, however there are some external factors that will change in the near future the current load profiles associated with EV charging stations installed in private homes. For example, ARERA, the Italian National Regulatory Agency, is promoting the adoption of intelligent charging systems that aims at spreading the peak demand requested for EV charging over a certain number of hours (during the nightly hours). For these reasons the local effects (i.e. on the low voltage network) of private refills may be limited and may concern only a limited set of network components (e.g.: secondary substations or primary substation transformers).

The second category of EV charging stations considered is represented by the stations used to feed the corporate fleet. These stations are not necessarily fast or ultra-fast, since the charging process can be optimized by recharging vehicles in rotation, reducing the power used and consequently the overall costs. Thus, the optimization of the charging process leads to decrease the power and at the same time to increase the utilization factor, limiting potentially local impacts on the grid with respect to a scenario in which the recharging process is not controlled.

The last category of EV charging station is represented by the fast charging stations that have high power but low utilization factors. These charging stations have highly discontinuous profiles characterized by high power peaks but a low overall energy level. These charging stations do not allow the operator to modulate the load profiles. This category represents the most critical type of charging stations because the DSO, in the planning process, must consider that the node in which the charging station will be installed, must bear a contracted power that is equal to the load peak: however, this contracted power is requested only for a limited number of hours.

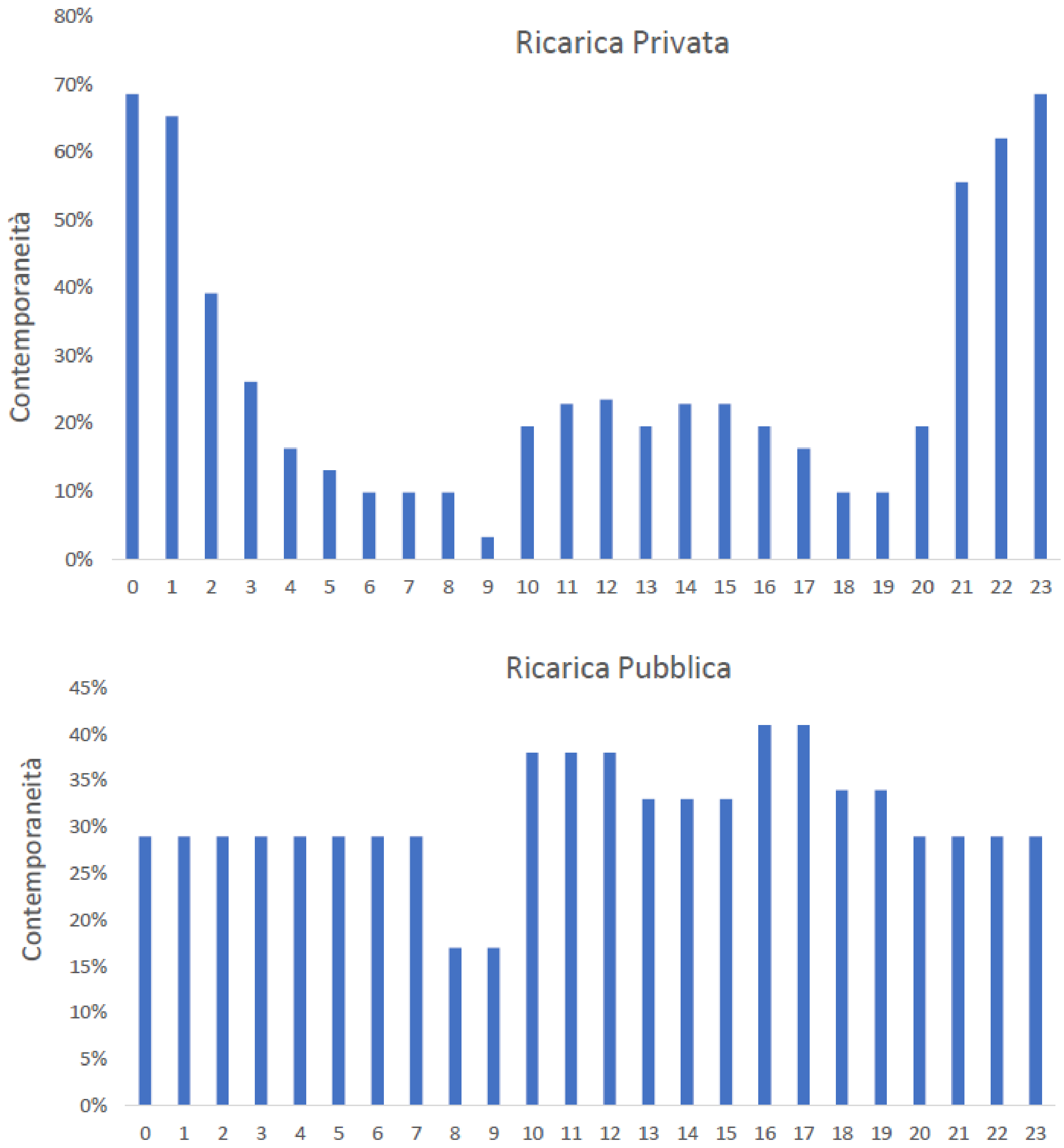


Figure 11 - Forecast for simultaneous EV penetration in the *areti* network in 2030 for private (top) and public (bottom) charging infrastructure [15].

Figure 11 summarizes the forecasts of the penetration of EVs in the *a*reti network in 2030. In urban networks, only photovoltaic generators can be installed and the space available is anyway limited to building roofs; since these are areas with a high load density, the ratio in any case, generation / load remains low even in the hours of low consumption from the grid. The only exception it consists of cogeneration plants serving the district heating networks, or plants for self-consumption of MV users (e.g.: hospitals), which may have large sizes and be placed in proximity to or within urban areas. The current situation for the Rome area reflects these trends; the majority of generators use non-renewable fuel (mainly gas) for applications of cogeneration and local self-consumption. There is also a fair share of photovoltaics, but that is it practically irrelevant given the load levels of the Rome network.

areti's 2019 development plan takes into account the critical issues caused by distributed generation already connected to the grid but, unlike the evaluations for the growth of the load, it does not make an explicit future forecast of PV penetration. The document indicates the connection requests that have already been accepted and will be installed in the short term, however these forecasts are not representative of a long-term scenario. Moreover, the development of the distributed generation is more uncertain and linked to technological evolution and the mechanisms of national subsidies. The future scenarios are therefore extremely uncertain and for this reason it is necessary to conduct different ones evaluations to understand the possible impacts in the various hypotheses of siting and sizing of the DG. For comparison, the PNIEC predicts [16] that by 2030 there will be 50 GW of photovoltaic installations, a capacity which is about 2.5 times the current installed (about 20 GW). From the geographical characteristics of the territories and the different density of a load, however, it can be assumed that the effects of generation will be more significant in rural areas with respect to the urban networks that are representatives of the network managed by areti [17].

The *areti* development plan considers the following three scenarios for the evolutions of PV and distributed generations in 2030 [15]: Each scenario describes a particular evolution of the energy system in 2030 (e.g. distribution of loads and generation units)

- Business As Usual (BaU): this scenario assumes that the rate of yearly installation of new capacity of PV remains equal to the trend experienced in 2019
- Target: it scales the target sets by the PNIEC to the *areti* network
- Target + storage: this scenario foresees the implementation of strong incentives to promote the penetration of small scale domestic storage, in order to promote self consumption. This scenario will maintain the local consumption limited to LV network thus limiting the possible congestions that might arise in MV network and in the neighbouring LV areas

The characteristics of the three scenarios developed by *areti* are summarized in Table 3.

Table 3 – Characteristics of the three scenarios considered by *areti* (source: [15])

	As Is	**BaU**	**Target**	**Target + Storage**
Installed Capacity [MW]	242	313	588	588
Installed Capacity of PV plants in LV [MW]	94	122	229	229
Self consumption	30%	30%	50%	90%
Installed Capacity in LV [MW]	28	37	115	206
Annual Production for Self-consumption [MWh]	54,468	70,754	221,772	399,190

areti estimates that the deployment of the 3rd scenario (target+storage) will enable the DSO to benefit from the reduction of the expected peak load seen in the network (a reduction equal to 121 MW with respect to the expected peak foreseen in the target scenario, as shown in Figure 12)

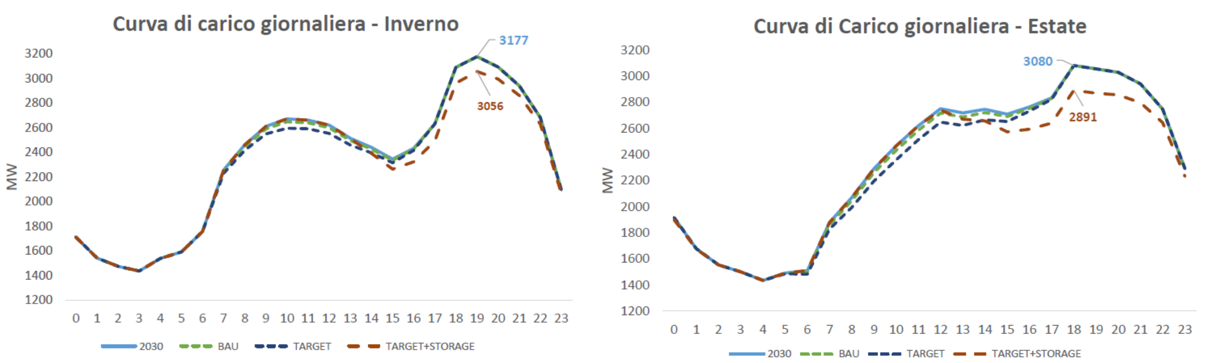


Figure 12 – Expected yearly peak in *areti* 2030 network in the 3 scenarios (source: [15])

Table 4 describes the results of the study. It quantifies the energy peak in 2030 in the four scenarios considered.

Table 4 – Results of the study of the three scenarios considered by *areti* (source: [15])

2030	Without PV	BaU	Target	Target + Storage
Annual Peak [MW]	3177	3177	3177	3056

3.3 Greek demo

. The Greek demo objectives are the following:

- To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).
- To improve grid operation through advanced grid observability.
- To achieve optimal dispatching, addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level.
- To investigate potential provision of ancillary services to the TSO by the users of the distribution network.
- To assess the penetration limits of DERs for better control and planning of the distribution network [18].

The test-bed for the Greek demo is a real-world distribution network operating in the geographical site of Mesogeia, which is located in the eastern part of Attica region. With regard to the existing metering infrastructure, the HV/MV substation of the test site, which is considered the slack bus for power flow purposes, is equipped with a SCADA system that provides voltage and current flow measurements at the top of the distribution feeders. In addition, there are dispersed metering devices throughout the network which support recording, storage and transmission towards HEDNO telemetry centres of measurement data (mainly referring to active/reactive power injection) obtained from all MV customers. The abovementioned metering equipment serves PVs operating at MV and LV levels. The related measurement data have a 15-minute temporal resolution.

3.3.1 Description of demo UCs under SRA perspective

WP7 focuses on two subjects, SRA and CBA. Out of the five Greek Demo UCs only two are of relevance to the SRA and CBA. UC-GR 1 and 2 (which test the State Estimation algorithm with and without the introduction of PMUs) are not suitable for SRA and CBA. Therefore, it is not considered in SRA and CBA. Similar arguments apply to UC-GR-5 which is a case that deals with the visualization capabilities offered by the Platone Platform to the Greek demo. Therefore, the SRA and CBA will focus on UC-GR 3 and 4 of the Greek demo. However, given that they follow a similar technical and conceptual narratives only one of the two will be chosen for thorough analyses. All results of the SRA and CBA apply to its companion UC, too. To this end, we will perform a more detailed discussion on UC-GR-3 - Distribution Network limit violation mitigation (see [18]). RES systems and customers with flexible loads are connected to the distribution network with the flexible loads considered aggregated for the scope of the UCs regarding their management in the MV level. The state of the network is known with a good degree of certainty.

The methodology proposed for the SRA of the Greek demo is summarized in Figure 13 and described in detail in D 7.1 [2].

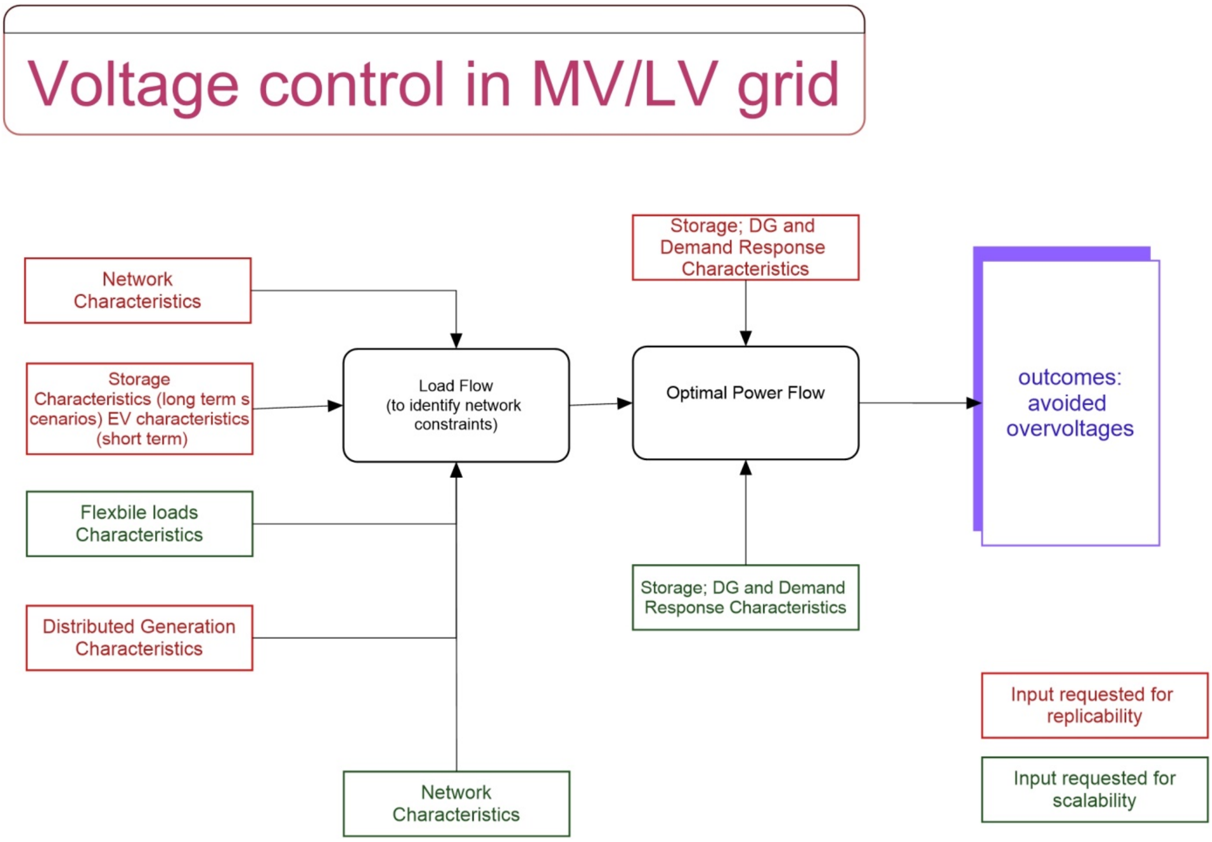


Figure 13 – Methodology for SRA of the UC3 of the Greek demo (Source: [2])

3.3.2 SRA scenarios

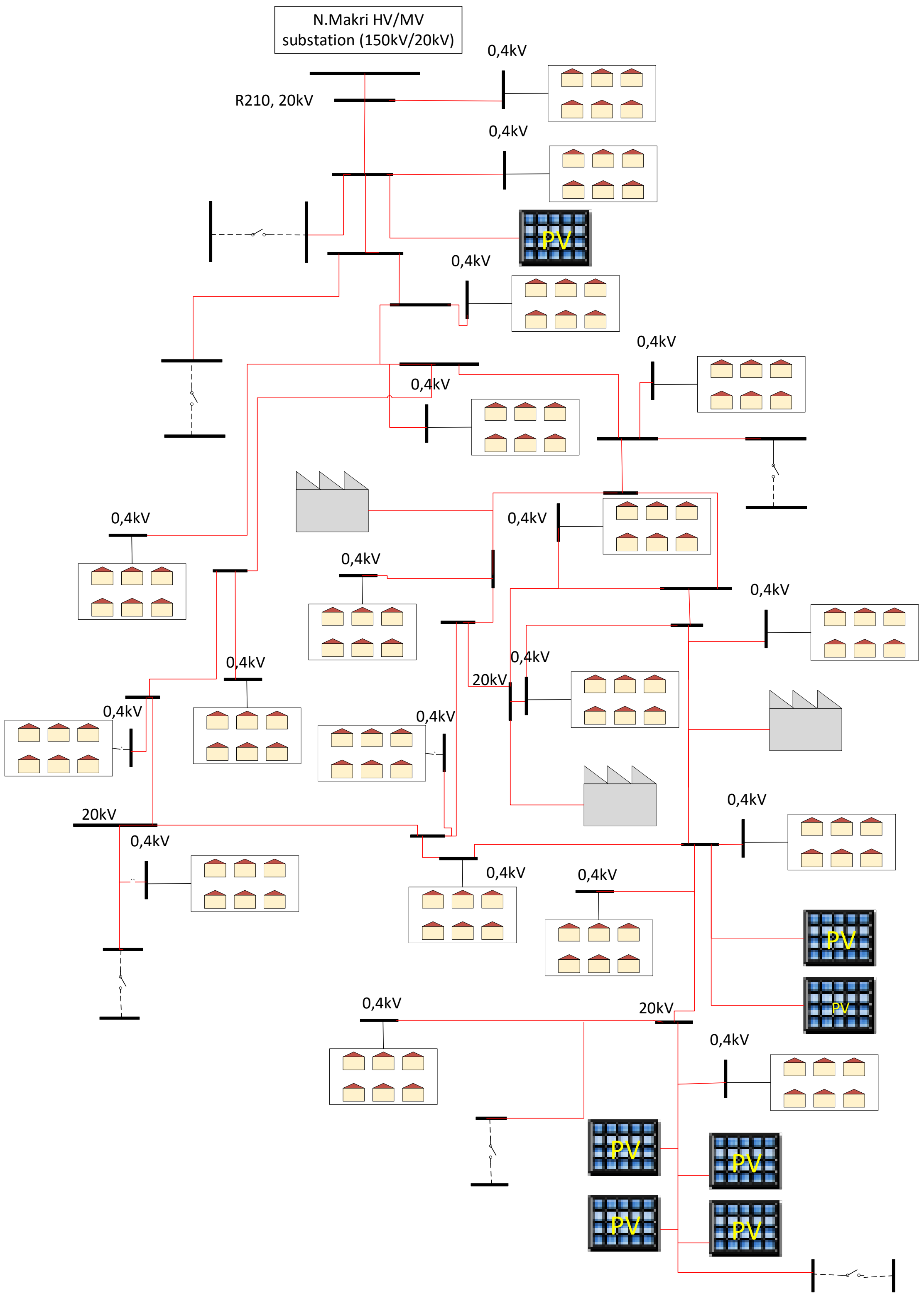
The first step of the scalability and replicability analysis of the Greek demo consists in the scalability in density that aims at evaluating the variation of project KPIs in the demo area when the penetration of the flexibility sources in the considered area increases. The electrical scheme of the area that will be analysed in the analysis is illustrated in Figure 14. In the SRA, we will calculate how the project KPIs will change (reduction of congestions of existing lines and transformers) when customers offer an increasing amount of flexibility (calculated as percentage with respect to the contracted power). In this step we shall consider both residential and industrial loads.

In the replicability intra-national analysis we will consider the contribution that the activation of flexibility sources can provide to the management of area considered in the demo in scenarios that include the achievement of the targets of the Greek energy policy in terms of penetration of renewable energy, electrification of transports and electrification of heating systems.

The objective of the Greek energy strategy [19] to be attained in terms of the RES share in gross final energy consumption is at least 35%. However, this target does not include the contributions provided by the expected penetration of heat pumps for covering cooling needs in an a more energy-efficient manner is not yet taken into account. The Greek Ministry of the Environment and Energy also considers the following goals for 2030:

- reaching at least 60% for the RES share in gross final electricity consumption;
- RES share used to supply heating and cooling demands shall exceed 40%;
- RES share in the transport sector shall exceed the 14% in line with the relevant EU calculation methodology.

The SRA of the Greek demo will calculate how the project KPIs will change when the flexibility solutions tested in the demo will be deployed in different representative networks, as described in Chapter 4.2.4.3.


N.Makri HV/MV substation (150kV/20kV)
R210, 20kV
0,4kV
20kV
PV

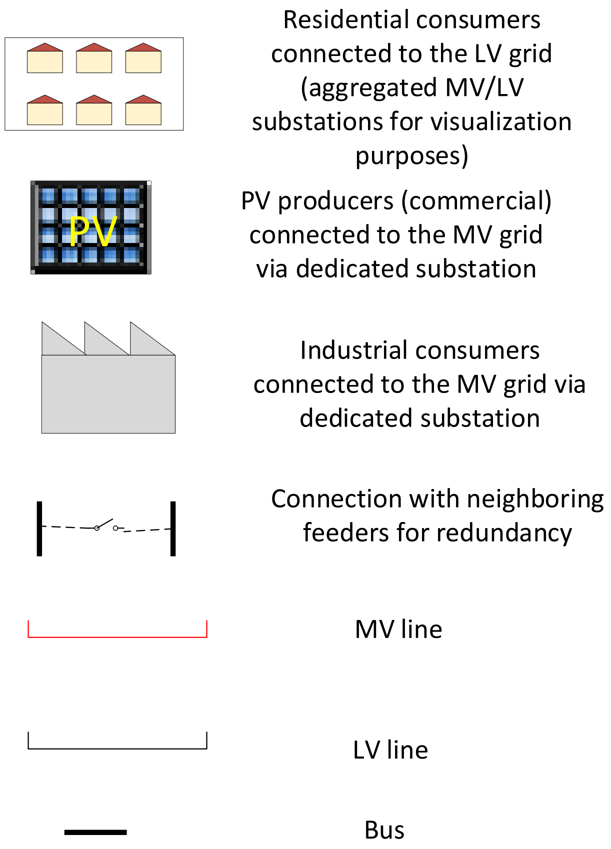


Figure 14 – Area of the Greek demo

The next steps of the analysis of the Greek demo consists in the definition of the scenarios for Scalability and Replicability Analysis.

4 Representative networks

This section is organized as follows: Chapter 4.1 introduces the concept of representative networks and contextualizes their usage inside the SRA activities. Afterwards, Chapter 4.2 explains the data collection activity performed within WP7, describes the process which has led to the selection of the representative networks to be used and specifies the details of the chosen networks for the different SRA simulation scenarios in each Platone demo.

Representative networks: definition and relation to SRA

As mentioned in the previous sections and in [2] the SRA methodology adopted in WP7 is based on the use of the so-called "representative networks" with the aim of (i) modelling the technical boundary conditions of the Platone demos, (ii) performing the SRA simulations under different scenarios and (iii) computing the KPIs for the assessment of the impact of the smart grid solutions implemented in the Platone UCs.

A set of representative networks can be defined as a reduced number of model networks or test networks, where each representative network is the best fit to describe the behaviour of a group of real feeders [20].

The adoption of representative networks in the power system simulation field is widely recognized as a flexible tool for reproducing the behaviour of actual distribution networks, so to account for the peculiarities of different networks/areas but in a condensed manner, thus efficiently enabling large-scale smart grid analyses. Different representative networks have to be designed/employed depending on the smart grid functionalities under study, reflecting different applicative aspects and having different levels of detail [21],[22].

Within the context of SRA, representative networks turn to be an effective tool for:

a) Replicability analysis (intra- and inter-national)
b) scaling-up analysis (in size and density)

In the case of replicability analysis, utilizing different representative networks (reflecting the behaviour and peculiarities of different geographical areas with different network characteristics) enables performing simulations by taking into account different technical boundary conditions (e.g., for urban/rural areas or with different regulatory grid voltage limits).

In the case of scaling-up analysis (both in size and density) utilizing a comprehensive and meaningful set of representative networks enables "projecting" the simulation results for wider areas (i.e. scaling-up in size) and at a larger scale regarding density aspects (i.e. scaling-up in density) with respect to the original study area.

The definition of a set of representative networks may be based upon a variety of methods ranging from actual feeder anonymization to clustering techniques, manual design and planning tools etc. (still starting from real networks as basis).

The process of representative network definition is undoubtedly a challenging task with various barriers mainly related to the availability (e.g., confidentiality issues) and accuracy (e.g., resolution level, format, infrastructure types) of the data needed for it. For characterizing in a comprehensive way the network of a given area, an efficient process of data collection is of paramount importance to define and employ a set of representative networks which are sufficiently "representative" of the area under study and of the scenarios under analysis.

4.2 Representative networks within WP7

4.2.1 Data collection process

With the scope of fulfilling the challenging task of collecting the data needed for the representative network elaboration, WP7 has put in place an interactive and iterative process with the Platone demo leaders so to effectively represent the typical architectures, topologies and characteristics of the actual Platone demo grids. The representative networks to be used inside the WP7 SRA simulations have to effectively reflect the different characteristics of e.g. population density, electricity use pattern, installed capacity etc. corresponding to the different rural/urban/industrial/residential areas hosting the Platone demos. For this purpose, WP7 has prepared a questionnaire to be filled out by each demo leader for performing the Platone demo network model data collection. This questionnaire is reported in [2]. The circulated questionnaire is divided in two parts. The first part (section A.2) aims at collecting general information of the DSO company which the demo site belongs to (sections A.2.1 and A.2.2) and some basic parameters on its network design, like number of customers connected, circuit length and technical data divided per voltage level (sections A.2.3 to A.2.6). The second part (section A.3) aims at providing further information regarding the network structure, connected DG and network reliability metrics.

4.2.2 The EC JRC representative networks

Within WP7, the choice of which representative networks to use had to be made taking into account the characteristics of the different Platone demo grid areas, the available tools for representative network creation and the possibility to adopt representative networks already available in the literature.

After a preliminary review of the representative networks already available at the European level, it was decided to put the focus on the recent interesting work performed within the "DSOs' Observatory" project by the Joint Research Centre (JRC) of the European Commission (EC) in 2014 [12] (i.e., those serving more than 100,000 connected customers), with the aim of collecting some technical parameters and indicators regarding the main DSOs in Europe and build some European representative networks at the distribution level without the need to have access to the real DSOs' data.

The number of European DSOs who participated to the survey was 79, and together they distribute over 70% of the electricity distributed by all DSOs serving over 100,000 customers. One result of this survey participation has been the derivation of several network structural indicators. Based on these network structural indicators, 13 MV and LV representative networks (corresponding to urban, semi-urban and rural areas and with different automation degree levels) have been elaborated. In Table 5, the set of the 13 representative networks built by the JRC is presented. These grid models (referred to as "JRC representative networks" in the following) are claimed to be representative of European networks, without specifically representing any particular DSO or country.

Table 5 - Representative networks developed by the EC JRC "DSOs' Observatory" project [12]

ID #	Type of area	Voltage levels	Degree of automation
RN1	Urban	LV & MV	Low
RN2	Semi-urban	LV & MV	Low
RN3	Rural	LV & MV	Low
RN4	Urban - Two substations interconnected	MV	Low
RN5	Urban - Two substations interconnected	MV	High
RN6	Urban - One substation and one switching station	MV	Low
RN7	Urban - One substation and one switching station	MV	High
RN8	Semi-urban - Substation ring	MV	Low
RN9	Semi-urban - Substation ring	MV	High
RN10	Rural	MV	Low
RN11	Rural	MV	High
RN12	Urban	LV	Low

RN13	Semi-urban	LV	Low

In particular, the JRC representative networks can be categorized into 2 major groups, large scale and feeder-type networks.

Large-scale networks (RN1-3) model the network downstream of a HV/MV substation, including LV and MV consumers, LV and MV feeders and MV/LV substations. The main difference between these 3 large-scale networks is the demand density since they aim to represent three different area types. In particular,

- the urban network (RN1) has been built modelling the distribution network inside a highly populated city;
- the rural network (RN2) has been built modeling farms and small settlements connected by a MV network;
- the semi-urban network (RN3) has been built modeling an intermediate situation in the outskirts of a city.

Feeder-type networks (RN4-13) include a restricted set of feeders downstream a single HV/MV (RN4-11) or MV/LV (RN12-13) substation. These feeder-type networks can be divided into:

- MV feeders (RN4-11), with specific network configurations for MV reliability analysis and different degree of automation (low and high)
- LV feeders (RN12-13), for specific analysis of a single LV network (e.g., installation of photovoltaic generation in a LV residential network).

Since the Platone demos are located in Italy, Greece and Germany (so covering very different geographical areas), using the representative networks coming from the significant work produced by the EC JRC “DSOs’ Observatory” project was considered an appropriate choice.

4.2.3 The JRC network indicators

As previously mentioned, one of the results of the European level survey carried out within the EC JRC “DSOs’ Observatory” project has been the elaboration of a set of network structural indicators, which condense characteristics related to network designs, network structure, reliability indices and connected DG, using the database derived from 79 of the largest European DSOs.

A subset of these DSOs’ network structural indicators is reported in Table 6 (second column) together with their median, 5th and 95th percentiles (fourth, third and fifth column, respectively) collected in the “DSOs’ Observatory” database[1]. These 9 network indicators have been specifically used for building the three large-scale JRC representative networks (i.e., RN1-3).

Table 6 - DSOs’ network indicators, median and 5th-95th percentiles (as of 2016).

ID #	DSOs Network indicators	5th percentile	Median	95th percentile
I.1	Number of LV consumers per MV consumer	26	354	1550
I.2	LV circuit length per LV consumer (km)	0.0104	0.023	0.0542
I.3	LV underground ratio	22.20%	79%	99.80%
I.4	Number of LV consumers per MV/LV substation	24.9	90	209.2

[1] An update of these values can be found in the “DSOs’ Observatory” project report of 2018, after that a bigger number of European DSOs joined the survey.

I.5	MV/LV substation capacity per LV consumer (kVA)	2.37	3.8	9.12
I.6	MV circuit length per MV Supply Point (km)	0.27	0.73	1.46
I.7	MV underground ratio	14.40%	56%	100%
I.8	Number of MV Supply Points per HV/MV substation	61	178	580
I.9	MV/LV transformer substation capacity (kVA)	400-1000 Urban		
		100-400 Rural		

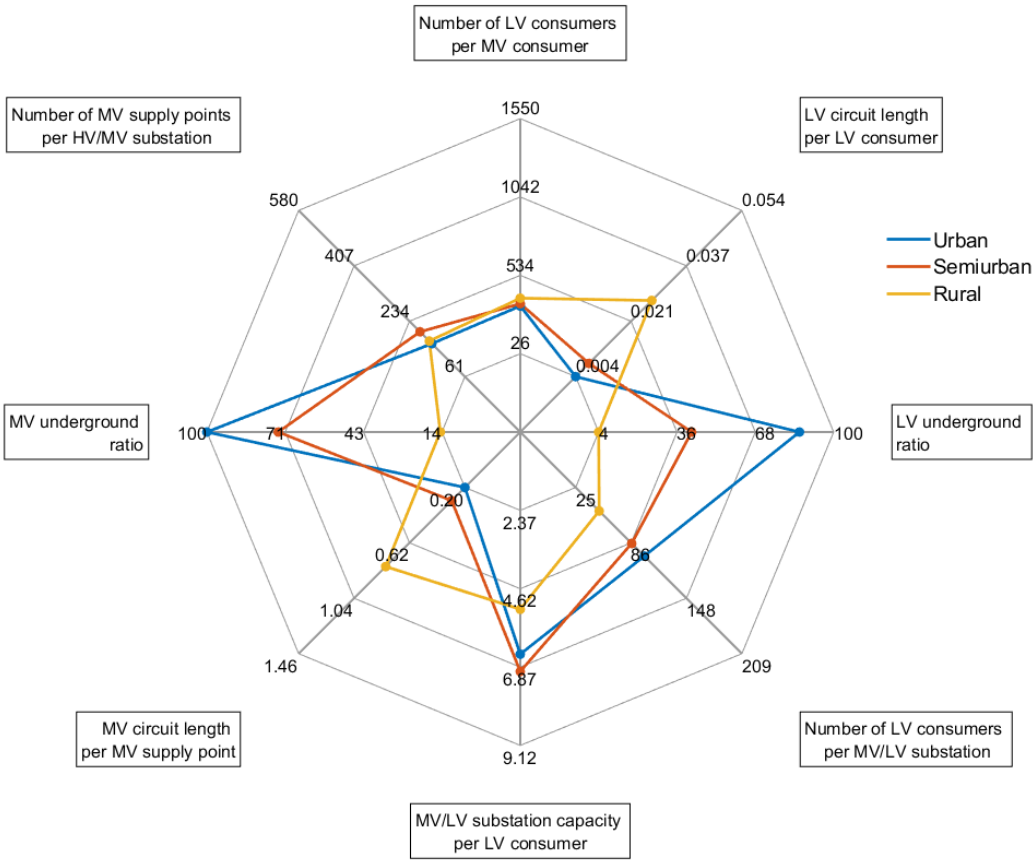


Figure 15 Visualization of the median values of the 3 large-scale JRC networks indicators

For the sake of visualization, the calculated median values of the DSOs' network structural indicators[2] corresponding to the three large-scale networks produced by the EC JRC "DSOs' Observatory" project (i.e., urban, semi-urban, rural) are reported in Figure 15 using a spider plot[3]. As can be seen, the indicators that most differentiate the three large-scale representative networks between each other are:

[2] For convenience, the last indicator (i.e., "ID9: MV/LV transformer substation capacity") is not shown, since it assumes multiple discrete values.

[3] The scale of the axes has been set up according to the following criterion: the 5^{th} and 95^{th} percentiles (reported in Table 4) are used as min-max values for each axis, except when the indicators' values of

- LV circuit length per LV consumer
- LV underground ratio
- Number of LV consumers per MV/LV substation
- MV circuit length per MV supply point
- MV underground ratio

More details regarding the JRC representative networks and the statistical distribution of the network indicators can be found in [12].

4.2.4 Selection of representative networks for SRA

At the end of the data collection process explained in Chapter 4.2.1, the data provided in the questionnaire[4] for each of the three Platone demos have been elaborated and the same indicators of Table 6 were computed. By so doing, the three Platone demos have been characterized in a standard way as done by the EC JRC "DSOs' Observatory" project for the sake of reproducibility. It is noteworthy that the exact values of the indicators computed for the three Platone demos are not reported here in order to guarantee Platone DSOs' data confidentiality.

After characterizing the three Platone demo areas by using the JRC network indicators of Table 6, a comparison was made between the indicators calculated for the Platone demo grids and the JRC representative network indicators. By evaluating the pattern similarity of the Platone demo grid indicators with that of the JRC network indicators (as shown in Figure 15), a categorization of the Platone demo grids into "urban", "semi-urban" or "rural" was also performed. With this approach, analogies and differences between the Platone demo grid models and the JRC representative networks have been highlighted and the usability of (some of) the JRC representative networks has been also investigated.

As a result of this comparison process and taking into account the different JRC representative networks of Table 5, it has been possible for all the three Platone demos to derive first proposals of which networks to use for the SRA simulations (i.e., for the "baseline", "scalability in density", "intra-national replicability", "scalability in size" and "inter-national replicability" analyses). These proposals for German, Greek and Italian demos are summarized in the next subchapters in Table 7, Table 9 and Table 8, respectively.

It is noteworthy that these proposals may be confirmed or slightly changed in the upcoming months of the project based on possible updates/developments of the Platone demos.

4.2.4.1 German demo

For the German demo the networks to be used in each of the SRA scenarios are as proposed in Table 7.

The German demo grid is an LV network characterized by low residential and commercial consumption. It has been classified as "rural" with the previously explained approach. Therefore, since the only LV feeder-type JRC representative networks correspond to urban and semi-urban area types, the natural choice would be to use:

- the original German LV grid model itself for baseline and scalability in density;
- the JRC representative networks RN12-13 (which are LV feeders corresponding to urban and semi-urban area types, respectively) for the intra-national replicability;
- the JRC representative network RN3 (which is a large-scale MV network corresponding to a rural area type) for the scalability in size;
- the JRC representative networks RN1-2-3 (which are large-scale MV networks corresponding to urban, semi-urban and rural area types, respectively) or RN12-13 (which are LV feeders

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any of the three large-scale networks lie outside the 5^{th} / 95^{th} percentiles boundary (in this case, the specific indicator value is used as extreme value).

[4] The questionnaire used for the data collection process, reported in Annex A, is a slightly adapted version of the original questionnaire used for the survey carried out in the context of the EC JRC "DSOs' Observatory" project.

corresponding to urban and semi-urban area types, respectively) but with different regulatory boundary conditions (e.g., grid voltage limits) for the inter-national replicability.

Table 7 Networks for the SRA scenarios of the German demo

	Baseline	Scalability in Density	Intra-national Replicability	Scalability in Size	Inter-national Replicability
Grid to be used	Original demo LV grid model	Original demo LV grid model	RN12-13	RN3	RN1-2-3 or RN12-13 (with different regulatory boundaries)

4.2.4.2 Italian demo

For the Italian demo, the networks to be used in each of the SRA scenarios are as proposed in Table 8. The Italian demo grid covers 2 MV feeders of the Tor di Valle grid area, a residential district located in the south-western area of Rome hosting both important industrial sites and different residential buildings. It has been classified as “urban” with the previously explained approach. The number of MV-LV customers and the MV/LV substation capacity are almost of one order of magnitude smaller compared to the corresponding large-scale JRC representative urban network (RN1).

On the other hand, it has almost the same number of MV consumers as well as the same average MV feeder length compared to the corresponding feeder-type JRC representative MV urban network (RN6-7)[5]. Therefore, the natural choice would be to use:

- the original Italian grid model itself for baseline and scalability in density;
- the JRC representative networks RN8-9/10-11 (which are feeder-type MV networks corresponding to semi-urban and rural area types, respectively) for the intra-national replicability;
- the JRC representative network RN1 (which is a large-scale MV network corresponding to an urban area type) for the scalability in size;
- the JRC representative networks RN1-2-3 (which are large-scale MV networks corresponding to urban, semi-urban and rural area types, respectively) or RN6-7/8-9/10-11 (which are feeder-type MV networks corresponding to urban, semi-urban and rural area types, respectively) but with different regulatory boundary conditions (e.g., grid voltage limits) for the inter-national replicability.

Table 8 Networks for the SRA scenarios of the Italian demo

	Baseline	Scalability in Density	Intra-national Replicability	Scalability in Size	Inter-national Replicability
Grid to be used	Original demo grid model	Original demo grid model	JRC feeder-type semi-urban/rural RN8-9/10-11	RN1	RN1-2-3 or RN6-7/8-9/10-11 (with different regulatory boundaries)

4.2.4.3 Greek demo

For the Greek demo the networks to be used in each of the SRA scenarios are as proposed in Table 9.

The Greek demo grid covers 2 out of 154 MV feeders of the MV network belonging to the Mesogeia area (of approx. 10 km^2) in the Attica region. It has been classified as “rural” with the previously explained approach. It has almost half of the consumers and MV/LV substation capacity compared to the corresponding large-scale JRC representative rural network (RN3). However, the Mesogeia area not an

[5] The two feeder-type JRC representative networks named RN6 and RN7 are actually the same network but with two different automation levels (classified as high and low), as shown in Table 1. The same reasoning applies to the networks labelled as RN8-9 and RN10-11.

exclusively rural area. On the contrary, it is a semi-urban area, close to the main urban area of Athens. The demo area features, apart from residential consumers, industrial loads and PV production, connected to the MV grid via dedicated substations. So, in case any discrepancies arise from classifying the demo grid as rural (RN3), a hybrid approach can be used considering also RN2 (semi-urban), in order to increase accuracy for the analysis. Therefore, the natural choice would be to use:

- the original Greek grid model itself for baseline and scalability in density;
- the JRC representative networks RN1-2 (which are large-scale MV networks corresponding to urban and semi-urban area types, respectively) for the intra-national replicability;
- the JRC representative network RN2 (which is a large-scale MV network corresponding to a rural area type) for the scalability in size;
- the JRC representative networks RN1-2-3 (which are large-scale MV networks corresponding to urban, semi-urban and rural area types, respectively) but with different regulatory boundary conditions (e.g., grid voltage limits) for the inter-national replicability.

Table 9 Networks for the SRA scenarios of the Greek demo

	Baseline	**Scalability in Density**	**Intra-national Replicability**	**Scalability in Size**	**Inter-national Replicability**
Grid to be used	Original demo grid model	Original demo grid model	RN1-2	RN2 -3	RN1-2-3 (with different regulatory boundaries)

5 Conclusions and next steps

This deliverable builds on the contents published in D7.1 [2] and provides more details about the methodology for the SRA proposed by the Platone consortium. Scalability and replicability is needed to estimate the increase of social welfare that can be enabled by the large scale deployment of the Platone solutions. The main concepts of the Platone SRA methodology have been explained. The proposed approach is in line with the guidelines for scalability and replicability analysis proposed by the BRIDGE task forces. The SRA methodology has been developed taking into account the Platone UCs. The process of defining representative networks for baseline scenarios has started based on the data collection process carried out by means of the questionnaire reported in Annex A.

The next steps of WP7 will encompass:

Analysis of scalability in density. In this step, in the network model that describes the demo areas, WP7 team will perform:

- identification of the nodes in the network where to install new Distributed Energy Sources that will be installed to meet the target set by the National Climate and Energy Plans;
- estimation of the foreseen evolution of loads based on historical trends;
- estimation of the evolution of EV and charging infrastructure;
- definition of load and generation profiles;
- network simulations considering different level of grid flexibility.

Analysis of scalability in size. In this step, in the network model that describes a larger area that has similar characteristics with respect to the demo area, WP7 team will perform:

- identification of the nodes in the network where to install new Distributed Energy Sources that will be installed to meet the target set by the National Climate and Energy Plans;
- estimation of the foreseen evolution of loads based on historical trends;
- estimation of the evolution of EV and charging infrastructure;
- definition of load and generation profiles;
- network simulations considering different level of grid flexibility.

Analysis of intra-national replicability. In this step, in the network model that describes a larger area that has different technical, economic and regulatory characteristics with respect to the demo area, WP7 team will perform:

- identification of the nodes in the network where to install new Distributed Energy Sources that will be installed to meet the target set by the National Climate and Energy Plans;
- estimation of the foreseen evolution of loads based on historical trends;
- estimation of the evolution of EV and charging infrastructure;
- definition of load and generation profiles;
- network simulations considering different sources of grid flexibility.

The above-mentioned actions correspond to the steps 4.2 of the BRIDGE methodology (see Figure 4).

6 List of Tables

7 List of Figures

8 List of References

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9 List of Abbreviations

Abbreviation	Term
ALF-C	Avacon Local Flex Controller
ASM	Ancillary Service Market
BaU	Business as Usual
BESS	Battery Energy Storage System
BRP	Balance Responsible Party
CAPEX	Capital Expenditure
CEC	Citizen Energy Community
CBA	Cost Benefit Analysis
CBES	Community Battery Energy Storage
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DG	Distributed Generation
DSO	Distributed System Operator
DSOTP	DSO Technical Platform
EMS	Energy Management System
EV	Electric Vehicle
FR	Flexible Resource
LEC	Local Energy Community
LV	Low Voltage
HV	High Voltage
JRC	Joint Research Centre
KPI	Key Performance Indicator
MSD	Mercato dei Servizi di Dispacciamento, Dispatching Services Market
MV	Medium Voltage
OPEX	Operational Expenditure
PoD	Point of Delivery
PMU	Phasor Measurement Unit
PV	Photovoltaic
RES	Renewable Energy Source
SCADA	Supervisory Control and Data Acquisition
SCD	Shared Customer Database
SGAM	Smart Grid Architecture Model
SRA	Scalability and Replicability Analysis
TSO	Transmission System Operator
UC	Use Case

Annex A

A.1 Identification

Company/Association	
Country	
Comments	

A.2 General information (Distribution Business - Basic Figures, Structure & Ownership)

A.2.1 Basic data

Legal Name of the DSO	
Country	
Regions and/or municipalities covered	
Distributed Annual Energy (on average) (GWh)	
Area of Distribution Activity (approximately) (km^2)	

A.2.2 Distribution business

Ownership of the DSO	
A. Private	
B Public state owned	
C Public owned by municipality	
D Other	
Is the DSO part of a bigger group operating in the power industry?	
If yes, type of unbundling with respect to the parent company:	
Business in the power sector the company (or their group) operate besides distribution (e.g. generation, transmission, supply/retail)	

A.2.3 Customers

Total Number of Customers connected	
Number of LV (< 1 kV) Customers	
Number of MV (1- 36 kV) Customers	
Number of HV (> 36 kV) Customers	

A.2.4 Circuit length per voltage level (km)

Total	
LV (< 1 kV)	
of that Overhead	
of that Underground	
MV (1-36 kV)	
of that Overhead	
of that Underground	
HV (> 36 kV)	
of that Overhead	
of that Underground	

A.2.5 Technical data

Number of HV/MV Substations	
Total installed capacity of HV/MV Substations (MVA)	
Number of MV/LV Secondary Substations	
Total installed capacity of MV/LV Secondary Substations (MVA)	
Total installed capacity of generation connected (MW)	
Installed capacity of generation connected to LV networks (MW)	
Number of electric vehicle public charging points	

A.2.6 Reliability

Reliability indexes (annual value of each reliability index for long unplanned interruptions)

Reliability index	Value	LV	MV	HV
SAIDI (min./customer)				
SAIFI (int./customer)				

Please fill in the following table in case your reliability indexes are not the proposed ones.

No.	Reliability Index	Unit	Value	LV	MV	HV

1						
2						
3						
4						
5						
…						

A.2.7 Comments

Please mention here any comments or suggestions you may have.

A.3 Additional data

A.3.1 Network structure

A.3.1.1 Network Data

Typical transformation capacity of HV/MV Substations (MVA)	
Typical transformation capacity of the MV/LV Secondary Substations in urban areas (kVA)	
Typical transformation capacity of the MV/LV Secondary Substations in rural areas (kVA)	
Average number of MV/LV Secondary substations per feeder in urban areas	
Average number of MV/LV Secondary substations per feeder in rural areas	
Average length per MV feeder in urban areas	
Average length per MV feeder in rural areas	
Number of TSO-DSO interconnection points	
Voltage levels of the distribution networks (kV)	
Typical number of voltage levels concatenated in distribution (for example 1 LV level, 1 MV levels and 1 HV level)	
Degree of automation in the MV network [Type of smart grid automation equipment and penetration (e.g. Circuit breaker, Tele-controlled circuit breaker, Switch (on-load), Tele-controlled switch, Fault detector, Directional fault detector, Recloser, …)]	

	Substations equipped with Monitoring/Automation Equipment	Degree of penetration (low/medium/high) °°	Percentage of substations equipped with these equipment (%)
1			
2			
3			
4			
5			
…			

°° Low penetration is 0-5%, medium penetration is 5-20% and high penetration above 20%.

A.3.1.2 Distributed generation

Generation connected to distribution network (ONLY!)

Total Installed Capacity [MW]	Total Gross Electricity Generation [GWh]	Connected to LV (1kV) [%]	Connected to MV (1-36 kV) [%]	Connected to HV (>36kV) [%]
Photovoltaic				
Wind				
Biomass				
Waste				
Hydro				

A.3.2 Reliability

Are the reliability indexes measured per type of area?

If yes, in what areas? What are the reliability indexes (annual value of each reliability index per type of area, for long unplanned interruptions)?

	Value
Urban-SAIDI (min./cust.)	
Urban-SAIFI (int./cust.)	
Rural-SAIDI (min./cust.)	

Rural-SAIFI (int./cust.)	

Please fill in the following table in case your reliability indexes or area type are not the proposed ones.

	Area type	Reliability Index	Units	Value
Area 1				
Area 2				
Area 3				
Area 4				