GWP3- gD3.1

Methodology for the definition of scaling up and replication rules and cost-benefit analysis

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• Short Description

This deliverable provides an overview of the methodologies that will be applied to perform the major tasks of GWP3: scalability and replicability and the cost benefit analyses. These two complementary studies intend to draw general conclusions from the experiences in the 6 project demos.

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Executive summary

GWP3 intends to build on the experiences gathered from the six demonstrations carried out within the GRID4EU project and evaluate their added value for the European community under a common framework. In order to achieve this goal, two complementary studies will be carried out: scalability and replicability analysis (SRA) and cost-benefit analysis (CBA). One of the main barriers to achieve these goals is related to the fact that the application of these methodologies to the smart distribution grids world is not mature yet. Consequently, significant work is required to adapt existing approaches and/or fill-in the various existing gaps. This document, which should be considered as a draft version of the final deliverable, summarizes the work done so far in this regard.

It is shown that both studies complement each other, bringing relevant conclusions that might facilitate the future deployment of Smart Grids solutions. On the one hand, the SRA aims at evaluating how the outcomes of the proposed Smart Grids solutions would be affected or the obstacles that might be encountered when these are implemented at a larger scale or under different boundary conditions. These boundary conditions comprise technical, economic, regulatory and societal issues. As a result, a set of scaling-up and replication rules will be developed so as to identify the most favourable conditions for the implementation of certain solutions as well as potential barriers.

The goal of the CBA is to assess the economic value of a specific innovative Smart Grids solution. In this case, the results will be firmly based on actual demonstration and measured impacts, thus constituting a relevant contribution to a European wide audience. The costs and benefits brought about by smarter distribution grids are usually unevenly distributed across the stakeholders involved. Moreover, these benefits are not always economic in nature. Hence, it is necessary to incorporate the different existing viewpoints within the sector as well as considering the potential qualitative impacts that may affect the adoption of innovative solutions.

Future developments, which will be presented in the next version of the deliverable, will provide further details about how to apply this general methodology to each one of the demo projects, tailoring it specifically to their singularities.

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1 Introduction

1.1 Notations, abbreviations and acronyms

CAPEX	Capital Expenditures
CBA	Cost Benefit Analysis
DER	Distributed Energy Resources
DOW	Description of Work
DSO	Distribution System Operator
ENS	Energy Non-Supplied
EU	European Union
GWP	General Work Package
ICT	Information and Communication Technologies
JRC	Joint Research Centre
KPI	Key performance indicator
OPEX	Operational Expenditures
PC	Project Coordinator
SGAM	Smart Grid Architecture Model
SGCG	Smart Grid Coordination Group
SRA	Scalability and Replicability Analysis
TM	Technical Manager
WP	Work Package

Table 1: Acronyms

1.2 Scope and structure of the Document

The purpose of GWP3 is to bring together the Smart Grids solutions implemented in the different demonstration projects and evaluate their added value for the European context under a coherent framework. This goal is addressed from two complementary perspectives. On the one hand, the potential for scalability and replicability of the tested solutions will be analyzed. On the other hand, this WP will assess and compare the costs and benefits derived from these solutions. However, the application of these techniques to evaluate smart distribution grid implementation is still incipient. Therefore, the first step in GWP3 is to design the methodologies that will be followed in order to achieve the GWP3 aims, adapting existing methodologies when possible.

The present document provides an overview of the methodologies that have been designed to fulfil the aforementioned objectives. Future developments will provide further details about how to apply this general methodology to each one of the project use cases of the different demos, tailoring it specifically to their singularities.

The document is structured as follows. After this brief introduction, section 2 provides an overview of the main objectives of GWP3 as well as a clarification on the complementarities and interactions between the scalability and replicability analysis (SRA) and the cost-benefit analysis (CBA). Section 3 is devoted to the description of the methodology developed to perform the SRA. The subsequent subsections explain the general methodology, the technical and economic analysis which constitutes the core of the SRA, the kind of boundary conditions considered and the expected outcomes. Section 4 describes the rationale, the goals and the methodology proposed for the cost benefit analysis (CBA) in the framework of GRID4EU project. Finally, section 5 will draw the main conclusions of this document.

2 Overview and objectives of GWP3

The main goal of GWP3 is to evaluate under a common framework the solutions and functionalities that are demonstrated in the project in order to draw conclusions that can be useful for decision makers regarding the potential future large-scale deployment of smarter distribution grids. This problem is tackled from two complementary perspectives: a SRA and a CBA. The remainder of this section will introduce the most important concepts related to these two analyses and describe how both studies interact and complement each other.

2.1 Scalability and replicability analysis - SRA

The GRID4EU project comprises six demonstrators that will test different Smart Grids solutions on real distribution networks at different locations. The results obtained will provide useful information on the impact of the implemented Smart Grids solutions, based on the evaluation of the Key Performance Indicators (KPIs) for different real-life conditions. However, these demonstrators will be conditioned by the technical, regulatory, environmental and social context of each location. Therefore, the impacts of the different tested smart solutions observed in the demonstrators are usually not directly applicable for different contexts and implementations. Therefore, a thorough specific analysis must be performed to understand the effects of implementing similar solutions at a larger scale or under different contexts that may be found across Europe. This is the so-called scalability and replicability analysis or SRA.

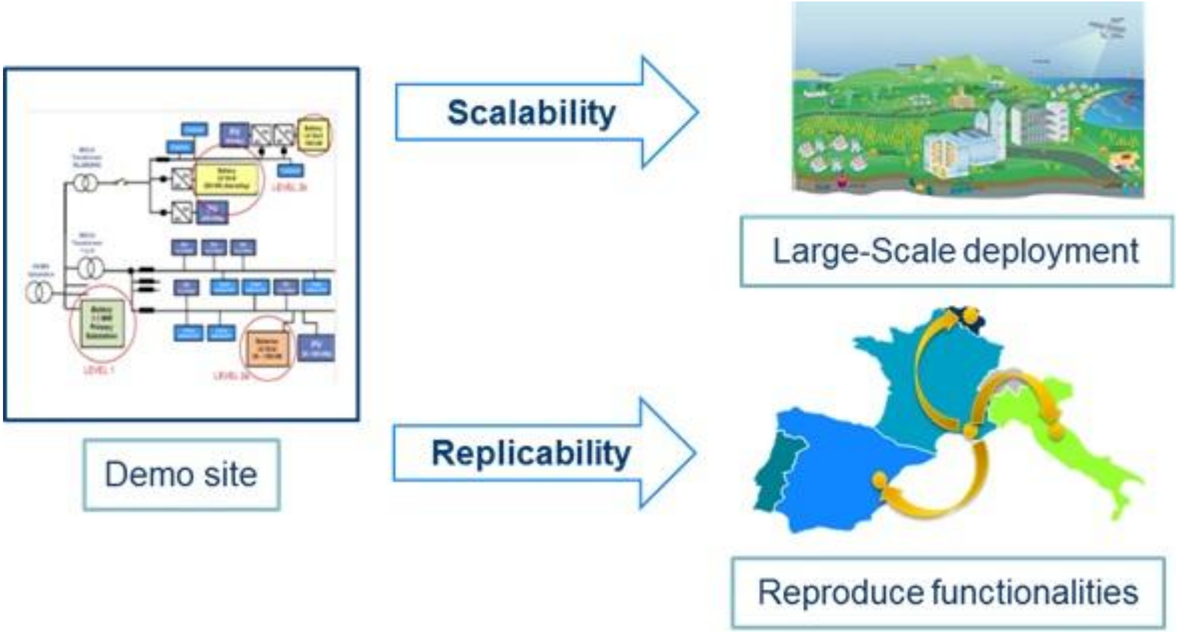

Figure 1: The vision of GWP3: Scaling-up and replicability

The methodology that will be followed to carry out the SRA will be described in section 3. Nonetheless, it is firstly needed to clarify and describe the major concepts related to scalability and replicability for a correct design and understanding of the methodology. Figure 1 illustrates the vision of GWP3, with the processes of scaling-up and replication and their scope. Thus, the concepts of scalability and replicability may be defined as follows:

Scalability: the ability of a system, network or process to increase its size/scope/range in order to adequately meet a growth in demand;
Replicability: the ability of a system, network or process to be duplicated in another location or time.

The demonstrators of the GRID4EU project will involve real-life testing within the technical, regulatory, environmental and social context of each location. This set of specific local conditions is called "**boundary conditions**". These boundary conditions directly affect the KPIs observed for each use case. Therefore, they have to be adequately characterized so as to evaluate their influence on the scalability and replicability potential of the different solutions.

Depending on what boundary conditions are modified, one may distinguish several dimensions both in terms of scalability and replicability. In this study, the scalability of the results gathered from the demos will be analysed from two perspectives. Firstly, how to infer results and extract conclusions at a larger scale within the demonstrator region where the same boundary conditions prevail will be assessed. This is known as **scalability in density**, which would yield a set of scaling-up rules and scaling factors in terms of performance for varying values of one or more controllable parameters.

> *Example:*
> *A certain KPI is measured in a demonstrator for a use case where results are observed for a particular Smart Grids solution (e.g. demand response) involving one hundred customers.*
> *The analysis of scalability in density would address questions like: How could results be affected if the same use case were to involve one thousand clients served in the same area by the same DSO (scaling up factors, corrective factors for scaling up barriers, etc)? What results and values for the KPIs would be expected?*

On the other hand, scalability can be understood as evaluating the effects of implementing a certain use case in a larger area that may involve different types of networks, but sharing the same or very similar boundary conditions in terms of regulatory framework, DG connection rules, stakeholders' perspective, etc. This will be referred to as **scaling-up in term of size**.

> *Example:*
> *A demand response solution has been tested in a sub-urban area with 1000 consumers whose effects have been measured through a set of KPIs such as deferred investment or energy losses.*
> *The scalability analysis in terms of size will evaluate the effects of implementing this solution in a larger region including millions of consumers and covering different types of distribution areas within the same region/country and determine the most advisable degree of implementation of the solution considering the weight of the different types of*

distribution areas within the whole region/country. This will answer questions such as: Is a large-scale deployment advisable or, on the contrary, the solution should be implemented only in certain location that fulfils a set of conditions?

On the other hand, replicability will be studied in order to evaluate how the different boundary conditions affect the results and conclusions obtained from the demos so that they can be applied to other regions. For this purpose, the "domain of validity" of the demonstrator's results must be defined, that is, the range or spread around the boundary conditions at the location of the demonstrator which ensures the validity of replication. Similarly to the case of scalability, two dimensions will be explored. The first stage consists in evaluating the replicability of a certain solution within the same country (similar boundary condition in term of regulation, stakeholders, voltage levels, etc) for different types of distribution areas (different network configuration, load concentration, reliability levels, etc.). Then, a similar process will be followed by considering as well the distribution network characteristics in a different country, i.e. under different boundary conditions. These are the **intranational** and **international** replicability analyses respectively.

Example:
A Smart Grids functionality has been tested in a sub-urban region in country A, resulting in some specific KPI values related to reliability improvements. An intranational replicability analysis is carried out to determine how results would be affected if the same DSO (e.g. subject to the same regulatory incentives to improve reliability) applied the same solution in a urban area in country A.
On the other hand, the international replicability analysis would tackle the question as to what would happen if the same solution were applied in a sub-urban region in country B (different network configuration, load density, regulatory and customers' environments, etc.). How would the different boundary conditions in this country affect results and to what extent (replication barriers, validity domain)?

Scalability and replicability will be studied under the main focus of regulatory, technical, economic and acceptance related barriers and conditions[1]. Furthermore, scaling-up and replication will be analysed for each demonstrator and relevant use case.

2.2 Cost benefit analysis - CBA

The objective of any cost-benefit analysis is to assess the economic viability and sustainability of a project by comparing the costs and the expected benefits within a certain time frame, typically related to the expected useful life of the project.

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[1] The requirements for scalability and replicability related to the characteristics of the technologies involved, such as modularity, standardization, appropriate design and equipment availability are out of scope of the GRID4EU project. Further details will be provided in section 3.1.

CBA is an important decision support tool to evaluate the worthiness of innovative Smart Grids solutions in view of an extended roll-out. As CBAs for development projects are usually largely based on estimated values of expected benefits and costs, the outcomes of GRID4EU demonstration projects can contribute to improve this benefits evaluation giving to the estimation a solid foundation, based on measured impacts. In addition, the realization of demonstration projects gives practical indications about all the cost items that have to be taken into account in the CBA.

Expected benefits from Smart Grids projects typically affect a wide range of stakeholders (e.g.: producers, consumers, distributors, aggregators, market players, etc.) and also include higher level and more general interests (e.g. environment, society, etc.). Therefore, CBA applied to this class of projects requires taking into account different point of views in order to evaluate global benefits and understand cost and benefits allocation among stakeholders. Two separate benefits and costs assessments should be considered:

- an overall economic evaluation including benefits and costs for all the involved stakeholders
- an economic/financial sustainability analysis taking into account benefits and costs regarding only the investor implementing the project (i.e. DSO) which aims at evaluating whether a public support to the investment is needed.

As technical limitations may prevent monetization of all the relevant impacts of a project as costs and benefits, a qualitative impact analysis is also recommended to evaluate possible non-monetary benefits.
Moreover the contribution of the project to different policy goals might be of concern and addressed within the qualitative impact analysis.

As it will be discussed in section 4, CBA could be done with several scopes, i.e. either at demo level considering current costs and the measured benefits only, or at a larger scale by scaling up the expected outcomes and evaluating the changing of costs due to time and scaling up. The main interest certainly concerns CBA outcome considering wide scale deployments, but the up-scaled values of costs and benefits may be affected by higher estimation uncertainties, (due to, for example, difficulties in estimating the development of prices over time and economy of scale effects).

2.3 Interaction and complementarities of SRA and CBA

The previous sections have shown that SRA and CBA pursue different objectives. The major result of a CBA would consist in a final figure determining the economic viability/profitability of a specific Smart Grid solution backed by quantitative studies on the associated costs and benefits. An evaluation of additional potential qualitative benefits is performed too. On the other hand, the main goal of scalability and replicability analyses is to determine as precisely as possible what is to be expected when that functionality is implemented at a larger scale or in a different context or location. Thus, the outcomes would consist in the identification and characterization of the key parameters and conditions that would determine the success of replicating or scaling-up the functionalities demonstrated. Hereinafter, these would be referred to as scaling-up and replication rules.

Both analyses intend to provide general conclusions that can be valuable beyond the scope of the demonstrations themselves. This is done by addressing both relevant and complementary questions. However, CBA and SRA will not be carried out fully independently. In order to achieve the WP goals, some interactions between both approaches have been identified so as to exploit them. In this regard, it is foreseen that some of the results of the SRA will be used as an input to the CBA. More specifically, SRA results will contribute to the quantification of certain benefits as well as the sharing of costs and benefits among the stakeholders affected. Note that implementation costs and their potential evolution will not be addressed within the SRA but within CBA.

As it will be shown in section 3, the SRA incorporates technical, economical and regulatory issues. Some of the indicators needed to quantify and monetize the benefits for the CBA, particularly those related to the impact on the distribution grids, will be quantified by the technical analysis. In fact, the economical SRA may even provide support and useful results regarding benefit monetization. Lastly, the analysis of the different regulatory frameworks included in the SRA can also contribute to the evaluation of how to quantify and share these benefits and costs among stakeholders in the CBA. In order to better clarify the interactions between the CBA and SRA, an example is explained below:

Example: Use Case “Reliability improvement through secondary substation automation”

This use case would consist in the automation of secondary substations so that the network can be reconfigured automatically when a fault is detected in the MV grid. As a result, the time required to locate and isolate the faults as well as to reconfigure the grid and resupply part of the consumers interrupted can be reduced. The associated KPIs would be mainly related to the decrease in the values of the reliability indicators measuring the frequency and duration of interruptions (longer than 3 min.).

The **SRA** will quantify the values of the relevant reliability indicators and their evolution for different degrees of automation (0% for a scenario without automation and 100% for a scenario where all secondary substations are automated) – density scalability. Such an analysis would be reproduced for different types of distribution networks (urban, rural, etc.) – intranational replicability- and in different countries –international replicability. Note that the network in each country/area will present different configurations, which implies different initial levels of reliability (redundancy). In turn, this can affect the incremental benefit of automation, either because automation does not affect reliability significantly due to a poorly meshed grid or due to the fact that the level of network redundancy is so high that automation brings about scarce incremental benefits. The previous results together with information about the relative importance of each type of area in each one of the countries analysed would finally allow performing the scalability analysis in terms of size.

Furthermore, the information concerning regulation in each region will determine whether DSOs would receive any additional revenues from improving quality of service and how these DSO benefits can be quantified. Note that in case specific regulatory incentives are not in place, this would constitute a clear regulatory barrier for replicability.

On the other hand, the CBA would need to quantify the benefits for consumers or other stakeholders of this enhanced reliability. This could require, for example, an evaluation of the reduction in energy non-supplied (ENS) by means of the reliability indicators obtained by the SRA and an estimation of the value of ENS, which may vary across countries. Moreover, the regulatory boundary conditions previously evaluated will be used to determine how these benefits would be shared between the DSO (additional revenues) and end consumers (reduction in the costs of ENS). Lastly, the costs of automating the secondary substations will be estimated for the corresponding scope (demo level, country level, etc.).

2.4 Scope of SRA within the GRID4EU project: interaction with the GRID+ project

This section will clarify the scope of the SRA performed in the GRID4EU project and how this complements the work carried out in the GRID+ project. Moreover, the general methodology developed for these purposes will be described.

GRID4EU and GRID+ are two EU-funded projects that, among other things, study the scalability and replicability potential of Smart Grids solutions. However, both projects differ significantly in terms of goals and scope. The main differences between both project approaches and goals are summarised in Table 2.

	GRID+	GRID4EU
Main focus	On the intrinsic elements of projects	On the background & context in which the project is inserted (the so-called "boundary conditions")
Target group	Distribution & transmission projects (within EEGI)	Distribution projects only (within GRID4EU)
Aim	• Check whether a project has taken into account the basic elements that favor scalability and replicability → Indicate whether a project can be scaled up and/or replicated • Understand the reasons of possible NO answers → Identify common barriers for scaling up & replication	• Identify the specific boundary conditions of the 6 demos within GRID4EU: regulatory, economic and technical • Estimate the results of the 6 demos if their scope or location is changed
Expected results (format)	YES/NO answers (+ if NO, why answers)	Both qualitative (regulatory) and quantitative (technical/economic) answers

Table 2: GRID4EU and GRID+ complementarities and synergies

The GRID+ project focuses on the technological aspects that may affect scalability and replicability. The project will analyse how finished, ongoing and planned projects handle scalability and replicability in order to ensure that future Smart Grids projects consider the scalability and replicability potential when selecting technologies and solutions. Hence, the emphasis is placed on issues such modularity, standardization, equipment availability (prototypes or marketed products), etc. The kind of questions that could be answered includes: to what extent is it possible/easy to perform a large-scale deployment of the devices? Could equipment availability be a barrier? Does a lack of standardization prevent an appropriate implementation in a different context?

On the contrary, GRID4EU evaluates what would be the result if a demo solution (use case) is implemented somewhere else or at a different scale, regardless of the technologies involved. In this view, the SRA aims to identify economic, technical and regulatory barriers to scalability and replicability specific to each of the relevant use cases implemented by the demos. The results could be used, for instance, to identify the functionalities that are worth replicating/scaling-up, the most suitable regions for the implementation of specific Smart Grids solutions, regulatory amendments required to facilitate the transition towards smarter distribution grids or the need to implement targeted campaigns aimed at shifting the perceptions of different stakeholders.

This decision has been made not only to differentiate the scope of both projects, but also to permit drawing more general conclusions. Thus, it will be possible to study the outcomes of a certain solution despite the fact that the same or similar solution could be implemented by using different technologies than those actually deployed in the demonstration projects. This is relevant because these technologies can be experimental (prototypes), selected due to historical reasons (a DSO having further experience with a certain communication technology) or partially confidential (proprietary protocols, etc.). The same example presented in section 2.3 will be discussed in order to illustrate both approaches.

Example: Use Case "Reliability improvement through secondary substation automation"

The **GRID+** project will analyze whether automation is based on local or central intelligence, what kind of communication technologies (PLC, GPRS, fibre optic) and protocols are used and whether these are modular and based on standards. Additionally, the study would include how the limitations of the ICTs selected may limit scalability, i.e. latency, congestions, amount of data to be stored, etc.

The **GRID4EU** project would alternatively focus on the effects of automating the substations. Assuming that any degree of automation can be technically attained, the reliability improvements obtained under different penetration of automated secondary substations will be quantified for different types of grids. This would show the areas and conditions under which the application is more suitable. For instance, the results could show that automating secondary substations in rural areas would yield scarce benefits due to the radiality of the network or that implementation should be prioritized in urban areas (meshed) where the initial levels of reliability are worse due to a lower redundancy or higher failure rates (e.g. older or partially overhead grids).

3 Methodology for SRA

The main objective of SRA is to analyse the scalability and replicability of the results observed in the demonstrators and assessed by means of the KPIs. For this purpose, a thorough analysis is needed to characterise the experiments carried out in each use case of the six demonstrators and all the parameters that may influence or have an impact on the results achieved with the different Smart Grids solutions tested. These parameters are the so called boundary conditions, which involve the context in which each demonstrator is framed, all the circumstances surrounding the particular case and the reaction of all the agents involved (for instance, these parameters would include geography and climate, network configuration and operation procedures, regulation and administrative incentives and requirements, demand patterns or consumer willingness to take an active participation). 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: (i) technical and economic analysis, (ii) regulatory framework and (iii) stakeholder acceptance. It is important to keep in mind that these aspects are interconnected and interdependent.

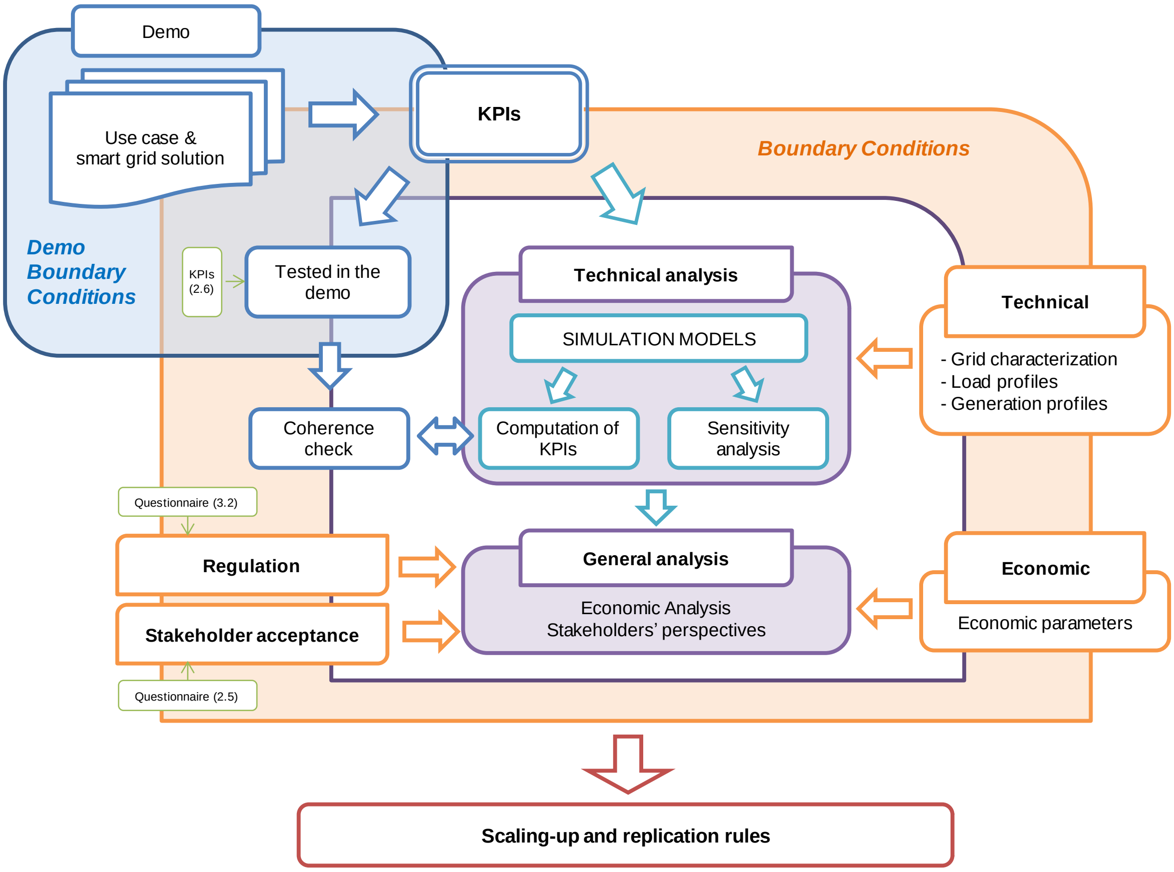

Figure 2: SRA general methodology diagram.

The diagram of Figure 2 represents the process that constitutes the work of SRA.

The demos consist of the implementation of different smart solutions in pursue of different benefits for real-life trial. For each demo, different use cases will be defined. In turn, each use case represents a certain set of functional requirements, i.e., a specific functionality. The use case will be performed by a system, i.e., using a set of technologies and/or solutions, and the testing will take place under a set of boundary conditions. The testing carried out in the demonstrator will result in actual impacts of the implemented system on the electric power system and effects on the actors involved.

The actual impact of the use case will be assessed according to a set of KPIs previously defined, both general KPIs common to several demos and KPIs specifically defined for each demo. The values of KPIs will be measured on site, and the data will be provided by the corresponding DSO by means of the clearing house. The values obtained for KPIs represent the actual impact of the use case tested under the conditions that prevail in the time and location of the demonstration.

First, the use case will be subject to technical analysis. The main objective is to learn how technical boundary conditions affect the effects of the use cases observed in the demonstrators, to study their scalability and replicability. The technical analysis is performed using simulation tools and models specifically adapted for that purpose. These tools are tuned and validated using the data provided by the demonstrators. Then, they are used to perform sensitivity analysis, to compute the expected values of the KPIs when the main parameters involved vary.

In order to enable such analysis, the technical boundary conditions of the demonstrator must be carefully studied. First, the grid must be characterised, considering the typical components, the topology, geographical conditions, operation schemes, reliability indices, etc. Additionally, generation and demand must be also characterised, considering their profiles, variability, peak values, etc. The information on the technical boundary conditions are gathered by means of a questionnaire addressed to the DSOs which will be thus requested to share their knowledge on the distribution system in the location of the demonstrator.

Similarly, an economic analysis will be performed to assess the effect of economic boundary conditions. It is important to perform this analysis under the perspective of the different stakeholders involved. Their behaviour may influence the results obtained and measured by the KPIs, such as for instance, whether users or suppliers engage in active demand response. Therefore, the acceptance of the stakeholders for the tested use case must be studied. For this purpose, GWP2 will provide the data on stakeholder acceptance gathered by means of questionnaires addressed at different stakeholders: DSOs, suppliers, consumer associations, regulators, producers and manufacturers, as well as from the opinions expressed by stakeholders in other dissemination activities carried out throughout the GRID4EU project, such as dissemination workshops.

Additionally, the factors that could have an impact on stakeholder acceptance must be studied, including the interaction among the different groups of stakeholder and, naturally, regulation. The regulatory framework sets the rules for the different actors and conditions their behaviour. The regulatory framework of each demonstrator is studied by means of a questionnaire aimed at DSOs.

Moreover, although technological aspects that affect scalability and replicability are out of scope of the GRID4EU project, they will be considered as a qualitative input coming from the GRID+ project.

The following subsections will further describe the main aspects and steps involved in the methodology, with the aid of illustrative examples.

3.1 Technical and economic analysis

The use cases defined for the demonstrators of the GRID4EU project will be subject to a technical and economic analysis in order to understand the impacts of the use cases. Both the technical and the economic impacts of the solution(s) implemented in each use case will be expressed as a set of pre-defined KPIs. Additional indicators resulting from the simulations may be used if deemed necessary. Thus, the actual impacts of the use case experienced in real-life testing carried out within the demonstrators will provide the measured values of the KPIs. The values observed will be taken as reference and sensitivity analysis of the KPIs will be carried out for the main parameters that constitute the boundary conditions.

> *Example:*
> *Within the use case “Reduce power demand”, the technical impact of the implemented solutions on energy losses could be measured through the KPI “Energy losses”, while, the KPI “Active participation” could be used to measure the impact on consumers, and the economic impact could be measured by a KPI such as “Investment deferral”.*

The technical and economic analysis, which constitutes the core of the SRA, will be performed using software tools specifically designed to enable simulation of the use cases, modelling the effects of the solutions implemented on the distribution grid and allowing computation of the KPIs values.

> *Example:*
> *In order to compute energy losses, a power flow tool is used accounting for the existing load flexibility.*
> *Investment deferral achieved through demand response can be computed using a network planning model*.

As mentioned above, simulation tools will be adapted for the use case(s) and KPI(s). These software tools must be adjusted to represent the actual conditions of the real-life use cases in the demonstrators. In order for the models to accurately reflect the use cases, technical and economic data will be required as an input in order to adjust the technical and economic parameters within these models.

The required technical data would involve the technical characterisation of the actual distribution system in the location of the demonstrator, namely network, generation and demand. For the purpose of network characterisation, data would include type of area (urban/rural...), reliability levels, network length, network configuration, installed devices for protection, voltage control, etc., operational limits of network assets, operation schemes (fault management, voltage control, reconfiguration, etc.). In the case of characterisation of load, distributed generation and other distributed resources, parameters would include its size, location, generation or demand profile, peak generation or demand values, etc.

Meanwhile, economic parameters will be used to identify the impact on each agent of the use case implementation or to evaluate potential economic barriers. These parameters comprise electricity prices, tariffs paid by end-consumers, incentives and subsidies for DER owners; remuneration of DSOs, etc.

> *Example:*
> *The value of a reduction in energy losses could depend on the electricity prices in each country. For example, this value would be much higher in a context where the generation system is essentially coal-based than in one mostly based on renewable.*

> *On the other hand, the design of the incentives to reduce losses will determine the value of the use case impact for the DSO.*

Then, sensitivity analysis will be performed to study the effect of variations in the main parameters. For this purpose, different values will be given to the input parameters and the new values of KPIs will be computed with the simulation tools.

> *Example:*
> *Power flows will be run for different degrees of demand response, i.e. varying the number of consumers enrolled or the flexibility of each consumer.*

It should be considered that the different stakeholders involved (DSOs; network users, both consumers and DER owners; manufacturers; regulators; etc.) will perceive different costs and benefits, depending on the cost and benefit allocation established by regulation and market rules. Therefore, the economic analysis will be performed, whenever possible, both under a general perspective of benefits for the system and under the perspective of the different stakeholders involved. The general analysis will consider the system as a whole, to assess whether use cases are beneficial, i.e. whether they make economic sense.

> *Example:*
> *The reduction of energy losses involves an economic benefit because less energy must be produced, thus reducing generation costs.*

On the other hand, the economic analysis considering the stakeholders' perspectives determines how each agent is affected.

> *Example:*
> *Suppliers will perceive a direct benefit from loss reduction, since they will have to buy less energy to supply the same demand. This benefit may be or may not be passed through to consumers, since their consumption will remain the same, and tariffs charged by suppliers are not totally determined by regulation.*
>
> *From the viewpoint of DSOs, if the regulatory scheme in place provided a pass-through to consumers of the cost of energy losses with no penalties or terms linked to losses, DSOs would have no incentive to reduce them.*

It is noteworthy that the viewpoint of network users (consumers and owners of distributed resources) and DSOs will be unavoidably linked to regulation, since they set the remuneration of DSOs and tariffs to pay by consumers. The regulatory framework is part of the so called boundary conditions, and will be analysed in detailed, as will be explained in the next section.

3.2 Boundary conditions

As already explained, the KPIs observed in the demonstrators correspond to the specific boundary conditions of the demonstrator. This it is necessary to characterize these and evaluate their influence of scalability and replicability. The boundary conditions considered, besides technical and economic issues, the regulatory framework and the viewpoint of the different stakeholders. Additionally, technological issues will be incorporated into the analysis, as an input from the GRID+ project. Technical and economic boundary conditions have been explained in the previous section. Hence, this section is devoted to the description of the issues related to regulation and stakeholder acceptance.

Regulation

Regulation is a key element within the activities related to the electricity sector. Regulation sets the framework for the activities of not only transmission and distribution, but also generation and supply, conditioning how the different agents involved (investors, consumers, etc) act and interact among themselves. Regulation provides the methodologies and formulae to compute allowed revenues for distribution companies, and distribution companies are responsible for investment decisions on the networks. Therefore, regulation may hinder or promote the implementation of different Smart Grids solutions, and regulatory decisions can affect the resulting impacts of the use cases.

> *Example:*
> *Considering the use case of power demand reduction, regulation will have an impact on the effects (KPI values) of the use case. For instance, regulation may incentivise the active participation of demand by implementing different time-of-use tariffs and penalising peak demand. Depending on how aggressive these tariffs are, more consumers will engage in power demand reduction, so that higher values of the KPI “active participation” will be obtained for the use case. Additionally, regulation may condition the solutions to adopt in order to achieve the objective of power demand reduction. For instance, if regulation promotes renewable energies with subsidies, fiscal advantages of favourable financing schemes, more consumers may choose to install solar panels in their houses in order to reduce their peak demand.*

A regulatory analysis will be performed for each demonstrator. The current regulatory framework will be considered, as well as future plans, observed trends and potential decisions. In order to learn about the regulation in the different countries where the demonstrations take place, a regulatory questionnaire has been developed in order to obtain a detailed description of the regulation in place.

The outcome of this analysis is twofold. On the one hand, barriers and drivers to the implementation of the Smart Grids solutions proposed by the demonstrators are identified. On the other hand, it will allow determining how regulatory changes or differences in the regulation could affect the observed results, and thus propose best-practices and regulatory recommendations to help overcome existing barriers.

Stakeholder acceptance

Different groups of stakeholders will have different interests and motivations, so that they will adopt different degrees of acceptance and engagement for the solutions and use cases implemented. The acceptance of stakeholders of the solutions implemented for the use case will affect the resulting KPIs, and must be therefore carefully studied in order to determine the scalability and replicability of the results observed in the use cases of the demonstrators.

> *Example:*
> *If consumers are not well informed about energy issues, are very averse to changing their habits or have little interest for demand response programs, the use case of power demand reduction will result in much lower active participation and a lower peak demand reduction will be achieved.*

Stakeholder acceptance will be monitored through an on-line questionnaire[2]. As additional input data, the stakeholders' opinions expressed in dissemination activities will be used. The analysis of stakeholder acceptance will help identify potential barriers, and recommendations will be made on how to overcome this problem.

3.3 Scaling up and replication rules

The main outcome of the SRA is a set of so-called scaling-up and replication rules presented in subsequent deliverables. This section will provide further details about what kind of rules can be inferred from the SRA results.

Scaling-up

The analysis of scalability aims at answering the question "what to expect if the use case were to be implemented at a larger scale in the same region?" 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 shown in Figure 3.

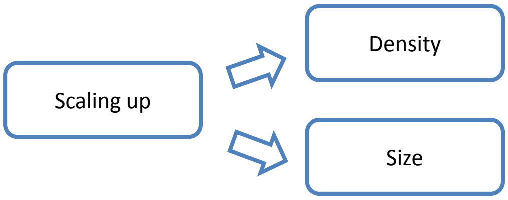

Figure 3: Dimensions of scaling-up.

On the one hand, scaling up may be studied for a certain network to consider density aspects. These density aspects include higher penetration degree of distributed generation in the

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[2] The questionnaire has been developed within task GWP2.5. It may be found at: http://www.grid4eu.eu/dissemination/smart-grids-stakeholder-questionnaire.aspx

network, higher degree of flexibility of consumers, higher degree of network automation, etc. On the other hand, scaling up may also be applied at a larger scale involving different types of areas within a region or country.

In order to analyse scalability, sensitivity to all aspects (technical, economic, regulatory and stakeholder related) involved in a larger-scale implementation must be studied. Technical aspects would 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 to analyse would mainly comprise the economic signals received by different agents. Similarly, the regulatory frameworks or the viewpoints of stakeholders can affect the scalability potential of the Smart Grids solutions implemented.

> *Example:*
> *If the use case of power demand reduction was implemented for a larger number of active consumers, the KPI of active participation would have much higher values. However, this would not necessarily be so if a larger area beyond the scope of a demonstration project (which may include economic compensations to end consumers) was to be considered.*

As a result of these sensitivity analyses, scaling factors will be defined, studying the relationship between changes in KPIs for scale variations. Furthermore, technical and economic implications and regulatory and stakeholder acceptance-related issues may impose barriers to the scaling-up of the results that must be identified, in order to define the domain of validity of scaling-up of the results, i.e. under which conditions scaling factor can be applied, and to provide recommendations to help overcome these barriers. Finally, a set of scalability rules will be defined for all relevant use cases.

Replication

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. According to the diagram presented in Figure 4, replication may be regarded within the country of the demonstrator or at an international level. In the first case, technical boundary conditions may differ, but the same economic and regulatory boundary conditions prevail and the different stakeholders have similar points of view. At an international level, similarities may be found, but 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.

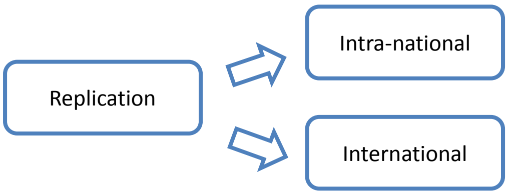

Figure 4: Dimensions of replication.

The effect of changes in technical and economic conditions that may vary from one location to another will be analysed, such as for instance how values of the KPIs change if a different network topology is assumed, to represent the effect of replicating a use case in a different type of area, e.g. to analyse power demand reduction in a rural network instead of in an urban area.

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. As a result, replication rules will be defined, to be applied within a defined domain of validity. Additionally the boundary conditions will introduce barriers or drivers. The identification of best-practices or more-friendly boundary conditions will be part of this work.

Process of scalability and replicability analysis

As already explained, the objective of scaling-up and replication analysis is to assess the expected outcome of implementing the use cases tested in the demonstrators under different conditions. For this purpose, sensitivity of the expected values of the KPIs and other relevant indicators to different parameters will be analysed. The process to be followed for this scaling-up and replication analysis is illustrated in Figure 5.

First, scaling-up will be analysed to determine the effect that would be obtained if the use case were implemented in the same network, but at a larger scale regarding density aspects. Aspects considered at this stage would include larger penetration of DG in the network, higher demand in terms of contracted power or new consumers, higher degree of demand response in terms of number of engaged consumers or higher shares of “shiftable” or “sheddable” load and higher amounts of storage connected to the network. For this purpose, different values will be given to the technical input parameters related to these aspects and the new values of relevant indicators will be computed with the simulation tools.

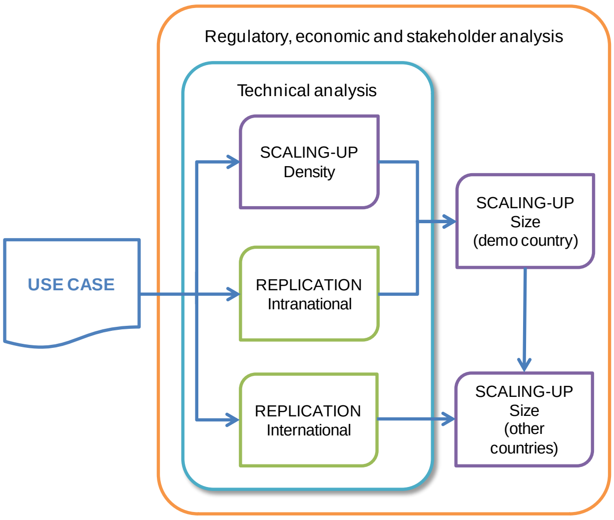

Figure 5: Process of scalability and replicability analysis.

Then, replicability to different networks is studied, computing KPIs for different types of representative networks (urban / sub-urban / rural / industrial / ...). In order to represent the typical characteristics of such networks, the technical parameters that will have to be re-adjusted need to include network configuration (architecture, length of feeders, typical values of cables and lines parameters such as resistance, reactance and thermal limits), reliability levels (protection schemes, typical values of reliability indices) and density of demand (number of consumers per feeder length, amount of power contracted, number of substations per km^2, installed capacity of MV/LV transformer substations), typical consumption profiles and characterisation of DG connected in the network (technologies, size, penetration degree). This analysis is focused on replication within the country, thus assuming the same boundary conditions of the demo regarding regulatory aspects and stakeholder acceptance.

On a third step, the scaling-up of the use case will be analysed, considering the implementation at a larger scale throughout the country to establish guidelines regarding its feasibility and advisability. The country will be characterised assuming the boundary conditions of the demo and assessing the share of areas of each type (urban / sub-urban / rural / ...).

Finally, replicability will be analysed to consider different boundary conditions to assess the potential effect of the use cases in other countries. As Figure 5 illustrates, this analysis would involve performing the previous stages for the corresponding boundary conditions of each country to consider.

4 Methodology for CBA

This section aims at describing the activity of Cost Benefit Analysis that will be carried out in the framework of the GRID4EU project. Section 4.1 highlights the importance of CBA for Smart Grids projects and the related challenges. Section 4.2 describes the rationale that justifies the need of including the CBA in the GRID4EU project. Section 4.3 briefly illustrates EPRI [1] and JRC [2] methodologies, recently developed specifically for CBA of Smart Grids implementations. Section 4.4 explains the CBA methodology choices adopted for GRID4EU analyses.

4.1 Cost-benefit analysis for Smart Grids projects

In order to ensure an efficient and worth roll out of the innovative Smart Grids technologies, to mitigate business risks and to encourage business investors it is necessary to use a general, standardized and fair methodological approach for the cost-benefit analysis of different Smart Grids projects allowing a consistent and uniform comparison of the results of various solutions. The method should possibly evaluate also non-monetary benefits through a qualitative impact analysis[3]. As the investments related to Smart Grids innovations are typically planned and realised by the local distributors, while the related benefits typically affect a wide range of stakeholders (e.g.: DER producers, consumers, aggregators, market players, etc.) and the environment, a traditional utility-centric cost-benefit approach doesn't fit the complexity of the benefits and costs evaluation for a Smart Grids project. The CBA procedure should first identify all the possible costs and benefits related to the analysed investment that spill over into the electricity system and the society at large and secondly should properly allocate them among all the involved stakeholders. This allocation strongly depends on technical, regulatory and other local conditions and requires a detailed analysis of the different boundary conditions that are locally implemented in each country.

The development of the necessary methodology poses significant challenges as the Smart Grids sector has a few additional peculiarities different from other traditional contexts of investment analysis; specifically, Smart Grids projects

- involve a large number of technologies, programs and operational practices: a variety of technologies can all take part in achieving a single Smart Grids benefit while some elements can contribute to more than one benefit;
- impact on all the operational areas of the electricity value chain in an interlinked way (transfer of costs and benefits);
- require long-term vision and commitment to fully implement;
- assume active involvement of customers in using new technologies and software, the extent of which is still highly uncertain.

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[3] non monetary appraisal of non quantifiable impacts and externalities e.g.: social impacts, contribution to policy goals, etc

Moreover:

- it is difficult to quantify the uncertainties associated with the magnitude of benefit streams deriving from Smart Grids solutions. For example the uncertainties related to the expected value of a given benefit can be influenced by some factors like stakeholders acceptance, evolution of regulations etc. that cannot be totally foreseen when the CBA is performed;
- some potential metrics associated with Smart Grids investments present particularly difficult issues for accurate quantification (e.g. environmental impact, reliable levels of response);
- the rationale and assumptions made for some chosen parameters (e.g. electricity demand and electricity prices, discount rate,..) can greatly affect the outcome of the analysis;

variation among European DSOs in existing grid infrastructure (e.g. current communications and metering systems, network age and condition) or service area characteristics (e.g. customer geographic density and consumer end-use loads) – even within a single country – is so great that decision makers so far could not rely on existing studies from other regions or DSOs to justify Smart Grids investments.

4.2 Rationale of cost-benefit analysis in GRID4EU project

Demonstration projects allow measuring the impact on real networks of the implemented technologies and provide the opportunity to acquire real data to evaluate the expected benefits. Moreover cost items related to the deployment of the actual systems can be better identified, although the incurred amounts are usually not representative of a full-scale roll-out condition. These projects give therefore the opportunity to validate at a local scale possible methodological approaches to carry out CBA of Smart Grids initiatives. Since various different contexts are considered, adjustments and improvements of the proposed benefits assessment procedures are likely to be performed too.

The members of the GRID4EU consortium would like to contribute significantly to the development of a consistent methodology for CBA that might be used as a reference for future CBA analyses of Smart Grids projects that test innovative Smart Grids solutions. Therefore, the GRID4EU consortium decided to enlarge the scope of the scalability and replicability analyses that were initially foreseen in the description of work of the project and to include in the GWP3 some activities related to CBA for the solutions tested in the six demonstrators included in the project.

Since the merit assessment of Smart Grids programs has to be eventually carried out on the foreseen final deployment scenario, the cost-benefit analysis should be performed taking into account the scalability and replicability potential of the proposed innovations.

The scaling up and replication analysis made in the framework of GWP3 evaluate the feasibility of the large scale deployment on real networks of different countries of the Smart Grids solutions tested in the GRID4EU demonstration projects, considering the influence of technical, regulatory, environmental and social context of each location.

These results provide the basis to carry out the CBA of a scaled-up project, so as to assess its worthiness.

4.3 Brief review of the most relevant methodologies for CBA available in the existing literature

In the last years two comprehensive methodologies for costs and benefits analysis (CBA) of Smart Grids projects have been developed and are here presented and compared.

The first one was developed in 2010 by EPRI (Electric Power Research Institute) in the U.S.A [1], while the other has been recently proposed by the JRC (Joint Research Institute) for Europe [2]. The EPRI methodology for monetary CBA was specifically intended as a basis to evaluate Smart Grids demonstration projects. Prior to EPRI no structural and global approach to CBA for Smart Grids investments had been developed.

The methodology identifies a list of possible benefits achievable by means of Smart Grids implementations, establishes the logical sequence of steps to recognize the benefits obtainable within a given project implementing specific assets and technologies, and finally suggests formulas to calculate the monetary value of the benefits. In the EPRI framework, a “benefit” is an impact that has a value to a firm, a household or society in general and it is not simply a project’s performance or an intermediate outcome of the project. To clarify this concept the following examples are reported.

Example.

1. *Intermediate outcome: customer participation*
   Benefit: reduction in customers’ electricity bills
2. *Intermediate outcome: peak load reduction*
   Benefit: deferral of investments in generation and distribution capacities
3. *Intermediate outcome: greater use of renewable energy sources*
   Benefit: reduction in emission (CO2, pollutants) related to energy generation

The benefits considered by EPRI are derived from the physical impacts produced by the functions enabled by the installed devices and technologies. The impact assessment is carried out considering the specific way (mechanism) the Smart Grids exercises each function and the specific application in which assets are used. Physical impacts have to be measured and clearly quantified using a proper metric and then monetized. Impacts and benefits are evaluated with respect to a reference scenario that is the state of the system that would have occurred if the project had not been implemented.

Benefits identified by EPRI are ultimate benefits to individuals and organizations and are mostly non-overlapping. The methodology provides a framework for evaluating economic, environmental, reliability, safety and security benefits from the perspective of all the different stakeholders groups (basically: utilities, customers and society).

The logical steps foreseen by the EPRI/DOE methodologies for the identification of the benefits deriving from Smart Grids projects are illustrated in Figure 6, considering two case studies related to distribution automation and storage systems.

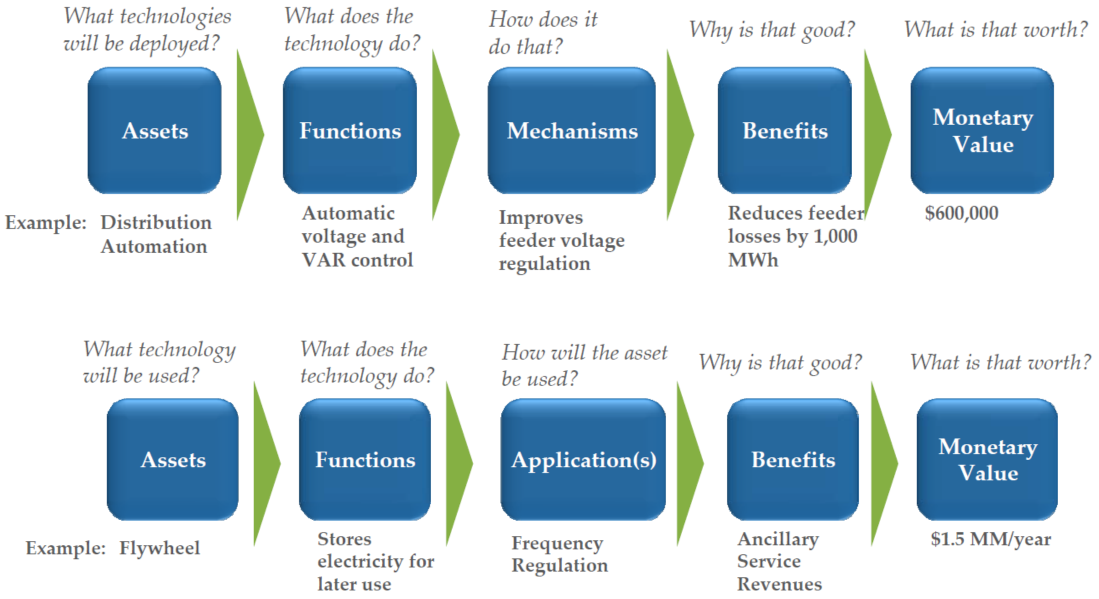


Figure 6: EPRI/DOE methodology suggested steps for the identification of project benefits (source: [4])

EPRI methodology has been applied by the Department Of Energy (DOE) to develop a software tool, the Smart Grid Computational Tool, in order to consistently compare and evaluate the economic benefits and costs of Smart Grids demonstration projects according to a standard procedure [3,4]. The intent of the projects considered was to verify the performance of Smart Grids technologies and systems, likely in restricted application areas. For this reason and since the tool is designed to be used by a number of different stakeholders, from the investor to the recipient of the initiative, the application presents characteristics that make it attractive for its ease of use but which appear reductive due to the rigid schematization adopted. Therefore this tool appears of little use for the cost-benefit analysis of the demos of the GRID4EU project.

The JRC methodology for the European context recognizes that what can be captured in monetary terms by means of a CBA constitutes only one aspect of a more comprehensive assessment of the impact of a Smart Grids project. The general approach proposed aims to integrate the economic analysis of the costs and benefits of all concerned parties with a qualitative assessment that considers the environmental and social impacts not quantified in monetary terms. With respect to the monetary appraisal, the JRC methodology is based on the EPRI one; however the EPRI proposal has been modified in order to take into account existing differences in the European context.

Figure 7 summarizes the steps foreseen in the JRC methodology for the CBA of Smart Grids projects. Further details about this approach are reported in Appendix I.5.1.

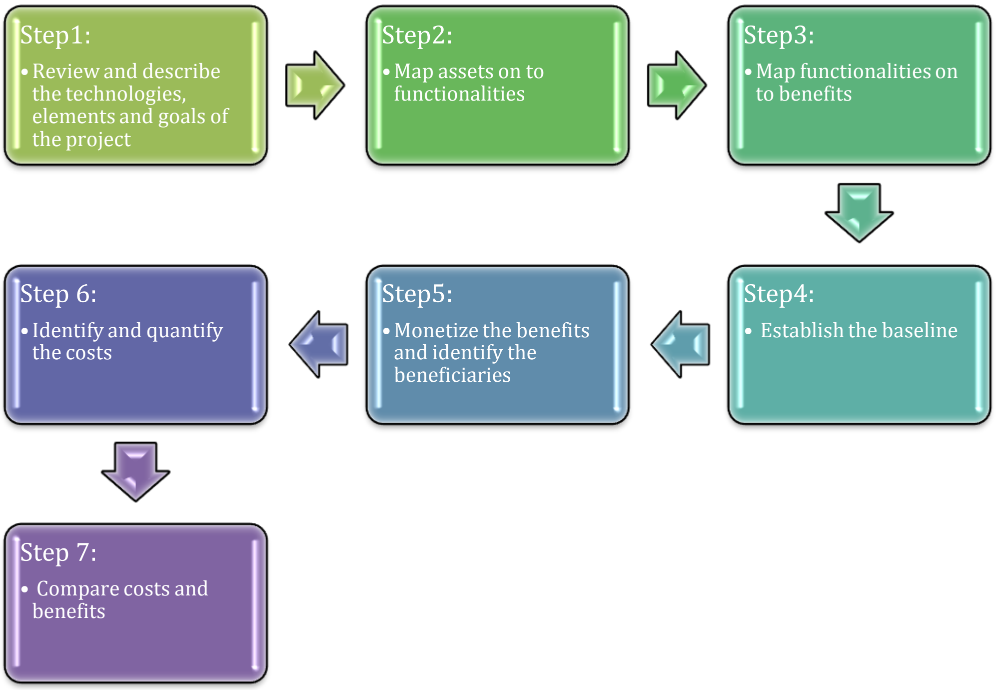


Figure 7: Planned Steps for Cost Benefit Analysis within the JRC methodology (source: [2]).

The logical steps leading to the identification of the monetary benefits are similar in both methodologies; however the JRC procedure presents a few significant differences. The most important ones are: the lack of a predefined list of possible grid assets (those relating to the project must be specified by the developer, who has subsequently to identify the correspondence with the functionalities) and the fact that there is no any suggestion about the correspondence between benefits and functionalities (this assessment too is entirely left to the person performing the CBA).

The CBA methodology proposed by the JRC is more adaptable than the EPRI one to the specific characteristics of individual projects and of various local conditions: it is therefore applicable to a wider range of projects, but requires an increased descriptive effort and, above all, implies a more subjective evaluation that eventually results in a lower comparability of the CBA results. Table 3 highlights the main differences between EPRI and JRC CBA approaches.

	EPRI- DOE	JRC
Assets	21 classes of possible assets are specified	No pre-defined list of possible assets. Project specific assets to be specified by the developer
Function-Functionality	13 Functions + 3 Enabled Energy Resource (Distributed Generation, Stationary Electricity Storage, Plug-in Electric Vehicles)	33 Functionalities (Based on EC Task Force for Smart Grids)
Benefits	22 Benefits	22 EPRI Benefits + "Detection of anomalies in Contracted Power"
Mechanisms	Each function is elaborated with 1 to 13 mechanisms	Not provided
Qualitative analysis	Assessment of the '7 principal characteristics' of the Smart Grids to which the project contribute	11 non-monetized benefits and 54 KPI (Based on EC Task Force for Smart Grids)
Source	EPRI, 2010, Methodological Approach for Estimating the BC of SG Demonstration Projects User Guide for US DOE Smart Grid Computational Tool (SGCT) (2011)	JRC, 2012, Guidelines for conducting a cost-benefit analysis of Smart Grids projects

Table 3 - Comparison between EPRI/DOE and JRC approaches to CBA.

4.4 The approach followed for the GRID4EU CBA

The GRID4EU consortium decided to analyse costs and benefits of the innovative Smart Grids solution of the six demonstrators included in the project applying the guidelines for CBA developed by JRC. Besides the obvious consideration that the JRC methodology represents the proposed European assessment framework for Smart Grids projects, this approach seems preferable as it offers greater flexibility in discovering project benefits and allows to take into account both monetary and qualitative benefits.

The application of the JRC guidelines to these demonstrators might contribute to refine the methodology, providing suggestions and recommendations that result from the analysis of real implementations.

Benefits identification (steps 1 to 3 in the JRC methodology) represents one of the most important phases of the CBA process. For this phase the main goals of each demonstrator, the new assets and technologies installed and the reference scenario will be considered. Outputs of the GWP2 and specific documentation from each demo will be reviewed; in particular, the Use Cases descriptions concerning each demo will be analysed as the functional requirements examination could help in goals and expected benefits identification.

It is worth pointing out that the objectives which create value and justify the implementation of the proposed technological improvements on the grid are considered as demonstrator goals. These goals are directly connected or may be also coincident with an expected benefit to be taken into account in the CBA. The Use Cases that have been defined for each demonstrator are essentially related to the implementation of functions, with objectives that might be not directly related to benefits (e.g. the objective of optimizing voltage profile in a voltage control use case is only an intermediate goal with respect to the higher level project objective to increase the grid hosting capacity). Afterwards we will always refer to the physical system(s) implementing these project objectives (and not to use cases) as the object(s) of the CBA.

According to JRC methodology, benefits identification requires relevant assets specification, assets to functionalities mapping and, finally, functionalities to benefits mapping (step 2 and 3). Suggested functionalities represent general capabilities of the Smart Grids, do not focus on specific technologies and seem sometimes too generic and not helping (e.g. Functionality No.2 “facilitate the use of the grid by users at all voltages/locations” resembles a benefit more than a functional attribute of the system). Therefore, while applying the methodology to specific demonstrators we have felt the need to introduce a few adjustments in the above mentioned procedure.

For benefits identification, we follow at first the EPRI conceptual approach (not constrained to the pre-defined lists of assets, functions and mechanisms indicated in EPRI methodology) believing that the technical functions implemented (which represent physical capabilities of the system) are more useful to identify the impacts and the benefits produced by the innovations. We eventually consider the JRC functionalities to check and refine the benefits assessment, placing the project in the Smart Grids context.

In GWP3 activities, the benefits identification process will therefore start with a detailed analysis of the key components and relevant functions related to the main declared goals of the project and will be subsequently carried out considering all the impacts, i.e. all the physical changes between the reference and the project scenario, produced by the implemented system. This process is schematically shown in Figure 8.

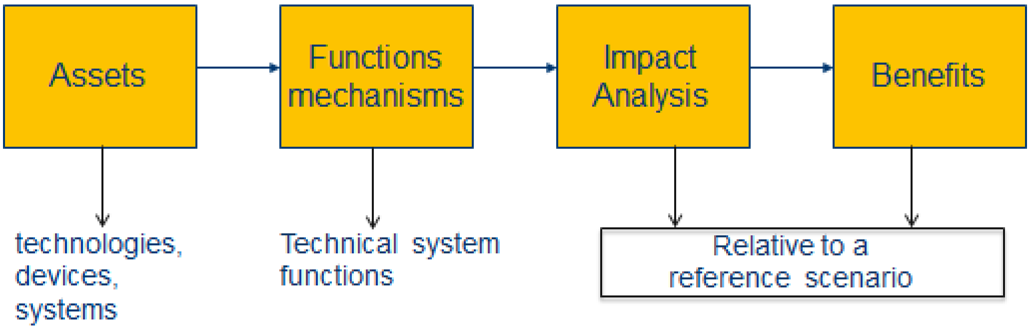


Figure 8: Benefits identification process

It is important to observe that, in order to correctly evaluate the impacts and assign the incurred cost of the system components, CBA requires to be applied to a specific implementation, clearly related to one or more goals. This means that impacts and benefits ascribed to a given implementation must be strictly due to the functionalities exercised by that implementation only. In demonstrators this requirement cannot always be satisfied because the same demonstrator can include distinct systems and different goals. In this case, before starting the benefits investigation for CBA, it is needed to select a relevant objective of the demonstrator and to consider all systems concurring to this goal.

The procedure of benefits identification will consider both direct (primary) impacts, which can be measured within the project area, and the indirect impacts produced outside the project area. The latter ones are generally not measured but just estimated from other measurable direct impacts.

Example:
direct impact: loss reduction
indirect impact: reduction of fuel use and emissions out on the power system

The output of the benefits identification process will likely include both the expected benefits (closely related to the main goals of the experimental implementation) and additional benefits.

Example:
in case of an AMI/Smart Metering implementation, benefits like 'reduced meter reading cost' and 'reduced electricity theft' are expected, while 'CO2 emission reduction' through consumption reduction and 'peak load shift' mechanisms is a possible additional benefit subject to the occurrence of participation and responsible behaviour of the electricity users.

It is worth noting that a Smart Grids implementation can produce a 'technical' benefit whose value might not have an economic appraisal in the related CBA. Possible reasons are, for example, factors like size and scope of the project, or when the Smart Grids implementation acts as an enabler for other technologies.

Example:
1) Influence of the implementation scale: a peak load reduction at local scale might not determine a deferral of investments in generation capacity; in fact the possibility to defer an investment in generation is enabled in this case only if the load peak reduction exceeds a given threshold.
2) The implementation of an Advanced Metering Infrastructure can enables active demand programs for direct load control and management at customer premises. Benefits like energy losses reduction and deferral of investment in generation and distribution capacity (related to peak load reduction by means of load shift and/or shedding) can be obtained (or increased with respect to customers voluntary actions) if smart appliances and special devices are installed at customer premises.

In case impacts can hardly be characterized in a quantitative way, a qualitative assessment of the related benefits will be attempted instead of a monetary appraisal.

As highlighted in the previous example, a few benefits (mainly those related to deferral of capacity investments) might not even be achieved because of the limited size of a demonstrator (unless a given threshold is exceeded) while other benefits just have a magnitude which is negligible although appreciable in principle. Besides this, implementation costs of a demonstrator are usually not representative of a wider deployment because:

- unit costs of innovative components are normally higher than those of a wider implementation (e.g. custom made components, small scale production, …);
- a large share of the development costs are linked to the demo and not linearly scaled up in the deployment phase;
- some technological choices (e.g. telecommunication solutions ...) may differ from the demo phase when the final roll-out is concerned.

These considerations raise the question about the proper deployment scale to be considered to perform CBA in the context of GWP3. GRID4EU demonstrators, in fact, are limited implementation at the local scale of innovative Smart Grids functions, aiming to test new technologies and grid control techniques in field, which afterwards might be deployed at larger scale in case of positive results. CBA is an important decision support tool to evaluate the worthiness of these initiatives in view of an extended roll-out.

The main interest to CBA outcome is certainly related to the wide scale deployment but it may be more difficult to obtain reliable results at this scale. Indeed uncertainties usually increase in evaluating both costs and benefits at a larger scale, also because of the several assumptions required to extrapolate locally acquired data.

The magnitudes of the main expected benefits and their relative importance are likely to be better evaluated at the demo scale relying on locally measured data.

Thus a useful CBA outcome might result from an assessment performed at the demo scale considering:

- **benefits derived from observed impacts and estimated data,**
- **properly estimated costs for the local implementation based on a deployment scenario at a wider scale. In this respect the demonstrational deployment is treated as if it were a portion of a larger final roll-out. The ending unit costs of the components can be evaluated according to different methods among which the "learning curve approach". The wide scale deployment strategy will be valued according to the results of the scalability analysis.**

The availability to disclose all the data required to perform CBA, including the possible sensible ones, will be discussed with each demo leader, after a preliminary analysis aimed to identify the benefits and the beneficiaries of the considered Smart Grids solution.

The initial CBA activity for demonstrators within GRID4EU will thus involve the following steps:

- identification of the system implementations (related to one or more goals of the demonstrator) that could be object of the CBA,
- the identification of all the possible quantifiable benefits that will derive from the deployment of the Smart Grids solution considered in the CBA,
- identification of non-monetary benefits and of the related KPI,
- allocation of the benefits and costs to the most relevant stakeholders.

This level of analysis will be performed on each demonstrator of the GRID4EU project.

The subsequent phases of CBA activity towards benefits monetization and comparison with costs is presently under discussion among the consortium partners and will be described in the next revision of this deliverable.

4.4.1 Interactions and exchanges with demonstrators for CBA

In this section the first foreseen interactions between GWP3 and demonstrators, finalized to CBA, are described. Indeed, the CBA analysis requires a close cooperation and information exchange between the CBA experts and the demo leaders in order to ensure the collection of all the data and information needed to evaluate all costs and benefits related to a defined Smart Grids implementation proposed in a demonstrator.

As starting point for a coherent application of CBA methodology to the analysis of GRID4EU demonstrators, the goals of the different demos and the description of the adopted technical solutions must be fully understood. For these reasons, in the framework of the CBA of the GRID4EU demonstrators, several GWP3 meetings will be organized with the different demo leaders.

The GWP3 leader will organize one initial meeting with each one of the six GRID4EU demonstrators. These meetings will aim at:

- reviewing the technologies, the components and the main demonstrator goals;
- agreeing with the demo leaders about which demonstrator goals should be analyzed in the CBA;
- sharing first ideas about the expected benefits;
- discussing about the baseline scenario to be considered for the CBA;
- gathering more detailed information about the stakeholder acceptance, the regulatory issues and other boundary conditions that might influence the CBA;
- exchanging reference contacts for specific questions: technical, regulatory, economical.

Each meeting will be prepared reviewing all the existing documentation that could be relevant for the analysis of the demo and preparing a list of possible questions, specific to the demonstrator that will be sent in advance to the demo leader. Table 4 presents, as example, the main arguments addressed by the questionnaire and that could be object of discussion during the first bilateral meetings between CBA experts and demo leaders.

QUESTION TYPES	NOTES
USE CASES DESCRIPTION	✓ Full understanding of the use cases describing the functions implemented in the demonstrator
TECHNICAL DESCRIPTION	✓ Assets installed for the Demo ✓ Upgrading of existing systems and devices VS new assets
REGULATORY CONTEXT	✓ Local regulation (for example on continuity of supply) ✓ Indexes and parameters considered in regulation (example: Statistic of service quality ✓ Incentives and penalty schemes
SETTING THE BASELINE	✓ Existing benchmark of specific Smart Grids solution ✓ What is the reference scenario to be considered as baseline for CBA of grid improvement through smart solutions ✓ Planning for network upgrades in Base As Usual Scenario

Table 4 – Examples of possible questions that could be discussed during ad hoc meetings with the demo leaders.

In more detail, the meetings between CBA experts and demo leaders will be structured according to the scheme illustrated in Figure 9.

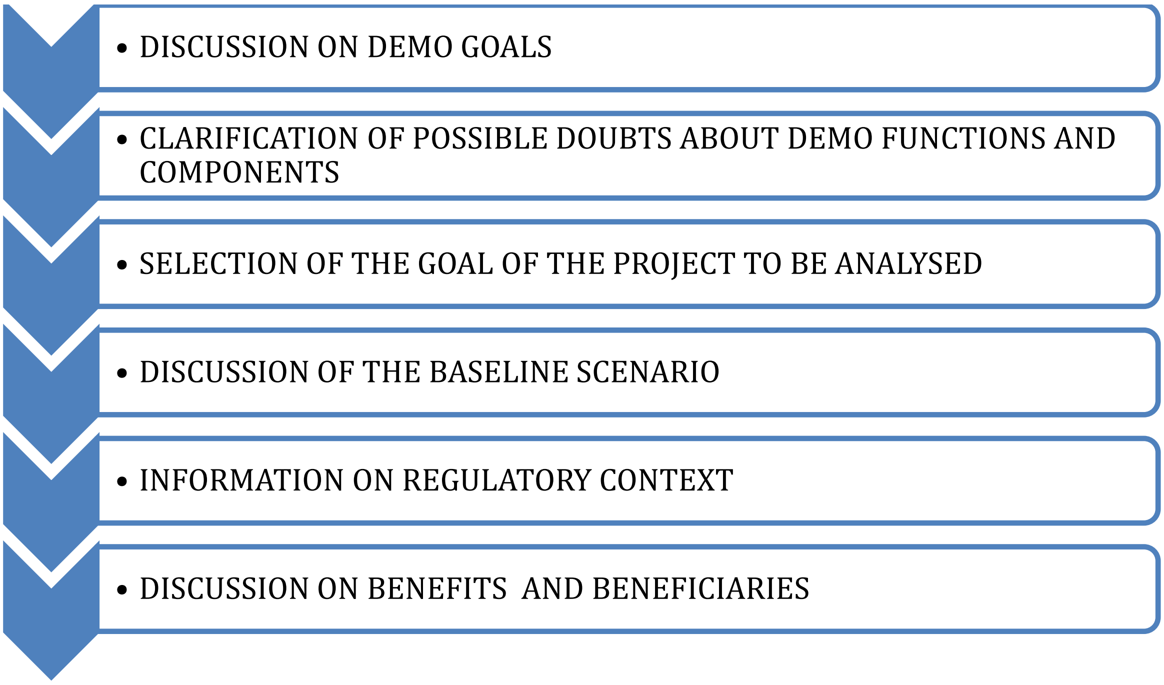


Figure 9: Scheme of first meeting with demos for CBA

DISCUSSION ON DEMO GOALS

CBA experts discuss with the demo leader about the demo objectives in order to verify whether hierarchy or dependencies among objectives exist or if independent goals are considered. CBA expert propose a preliminary analysis based on existing demo documentation. This step aims at ensuring a common understanding of the demonstrator goals for the successive selection of the object of the CBA.

Example.

1. *For DEMO4 two main objectives can be listed, namely ‘increasing of hosting capacity of MV network’ and ‘secure DERs connection to the grid’. The “voltage control” and “anti-islanding protection” use cases represent the implemented functions to achieve these goals. Both objectives can be considered parts of the overarching goal “to fulfil all DERs connection requests to MV grid”. In principle, each goal might be disjointly implemented; in this demonstrator most of the installed assets are shared by the two systems which implement the two distinct use cases.*
2. *DEMO3 presents three main goals (faster automatic MV grid recovery after a fault, automatic LV grid outage recognition, make customers Smart Grids active players) that can be considered as disjoint goals, realized by independent systems.*

CLARIFICATION OF POSSIBLE DOUBTS ABOUT FUNCTIONS AND COMPONENTS OF THE DEMONSTRATOR

CBA experts discuss with the demo leaders the outcome of the analysis of the relevant documentation (the use cases description and the technical description of the demo). This step aims at ensuring that CBA experts have a complete and correct understanding of the demo characteristics and architecture. The discussion will focus on technical aspects of the demonstrator: its functions (through use cases descriptions), implementation choices, new installed assets and their role in goal achievement, use details of the pre-existing systems in the demo and eventual improvements implemented, etc.

> *Example.*
> *In DEMO3 it has been clarified that the automatic grid recovery is realized using the existing MV breakers remote control system automating the execution for fault location and grid reconfiguration operational sequences.*

SELECTION OF THE GOAL OF THE DEMONSTRATOR TO BE ANALYSED

CBA experts and demo leaders identify the most significant goal of the demonstrator that will be addressed in the CBA. The selection process will take into account several factors like: the importance of the goal with respect to the objectives declared in the DOW, the contribution of the goal to the European energy targets, the availability of data, the relationship with the SRA. A demonstrator might include distinct systems related to different goals. It is important to apply the CBA to a specific implementation clearly related to a goal so as to correctly evaluate the impacts and assign the incurred cost of the system components too.

> *Example.*
> *DEMO3 includes the 'Automatic Grid Recovery' (AGR) system, which is an automation solution for service recovery after a fault on MV network, and an implementation of In Home Display (IHD) to check the 'Customer Engagement'. These are distinct and non-interactive systems with disjoint goals, thus each related implementation could be a well-defined object of a CBA. The 'customer engagement' represents an important European Smart Grids goal, nevertheless the selection of AGR for the CBA take advantage from availability of performance data of the new solution, availability of historical data for the baseline scenario, availability of SRA results which are pre-condition to carry out a worthiness evaluation of the large scale deployment.*

DISCUSSION OF THE BASELINE SCENARIO

CBA experts and demo leaders discuss about the assumptions that are needed to define the baseline scenario that will be used in the CBA.

> *Example.*
> *In case of the FDIR application considered in DEMO1, information related to the level of automation of the present fault recovery system as well as the description of the current procedures used to locate and isolate faults have to be acquired.*

INFORMATION ON REGULATORY CONTEXT

In this step the demo leader highlights regulatory aspects that can influence the CBA of the demo for the selected goal. The discussion includes also other boundary conditions that can be relevant for the CBA of the demo. This discussion supports the CBA experts in the definition of the related set of information needed for the CBA.

Example.

- *Knowledge of the values of the power quality supply reference indexes considered in the current regulations.*
- *Knowledge of regulations regarding DER connection requests.*

DISCUSSION ON BENEFITS AND BENEFICIARIES

During the meeting, a first brainstorming about the expected benefits and beneficiaries related to the proposed implementations is carried out. CBA experts and demo leaders agree on a preliminary list of benefits to be included in the CBA. This list usually includes both monetary and qualitative benefits. Beneficiaries identification requires regulatory and market context definition.

5 Conclusions

This document has presented the two main analyses carried out within the GWP3, i.e. SRA and CBA, highlighting the complementarities and interactions between both studies. It has been shown that some of the results from the SRA will be used as an input to the CBA. More specifically, the technical and economic analyses will contribute to the quantification of some of the benefits included in the CBA. Additionally, the regulatory analysis will help to characterize the sharing of costs and benefits among stakeholders.

Furthermore, a general description of the scope and the methodologies selected to perform SRA and CBA have been presented. It has been shown that the SRA within GRID4EU will focus on the effects on the distribution network of implementing the use cases tested by the demonstrators. Thus, technological aspects such as modularity, standardization or equipment availability will not be directly considered. In order to achieve this, four dimensions will be addressed: technical, economic, regulatory and stakeholders' perspectives.

The economic and, especially, the technical analyses constitute the core of SRA; whereas the regulatory and stakeholders analyses, together with inputs from the GRID+ project, will be incorporated in a qualitative way to characterize the boundary conditions that may act as barriers or drivers of the Smart Grids implementation. The main outcome will be a set of scaling up and replication rules which essentially determine the conditions (type of network, DG penetration, regulatory environment, etc.) under which it is more suitable to implement a certain Smart Grids solution.

On the other hand, the CBA methodology has been developed from the one originally proposed by the JRC. Nonetheless, some further developments were required to achieve a full applicability to a real case study.

Future deliverables will provide further details about how these methodologies are applied to each demonstrator and will show the results obtained.

References

1. EPRI (Electric Power Research Institute). Methodological Approach for estimating the Benefits and Costs of Smart Grids Demonstration Projects. Palo Alto, CA-USA : EPRI, 2010. 1020342.
2. European Commission-Joint Research Centre. Guidelines for conducting a cost-benefit analysis of Smart Grids projects. 2012. Report EUR 25246 EN.
3. User Guide for US DOE Smart Grid Computational Tool (SGCT) Version 2.0. 2011. http://ebookbrowse.com/us-doe-smart-grid-computational-tool-user-guide-version-2-0-pdf-d201096805.
4. U.S. Department of Energy. US DOE Computational Tools for Smart Grid and Energy Storage. 11-07-2011.

APPENDICES

5.1 The JRC approach

A “Cost and Benefit analysis” assesses the economic value of a Smart Grids solution and associated investment. An essential outcome of this analysis is the identification of the specific beneficiaries. Benefits from Smart Grids investments accrue throughout the value chain from generators, suppliers and customers to society as a whole. This is why economic regulation defining the conditions for the so-called socialisation of a major part of the investments is key for the successful implementation of Smart Grids. Too narrow a view when evaluating the cost efficiency of Smart Grids investments – to be undertaken mainly by DSOs – should be avoided.

The JRC general target is an economic-oriented CBA of Smart Grids projects that goes beyond the costs and benefits incurred by the actors carrying out the Smart Grids project. The JRC methodology aims to consider the CBA from a social perspective, considering the project’s impact on the entire value chain and on society at large. This approach recognizes that the impact of Smart Grids projects goes beyond what can be captured in monetary terms and for this reason it want to integrate an economic analysis with a qualitative impact analysis (non-monetary appraisal of non-quantifiable impacts and externalities).

Economic and qualitative analysis

The economic analysis take into account all costs and benefits that can be expressed in monetary terms. The analysis should try to include costs and benefits that spill over from the Smart Grids projects into the electricity system at large and society at large. The goal of the economic analysis is to extract the range of parameter values enabling positive outcome of the CBA and define action to keep these variables in that range. The overall analysis should also consider externalities that are not quantifiable in monetary terms. This includes the costs and benefits derived from broader social impacts like security of supply, consumer participation and improvements to market functioning.

Benefit Definition

A benefit is an outcome of a project which has a value to a firm, a household or society in general. For example are: lower transmission and distribution losses, fewer and shorter power interruptions, lower electricity cost to consumers or reduced damages by green-house emission. A benefit is not simply a project performance or an intermediate outcome, so customer participation or greater use of renewable energy sourced are not benefits. Moreover a benefit is something measurable and has an impact value that can be monetized. The benefits identified by EPRI are 22; the JRC introduced one more benefit related to the detection of anomalies relating to contracted power. For Smart Grids systems, it is well accepted that there are four fundamental categories of benefits:

- Economic – reduced costs, or increased production at the same cost, that result from improved utility system efficiency and asset utilisation;
- Reliability and Power Quality – reduction in interruptions, service quality assistance improvement and power quality events;
- Environmental – reduced impact of climate change and effects on human health and ecosystems due to pollution;
- Security and Safety – improved energy security (i.e. reduced oil and gas dependence); increased cyber security and reductions in injuries, loss of life and property damage.

Within each of the broad categories, there are several types of benefit and by definition they are mutually exclusive in terms of accounting for different benefit categories. However, Smart Grids functionalities that lead to one type of benefit can also lead to other types of benefits. For example, improvements that reduce distribution losses (an economic benefit) mean that pollutant emissions are reduced as well (which is an environmental benefit). Having identified the achieved benefits, it is very important to identify the beneficiaries in the process. In general, benefits are reductions in costs and damages, whether to generators, distribution system operators, consumers or to society at large. In this evaluation process the various benefits are defined so as to avoid instances of transfer payments between these groups of beneficiaries, to avoid mistakes in the evaluation of the total benefits, and to illustrate benefits from the separate perspectives of each group. In Table 5, a complete list of benefits is reported.

Beneficiaries identification

The benefits and costs of a Smart Grids system can accrue to different parties. It is informative to these different groups, as well as to the broad range of stakeholders, to identify those who receive the different types of benefits and their magnitude, and those who incur the costs. Some possible beneficiaries are:

- **Consumers**: Consumers can balance or reduce their energy consumption with the real-time supply of energy. Variable pricing will provide consumer incentives to install their own in-home infrastructure that supports the Smart Grids development. The Smart Grids information and communication infrastructure will support additional services not available today.
- **Utilities** (generators, transmission system operators, distribution system operators and

suppliers): Utilities can provide more reliable energy, particularly during challenging emergency conditions, while managing their costs more effectively through efficiency and information which can be used for more effective infrastructure development, maintenance and operation.

- **Society**: Society benefits from more reliable supplies and consistent power quality for both domestic customers and all industrial sectors – manufacturing, services, ICT – many of which are sensitive to power outages. Renewable energy, increased demand efficiency, and electric vehicles or other distributed storage support will reduce environmental costs, including society's carbon footprint.

BENEFIT CATEGORY	BENEFIT
ECONOMIC	Optimized generation operation
	Deffered generation capacity investments
	Reduced ancillary service cost
	Reduced congestion cost
	Deferred transmission capacity investments
	Deferred distribution capacity investments
	Reduced equipment failures
	Reduced distribution equipment maintenance cost
	Reduced distribution operations cost
	Reduced meter reading cost
	Reduced electricity theft
	Reduced electricity losses
	Reduced electricity cost
	Detection of anomalies in contracted power
RELIABILITY	Reduced sustained outages
	Reduced major outages
	Reduced restoration cost
	Reduced momentary outages
	Reduced sags and swells
ENVIRONMENT	Reduced CO_2 emissions
	Reduced SO_x, NO_x, PM10 emissions
SECURITY	Reduced oil usage
	Reduced wide-scale blackouts

Table 5 - List of benefits divided into categories

Identifying these groups of beneficiaries enables one to distinguish who (which group in general) is benefiting from which types of Smart Grids investment.

A benefit to any one of these stakeholders can in turn benefit the others. For example, those benefits that reduce costs for a DSO could lower prices, or prevent price increases, for customers. However in such cases it is vital to ensure that benefits transferred from one party to another are not double counted. Lower costs and decreased infrastructure requirements enhance the value of electricity to consumers. Reduced costs increase economic activity which benefits society. Societal benefits of the Smart Grids can be indirect and hard to quantify, but cannot be overlooked.

Other stakeholders also benefit from the Smart Grids. Regulators can benefit from the transparency and audit-ability of Smart Grids information. Vendors and integrators benefit from business and product opportunities around Smart Grids components and systems.

Total benefits are the sum of the benefits to utilities, consumers and society at large – though any transfer payments between these beneficiary groups must be taken into account and dealt with suitably. Ultimately transfer payments could be a solution to realize project financing where the global balance is positive, but where some stakeholders clearly benefit while others lose out.

Functionalities of Smart Grids distribution grids

The JRC methodology considers 33 functionalities defined by the European Commission Task Force for Smart Grids (EG1). The functionalities present general capabilities of the Smart Grids and they are not focused on specific technology. They are grouped into 6 high level services.

(i) ***A. Enabling the network to integrate users with new requirements***

1. Facilitate connections at all voltages/locations for all existing and future devices with SG solutions through the availability of technical data and additional grid information to:

- simplify and reduce the cost of the connection process subject to maintaining
- network integrity/safety;
- facilitate an ‘open platform’ approach – close to ‘plug & play’;
- make connection options transparent;
- facilitate connection of new load types, particularly EV;
- ensure that the most efficient DER connection strategies can be pursued from a total system perspective.

2. Better use of the grid for users at all voltages/locations, including in particular renewable generators.
3. Registers of the technical capabilities 8 of connected users/devices with an improved network control system, to be used for network purposes (ancillary services).
4. Updated performance data on continuity of supply and voltage quality to inform connected users and prospective users.

(ii) ***B. Enhancing efficiency in day-to-day grid operation***

5. Improved automated fault identification and optimal grid reconfiguration after faults reducing

outage times:

- using dynamic protection and automation schemes with additional information where distributed generation is present;
- strengthening Distribution Management Systems of distribution grids.

6. Enhanced monitoring and control of power flows and voltages.
7. Enhanced monitoring and observability of network components down to low voltage levels, potentially using the smart metering infrastructure.
8. Improved monitoring of network assets in order to enhance efficiency in day-to-day network operation and maintenance (proactive, condition based, operation history based maintenance).
9. Identification of technical and non technical losses through power flow analysis, network balances calculation and smart metering information.
10. Frequent information on actual active/reactive injections/withdrawals by generation and flexible consumption to system operator.

(iii) ***C. Ensuring network security, system control and quality of supply***

11. Solutions to allow grid users and aggregators to participate in an ancillary services market to enhance network operation.
12. Improved operation schemes for voltage/current control taking into account ancillary services.
13. Solutions to allow intermittent generation sources to contribute to system security through automation and control.
14. System security assessment and management of remedies, including actions against terrorist attacks, cyber threats, actions during emergencies, exceptional weather events and force majeure events.
15. Improved monitoring of safety particularly in public areas during network operations
16. Solutions for demand response for system security purposes in required response times.

(iv) ***D. Better planning of future network investment.***

17. Better models of DG, storage, flexible loads (including EV), and the ancillary services provided by them for an improvement of infrastructure planning.
18. Improved asset management and replacement strategies by information on actual/forecasted network utilization.
19. Additional information on supply quality and consumption made available by smart metering infrastructure to support network investment planning.

(v) ***E. Improving market functioning and customer service***

20. Solutions for participation of all connected generators in the electricity market.
21. Solutions for participation of VPPs in the electricity market, including access to the register of technical capabilities of connected users/devices.
22. Solutions for consumer participation in the electricity market, allowing market participants to offer:
    - time of use energy pricing, dynamic energy pricing and critical peak pricing;
    - demand response / load control programs;
23. Grid solutions for EV recharging:
    - open platform grid infrastructure for EV recharge purposes accessible to all market players and customers.

- smart control of the recharging process through load management functionalities of EV.

24. Improved industry systems for settlement, system balance, scheduling and forecasting and customer switching.
25. Grid support to intelligent home/facilities automation and smart devices by consumers.
26. Individual advance notice to grids users for planned interruptions.
27. Customer level reporting in event of interruptions (during, and after event).

(vi) ***F. Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management***

28. Sufficient frequency of meter readings, measurement granularity for consumption/injection metering data (e.g. interval metering, active and reactive power, etc).
29. Remote management of meters.
30. Consumption/injection data and price signals via the meter, via a portal or other ways including home displays, as best suited to consumers and generators.
31. Improved provision of energy usage information, including levels of green energy available at relevant time intervals and supply contract carbon footprint.
32. Improved information on energy sources.
33. Individual continuity of supply and voltage quality indicators via meter, via portal or other ways including home displays.

The JRC 7 steps for conducting a cost and benefit analysis

This section will explain the step by step process of JRC framework.

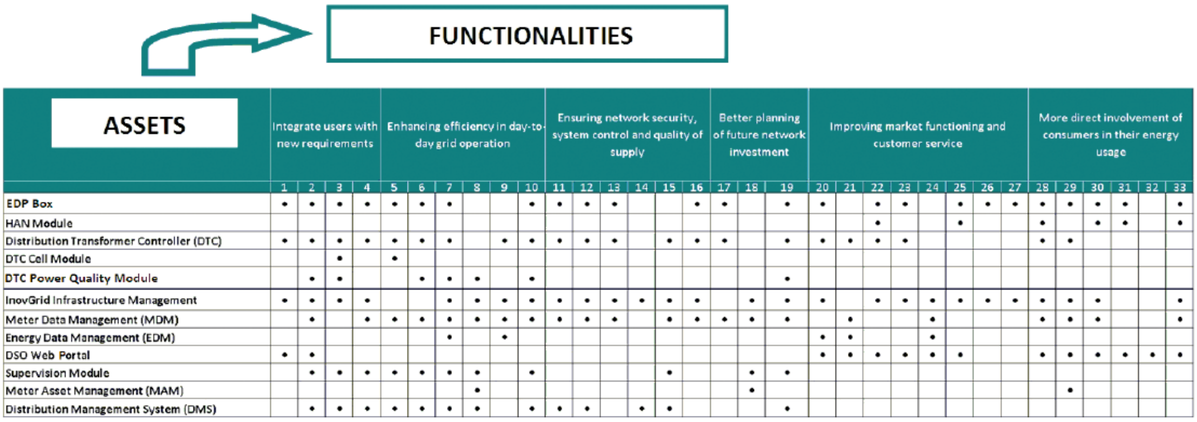
Step1: Review and describe the technologies, elements and goals of the project

The first step consists in providing a main summary of the demo that describes the elements and goals of the project. The project must be clearly defined as a self-sufficient unit of analysis.
This may requires providing:

- The scale and dimension of the project,
- The engineering features,
- The local characteristics of the grid,
- The relevant stakeholders,
- A clear statement of project’s objective and its expected socio-economic impact,
- The regulatory context and its impact on the project.

Step2: Map assets on to functionalities

Determining which Smart Grids functionalities are activated by the assets proposed by the project is an important early step in the CBA for Smart Grids projects. Smart Grids assets provide different types of functionalities that enabled by the project are unclear, the analysis is likely to be incomplete. To complete this step, consider the assets of the project. Asses each asset in turn and select from among 33 functionalities those are activated by the assets.

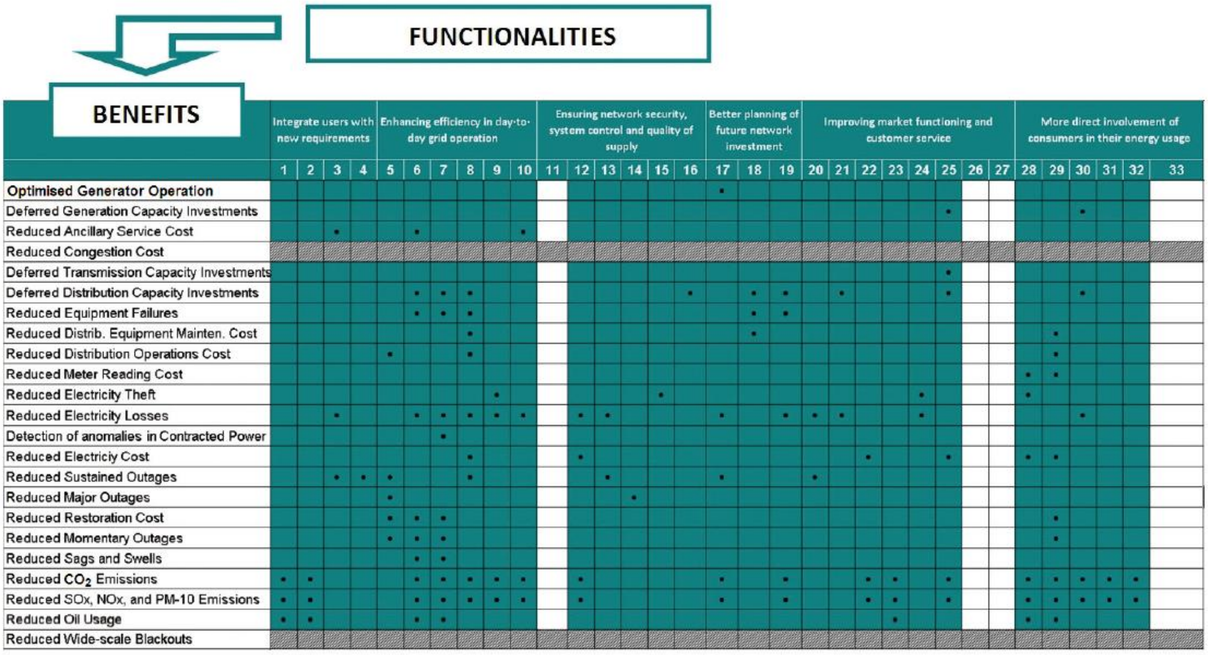


ASSETS	Integrate users with new requirements				Enhancing efficiency in day-to-day grid operation						Ensuring network security, system control and quality of supply						Better planning of future network investment			Improving market functioning and customer service								More direct involvement of consumers in their energy usage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
EDP Box	•	•	•	•	•	•	•			•	•	•	•			•	•		•	•		•	•		•	•	•	•	•	•	•		•
HAN Module																						•			•			•		•	•		•
Distribution Transformer Controller (DTC)	•	•	•	•	•	•	•		•	•	•	•	•		•	•	•		•	•	•	•	•					•	•				
DTC Cell Module			•		•																												
DTC Power Quality Module		•	•			•	•	•		•									•														
InovGrid Infrastructure Management	•	•	•	•			•	•	•	•	•	•	•	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•			•
Meter Data Management (MDM)		•		•	•	•	•	•	•	•	•	•	•		•	•	•	•	•		•			•				•	•	•			•
Energy Data Management (EDM)							•		•											•	•			•									
DSO Web Portal	•	•																		•	•	•	•	•	•			•	•	•	•	•	•
Supervision Module		•	•	•	•	•	•	•		•					•			•	•														
Meter Asset Management (MAM)								•										•											•				
Distribution Management System (DMS)		•	•	•	•	•	•	•		•	•	•		•	•				•														

Table 6 - Map each asset on to the functionalities it provides

Step3: Map functionalities on to benefits

The methodology proposes 22 Smart Grids benefits put forward by EPRI methodology and adds one more. These benefits are divided into 10 sub-categories, which are grouped into 4 main benefit categories: economic, reliability, environmental and security. The developer should consider each functionality individually and contemplate how it could contribute to any of the benefits. This analysis should continue until all applicable functionalities have been considered.



BENEFITS	Integrate users with new requirements				Enhancing efficiency in day-to-day grid operation						Ensuring network security, system control and quality of supply						Better planning of future network investment			Improving market functioning and customer service								More direct involvement of consumers in their energy usage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Optimised Generator Operation																	•																
Deferred Generation Capacity Investments																									•					•			
Reduced Ancillary Service Cost			•			•				•																							
Reduced Congestion Cost	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Deferred Transmission Capacity Investments																									•								
Deferred Distribution Capacity Investments						•	•	•								•		•	•		•				•					•			
Reduced Equipment Failures						•	•	•										•	•														
Reduced Distrib. Equipment Mainten. Cost								•										•											•				
Reduced Distribution Operations Cost					•			•																					•				
Reduced Meter Reading Cost																												•	•				
Reduced Electricity Theft									•						•									•				•					
Reduced Electricity Losses			•			•	•	•	•	•		•	•				•		•	•	•			•						•			
Detection of anomalies in Contracted Power							•																										
Reduced Electriciy Cost								•				•										•			•			•	•				
Reduced Sustained Outages			•	•	•			•					•				•			•													
Reduced Major Outages					•									•																			
Reduced Restoration Cost					•	•	•																						•				
Reduced Momentary Outages					•	•	•																						•				
Reduced Sags and Swells						•	•																										
Reduced CO_2 Emissions	•	•				•	•	•	•	•		•					•		•			•	•		•			•	•	•	•	•	
Reduced SOx, NOx, and PM-10 Emissions	•	•				•	•	•	•	•		•					•		•			•	•		•			•	•	•	•	•	
Reduced Oil Usage	•	•				•	•																•					•	•				
Reduced Wide-scale Blackouts	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Table 7 - Map each functionality on to a standardized set of benefit types

Step4: Establish the baseline

The objective of establishing the project baseline is to formally define the “control state” that reflects the system condition which would have occurred had the project not taken place. This is the baseline situation against which all other scenarios of the analysis are compared. The CBA of any action or investment is based on difference between the cost and benefits associated with the “Business as Usual” (BaU) scenario and those associated with the implementation of the project. It is most appropriate to use incremental, or marginal costs and benefits associated with Smart Grids investments. This is important when developing baselines, as they comprise the incremental component of both cost and benefits.

Step5: Monetize the benefits and identify the beneficiaries

The projects need to identify, collect and report the data required for the quantification and monetization of the benefits. The baseline scenarios need to calculate the benefits and to determine the type of data needed. Data should be collected both before and after implementation of the Smart Grids project.

The benefits of a project represent the change between baseline and project condition.
In general, the monetary value of a benefit can be calculated as:

$$\text{Value (€)} = [\text{condition}]\text{baseline} - [\text{condition}]\ \text{project}$$

The benefits quantified have to be monetized. Compilation and comparison of benefits which are very different in nature requires expressing them in a common unit of measurement. When conducting a CBA it is important to consider an expensive value chain and allocate benefits to different beneficiaries, like consumers, DSOs, etc.

The results of CBAs are likely to vary across different stakeholder groups. In undertaking the CBA, the advice is to not restrict the perspective to cost and benefits incurred by the player responsible for the Smart Grids implementation. Whenever feasible, it is also performing a CBA for each of the actors involved. This may provide a useful indication of how costs and benefits are distributed across the whole value chain. When undertaking Step 5, it may be useful to characterize the relative level of the precision of quantified benefits. It may not be possible to estimate some Smart Grids benefits, like those based on environmental or social factors, with the same level of confidence as other benefits. Therefore the EPRI methodology suggests providing at least some basic information regarding uncertainty in cost estimates and project outcomes with the goal of making available useful information on the certainty level of estimates to potential users of the CBA results.

Step 6: Identify and quantify the costs

The costs of a project are those costs incurred in implementing the project, relative to the baseline. Some costs can be measured directly by the investing companies, while others are typically easy to estimate since their price, or very good proxies, can be obtained in the marketplace. This step is important in order to evaluate the cost-effectiveness of the Smart Grids project. Collecting information on the project’s costs allows the calculation of a project’s return on investment, which shows whether it is positive, and if so, when the project will break even.

Step 7: Compare costs and benefits

Once costs and benefits have been estimated, there are several ways to compare them in order to evaluate the cost-effectiveness of the project. The most common methods are summarized below:

- Annual Comparison. This method consists in compiling costs and benefits annually over the study period in order to make annual comparisons
- Cumulative Comparison. This method presents costs and benefits cumulatively over time
- Net Present Value (NPV). This method consists of estimating the sum of net present values of individual cash flows of the Smart Grids project for the entire study period.
- Benefit-Cost Ratio. A project's value can also be represented as a ratio of benefits to costs (either on a present value basis or on an annual basis)

Qualitative impact analysis

JRC argues that an overall project assessment should address both quantifiable and non-quantifiable benefits. There are certain benefits, like consumer participation or transparency of bills and social impact such as job creation, strengthening of know-how, improvement of safety conditions and social acceptance, which are difficult to monetize and be included in the CBA. All these externalities should be taken into account in the project assessment, at least qualitatively, and complement the quantitative results of the CBA.

The assessment framework proposed by EC Task Force for Smart Grids is based on a merit deployment matrix, where benefits and corresponding KPIs are given in the rows, whereas functionalities (which are grouped into homogeneous clusters called services) are given in the columns.

For each project, the matrix is completed in two main steps:

- identify links between benefits/KPI and functionalities Select the corresponding cell;
- For each cell, explain how the link between benefits/KPI and functionalities is achieved in the project. Assign a weight (in the range of 0-1) to quantify how strong and relevant the link is.

By summing up the cells among the columns, it is possible to quantify the impact of the project in terms of functionalities, whereas by summing up the cells along the rows, it is possible to quantify the impact of the project in terms of benefits. In Table 8 a possible example of a sub-set of the merit deployment matrix to assess services and benefits is reported.

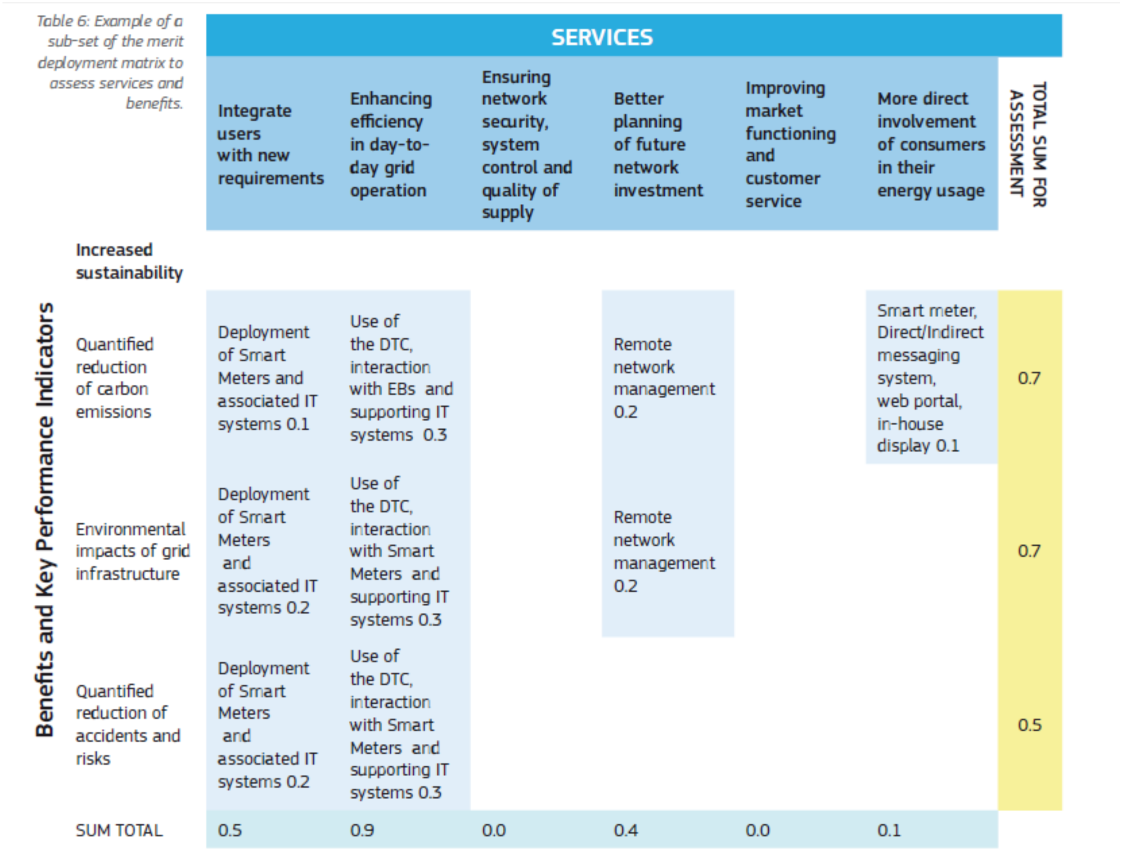


Table 6: Example of a sub-set of the merit deployment matrix to assess services and benefits.

Benefits and Key Performance Indicators	SERVICES: Integrate users with new requirements	Enhancing efficiency in day-to-day grid operation	Ensuring network security, system control and quality of supply	Better planning of future network investment	Improving market functioning and customer service	More direct involvement of consumers in their energy usage	TOTAL SUM FOR ASSESSMENT
Increased sustainability							
Quantified reduction of carbon emissions	Deployment of Smart Meters and associated IT systems 0.1	Use of the DTC, interaction with EBs and supporting IT systems 0.3		Remote network management 0.2		Smart meter, Direct/Indirect messaging system, web portal, in-house display 0.1	0.7
Environmental impacts of grid infrastructure	Deployment of Smart Meters and associated IT systems 0.2	Use of the DTC, interaction with Smart Meters and supporting IT systems 0.3		Remote network management 0.2			0.7
Quantified reduction of accidents and risks	Deployment of Smart Meters and associated IT systems 0.2	Use of the DTC, interaction with Smart Meters and supporting IT systems 0.3					0.5
SUM TOTAL	0.5	0.9	0.0	0.4	0.0	0.1	

Table 8 - Example of a sub-set of the merit deployment matrix to assess services and benefits.

(Source JRC 2012)