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DEFINITION OF AN ASSESSMENT FRAMEWORK FOR PROJECTS OF COMMON INTEREST IN THE FIELD OF SMART GRIDS

Under the EC "Proposal for a regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure"

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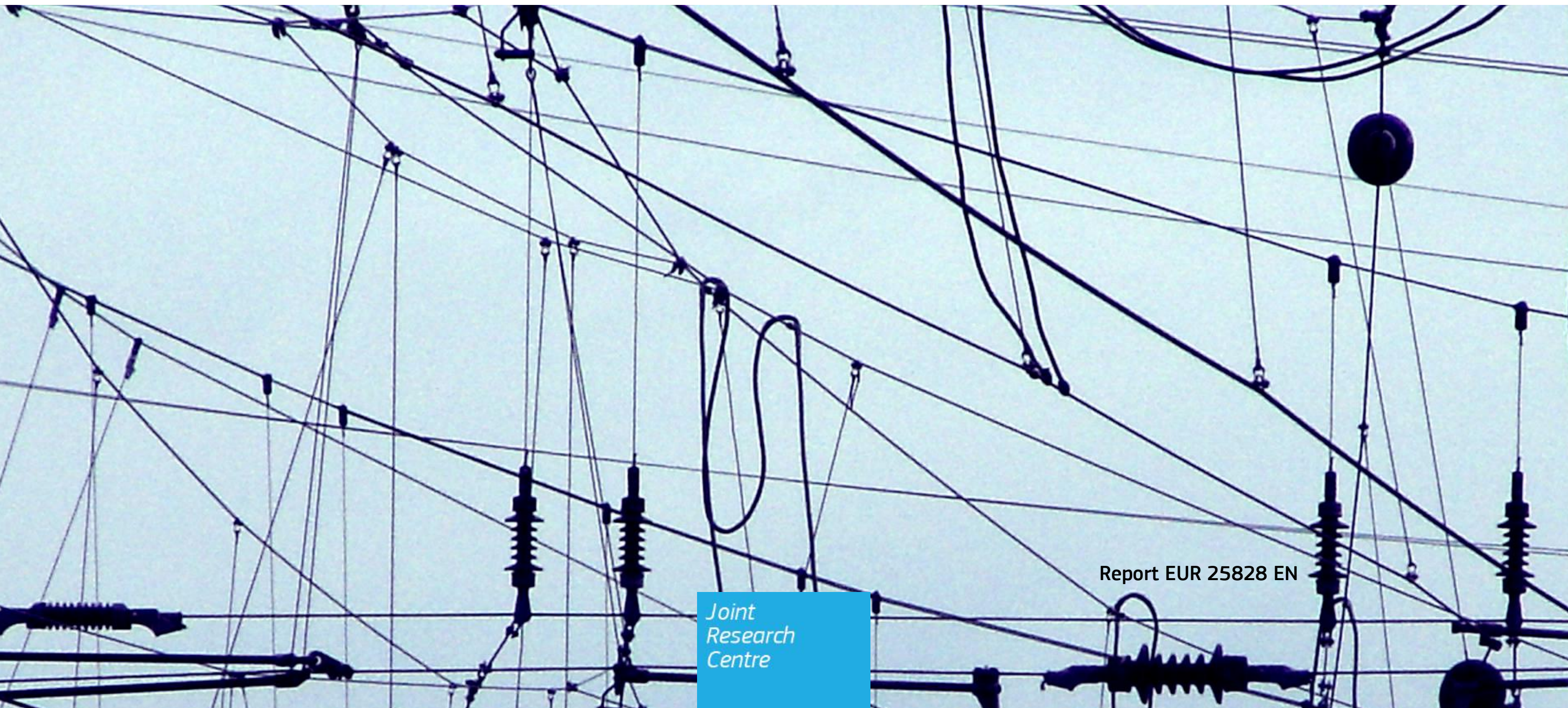

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Abstract

The document presents the methodology elaborated by JRC within the framework of its participation to the work of the Smart Grids Task Force, Expert Group on Smart Grid Infrastructure Deployment (Expert Group 4). The then adopted Regulation 347/2013 on guidelines for trans-European energy infrastructure provides for the establishment of a EU-wide list of "Projects of Common Interest", a label identifying key energy infrastructure projects in EU. Within this framework, Expert Group 4 had the mandate to define an evaluation framework for projects proposals in the field of smart grids. On the basis of its experience on Cost Benefit Analysis of smart grid projects, JRC developed a multi-criteria assessment framework including: a) a checklist to check that project proposals meet the requirements set out by the Regulation; b) a techno-economic assessment through Key Performance Indicators to capture the key features of each project; c) a Cost Benefit Analysis of each projects.

Smart Grids Task Force

Expert Group 4 – Infrastructure Development

DEFINITION OF AN ASSESSMENT FRAMEWORK FOR PROJECTS OF COMMON INTEREST IN THE FIELD OF SMART GRIDS

under the EC 'Proposal for a regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC' (COM(2011) 658)

Brussels, July 2012

EUROPEAN TASK FORCE FOR THE IMPLEMENTATION OF SMART GRIDS INTO THE EUROPEAN INTERNAL MARKET

The mission of the Smart Grids Task Force (SGTF) is to advise the Commission on policy and regulatory frameworks at European level to co-ordinate the first steps towards the implementation of Smart Grids under the provision of the Third Energy Package and to assist the Commission in identifying projects of common interest in the field of Smart Grids under the context of regulations on guidelines for Trans-European Infrastructure (COM (2011)658) [1].

The Smart Grids Task Force was reactivated in 01/02/2012 and four Expert Groups were launched[2]. This report has been developed and adopted by the *Expert Group for Smart Grid Infrastructure Deployment (*Expert group 4).

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[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0658:FIN:EN:PDF

[2] http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/mission_and_workprogramme.pdf

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1 INTRODUCTION

The scope of this document is to sketch an assessment framework in order to identify and evaluate Smart Grid projects in line with the requirements put forward by the European Commission (EC) in the Proposal for a regulation on guidelines for trans-European energy infrastructure (COM(2011)658) [EC 2011a]. This identification and evaluation shall be carried out in the course of 2012 in line with the missions of the Smart Grid Task Force expert group 4 "infrastructure development" [EC 2012a].

Smart Grid priority

The draft Regulation identifies "Smart Grids deployment" among the proposed 12 priorities, with the objective to adopt Smart Grid technologies across the Union to efficiently integrate the behaviour and actions of all users connected to the electricity network, in particular the generation of large amounts of electricity from renewable or distributed energy sources and demand response by consumers.

Smart Grid definition

A Smart Grid is a network efficiently integrating the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure an economically efficient, sustainable electricity system with low losses and high quality and security of supply and safety" [Proposal for a Regulation on Guidelines for trans-European energy infrastructures, Annex II – Energy Infrastructure categories]. The draft Regulation considers as Smart Grid infrastructure "any equipment or installation, both at transmission and medium voltage distribution level, aiming at two way digital communication, real-time or close to real-time, interactive and intelligent monitoring and management of electricity generation, transmission, distribution and consumption within an electricity network".

Eligibility requirements

The Regulation proposal defines the following general requirements for project eligibility:

- ✓ Contributing to the implementation of the energy infrastructure priority corridors and priority thematic areas, including Smart Grids deployment (article 4 point 1a and Annex I (10))

- ✓ Fulfilling the minimum technical requirements reported in Annex IV (1)(e) of the Regulation proposal
- ✓ Significantly contributing to the six specific functions (these functions are indicated as 'services' in [EC Task Force for Smart Grids 2010a]) of the "ideal" Smart Grid (article 4 point 2c). Project contribution to the six functions shall be evaluated against six different criteria. Each criterion shall be measured according to a number of key performance indicators (KPIs), as detailed in annex IV (4).
- ✓ The potential benefits of the project assessed according to the proposed criteria and KPIs outweigh its costs (article 4 point 1b)

Goal of this report

The goal of this report is to define an assessment framework for the evaluation of projects against all the aforementioned criteria and to guide project promoters in compiling their project proposals.

Table 1 summarizes the evaluation criteria and highlights the proposed tool to perform the evaluation. The compliance of the project with the minimum technical requirements is verified through a checklist. Key performance indicators and corresponding calculation metrics are proposed to assess the contribution of projects to Smart Grid functions. A cost-benefit analysis framework is presented to assess the economic viability of the project.

SMART GRID PROJECT EVALUATION CRITERIA	ASSESSMENT TOOL
1)Fulfil minimum technical requirements	Checklist
2)Contribute significantly to the specific target functions defined in Article 4.2.c	Evaluation against six policy criteria: key performance indicators (KPI) and corresponding metrics
3)Benefits outweigh costs	Cost-benefit analysis (CBA) and qualitative impact analysis of additional impacts that cannot be reliably monetized

Table 1 Requirements of the overall Smart Grid project assessment

The assessment should consider the following two scenarios:

- Business as Usual (BaU) scenario (without Smart Grids deployment), considering only planned maintenance. This is the reference scenario to assess the impact of the Smart Grid project.
- Smart Grid project implementation (SG scenario). This is the scenario with the Smart Grid project in place. Particular attention should be devoted to clearly defining the portion of the grid that will be affected by the Smart Grid project and that will be thus considered in the analysis. The choice of the boundary of the analysis should be clearly illustrated and motivated.

More details on the set of tools composing the proposed assessment framework are provided in the next sections. Chapter 2 discusses the implementation of the checklist to verify project compliance with the minimum technical requirements. Chapter 3 discusses the KPI-analysis for the evaluation of the policy-related criteria reported in ANNEX IV of the Regulation Proposal. Chapter 4 presents cost-benefit analysis guidelines to capture the economic impact of candidate projects. Finally chapter 5 summarizes the content of the project proposals that is required for the evaluation process.

The general idea of the assessment framework is that it is up to project promoters to clearly and convincingly build the case for their project. They shall demonstrate how the project proposal is fully in line with the technical, economic and policy criteria, as laid down in the energy Regulation. To this end, the project information template in ANNEX I should be accurately filled by all project promoters. The guidelines presented in this document are intended to support project promoters in performing this exercise.

In particular, the project proposal should argue convincingly about the project contribution to policy criteria, by making reference to the corresponding KPIs. As much as possible, the argumentation of the project contribution to a particular criterion (e.g. level of sustainability) should be supported by a quantification of the corresponding KPIs (e.g. reduction of greenhouse gas emissions, environmental impact of electricity grid infrastructure).

Likewise, the project proposal should argue convincingly about the economic viability and cost effectiveness of the project, by discussing how achieved benefits outweigh the costs. These arguments should be credibly supported by both numerical quantifications (societal CBA) and qualitative appraisals of benefits that cannot be reliably monetized.

To this end, the report also proposes a number of calculation options which are intended to facilitate the preparation of project proposals by project promoters. In particular, ANNEX II and ANNEX III present guidelines for the calculation of KPIs and of the monetary benefits of the CBA. Chapter 4 discusses also the qualitative appraisal of some project impacts that cannot be reliably monetized and included in the CBA (e.g. social impacts).

However, project promoters can, if duly justified, propose other evaluation methods for both the CBA and the KPI analysis. In any case, they need to clearly and transparently provide a detailed explanation of the rationale and of the assumptions of the evaluation methods they have employed.

2 MINIMUM TECHNICAL REQUIREMENTS

Proposed projects need to comply with the following minimum technical requirements

- ✓ Being implemented at a voltage level of 10kV or more
- ✓ Involving at least two Member States (MS), either by directly crossing the border of one or more MS or by being located on the territory of one MS and having significant cross-border impact; involve transmission and distribution operators from at least two MS
- ✓ Covering at least 100,000 users (producers, consumers and prosumers)
- ✓ Focusing on a consumption area of at least 300 GWh/year, of which at least 20%[3] originate from non-dispatchable resources.

Project promoters shall argue convincingly about the project compliance to these technical requirements. In particular, project promoters shall clearly demonstrate the cross-border impact of the project and describe in detail the role of the project participants (particularly DSOs and TSOs) from the involved Member States. This analysis shall be supported by all relevant technical documentation. Project promoters shall fill in detail the checklist of minimum technical requirements, as reported in section A3 of ANNEX I of the present document. The checklist shall be drawn by Art. (4.1) (c) (Chapter II) and Art. (1) (e) of Annex IV of the Regulation proposal.

[3] Following discussions in the Expert Group 4 of The Smart Grid Task Force, it has been clarified that this requirement refers to capacity

3 PROJECT CONTRIBUTION TO SMART GRID FUNCTIONS – EVALUATION CRITERIA AND KEY PERFORMANCE INDICATORS

As detailed in the regulation proposal, selected projects are expected to contribute to the six Smart Grid functions presented in article 4 point 2c.

The functions will be evaluated via a set of six criteria, which are directly related to Smart Grid policy objectives. In turn, the contribution of the project to each criterion will be evaluated via a set of Key Performance Indicators (KPI) as set out in Annex IV, point (4). The six policy criteria and the corresponding KPIs are reported below:

a. Level of sustainability
   1) Reduction of greenhouse emissions
   2) Environmental impact of electricity grid infrastructure
b. Capacity of transmission and distribution grids to connect and bring electricity from and to users
   1) Installed capacity of distributed energy resources in distribution networks
   2) Allowable maximum injection of electricity without congestion risks in transmission networks
   3) Energy not withdrawn from renewable sources due to congestion or security risks
c. Network connectivity and access to all categories of network users
   1) Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both
   2) Operational flexibility provided for dynamic balancing of electricity in the network
d. Security and quality of supply
   1) Ratio of reliably available generation capacity and peak demand
   2) Share of electricity generated from renewable sources
   3) Stability of the electricity system
   4) Duration and frequency of interruptions per customer, including climate related disruptions
   5) Voltage quality performance
e. Efficiency and service quality in electricity supply and grid operation

1) Level of losses in transmission and distribution networks
2) Ratio between minimum and maximum electricity demand within a defined time period
3) Demand side participation in electricity markets and in energy efficiency measures
4) Percentage utilisation (i.e. average loading) of electricity network components
5) Availability of network components (related to planned and unplanned maintenance) and its impact on network performances
6) Actual availability of network capacity with respect to its standard value

f. Contribution to cross-border electricity markets by load-flow control to alleviate loop-flows and increase interconnection capacities

1) Ratio between interconnection capacity of a Member State and its electricity demand
2) Exploitation of interconnection capacities
3) Congestion rents across interconnections

The aforementioned criteria and KPIs are outcome-oriented and not limited to delivering a certain type of physical (hardware or software) infrastructure (that means that ‘number of intelligent substations deployed’ for example is not a criterion or KPI) (see also [ERGEG 2010]).

It is up to project promoters to build a convincing case for their project according to each of the six criteria, taking into account the corresponding KPIs (see figure 1).

The outcome of this analysis should therefore be a detailed explanation of how the project is contributing to each of the six criteria (sections B2.1 – B2.6 in ANNEX I). For each criterion, arguments should be supported as much as possible by a quantification of the corresponding KPIs and a clear and detailed explanation of the KPI calculation assumptions. When duly justified, qualitative assessment of KPIs will also be accepted. If a KPI is not directly relevant or applicable to the project, project promoters shall clearly demonstrate it.

In order to facilitate this exercise, Annex II proposes options on how to transform the KPIs into computable metrics. For some of them, formulas have been proposed for their quantification. Project promoters should express as many KPIs as possible in quantitative values. However, given the uncertainties surrounding many KPIs and their underlying assumptions, these shall be clearly stated together with the numerical results. Qualitative assessments, where duly justified, will be accepted as well. In any case, project promoters need to make sure that their KPI assessment is technically sound and verifiable.

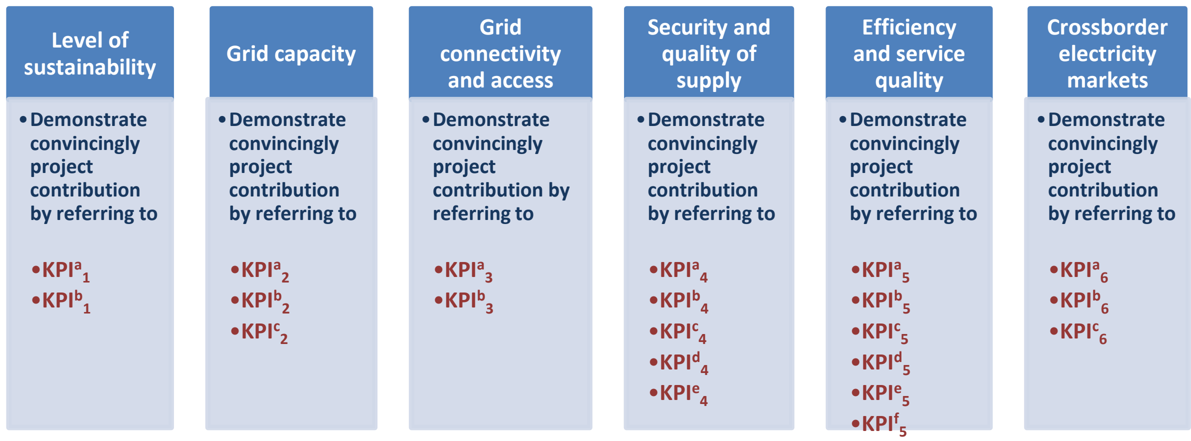

Figure 1 Project appraisal against the six policy criteria based on the KPI analysis (section B2 of ANNEX I)

In the discussion of the project performance according to the different criteria, we underline three main issues.

Criteria and KPIs might pull in opposite directions

First of all, the proposed criteria and KPIs evaluate the impact of Smart Grid technologies from different perspectives. It is possible that some projects will perform well against a certain criterion and less well against others. Criteria 2 (adequate grid capacity), 4 (security and quality of supply) and 5 (efficiency and service quality) are in several occasions pulling in opposite directions. For example, an improvement in the penetration of DERs might be at odds with a reduction in the level of energy losses or in the level of voltage harmonic distortion. The proposed multi-criteria analysis framework proposed in ANNEX V is intended to transparently trade-off possibly contradictory scores of projects according to the different criteria and come up with a single overall assessment of the project. In any case, project promoters shall clearly highlight possible contradictory scores against different criteria and KPIs and explain the reasons.

Influence of local conditions on the project evaluation

Secondly, we remark that, in many instances, the comparison of different projects against a certain KPI or criterion might not be straightforward, because of specific local conditions that affect the outcome of the KPI calculation (e.g. different starting conditions of smartness of the grid, different regulations, different climate hazards etc.).

The goal of this assessment framework is to identify Smart Grid projects that have a high impact in a specific area. In doing so, one must take into account the starting conditions of that area, while acknowledging that Smart Grids deployment should proceed at a similar pace in the different Member States [EC 2011b], because large differences between national energy infrastructures would prevent businesses and consumers from reaping the full benefits of Smart Grids and would make trade and cooperation across national borders difficult. As smart grid is not an end in itself but rather a means to an end, the proposed assessment framework aims at rewarding those projects in Europe that contribute the most to improve local conditions with smart solutions, whatever these conditions are at the outset.

KPIs influenced by developments beyond the control of project promoters

Finally, it is acknowledged that certain projects can create the conditions to improve some of the KPIs but that actual improvement of the KPIs might also depend on external developments beyond the control of project promoters (particularly DSOs and TSOs). In other words, it is possible that in some cases a project might facilitate the improvement of a KPI rather than actually actively improving it.

For example, the improvement of the KPI " Share of electricity generated from renewable sources" might also depend on investments by external actors (e.g. generation companies investing in renewable energy sources) or by regulatory and policy developments (e.g. incentive schemes for DGs, approval and enforcement of connection codes).

In the KPI analysis, the contribution of projects in enabling the improvement of certain KPIs will also be considered. However, project promoters shall (1) clearly demonstrate how their project is enabling the future improvement of a KPI; (2) explain clearly which external developments need to take place for an actual improvement of the KPI; (3) discuss how these external developments might take place in the near future in the project area.

It is recommended to support these claims, as much as possible, with results from similar projects or relevant pilot projects.

4 ECONOMIC VIABILITY - COST-BENEFIT ANALYSIS

As mentioned in the regulation proposal, project promoters shall demonstrate that the potential project benefits outweigh the costs (see figure 2 and section B3 of ANNEX I).

Project promoters shall argue convincingly about the economic viability and cost-effectiveness of the project, supporting their analysis as much as possible by monetary quantification of costs and benefits (see section B3.1 of ANNEX I). Positive and negative externalities shall also be included. It is necessary to perform a societal CBA, which goes beyond the costs and the benefits incurred by the project promoter. Calculation assumptions shall be clearly and transparently indicated.

Expected impacts (positive or negative) that cannot be reliably monetized (e.g. employment impact, safety, social acceptance) can also be used to support the economic case of the project (see section B3.2 of ANNEX I). Their appraisal should however be convincingly argued and supported. The potential economic dimension of these impacts shall be convincingly discussed.

To be eligible for funding, moreover, project promoters shall clearly demonstrate the economic viability of the project (from a societal point of view, including positive and negative externalities) and the lack of commercial viability.

We recommend following the CBA guidelines defined in [EC 2012b[4]], offering a structured evaluation of costs and benefits of different Smart Grid solutions, from the point of view of society. However, if duly justified, project promoters can propose alternative quantification formulas, provided that their rationale is clearly and convincingly illustrated.

Some of the benefits included in the CBA are expected to be directly related to the KPIs presented in chapter 3 (e.g. level of losses, value of lost load etc.).

Any overlapping with the KPI-analysis should be clearly highlighted. In performing the economic appraisal, the focus should be on the economic dimension of the impacts captured by the proposed KPIs. For example, the project economic evaluation could include the monetary value of reduced CO2 emissions, whereas the KPI analysis might just refer to the amount of CO2 reduction expressed in tons.

[4] http://ses.jrc.ec.europa.eu/sites/ses/files/documents/guidelines_for_conducting_a_cost-benefit_analysis_of_smart_grid_projects.pdf

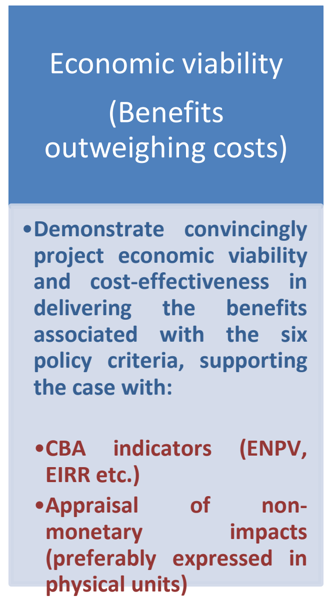

Figure 2 Appraisal of the economic viability of the project (section B3 of ANNEX I)

4.1 Economic viability - Monetary appraisal

The economic analysis takes into account all costs and benefits that can be expressed in monetary terms, considering a societal perspective.

The benefits of implementing any Smart Grid project will be measured against the Business as Usual scenario.

As shown in figure 3, the proposed approach to CBA is composed of three main parts [EC 2012b]:

- definition of boundary conditions (e.g. demand growth forecast, forecast of supply side evolution, local grid characteristics, technological/engineering design)
- identification of costs and benefits
- sensitivity analysis of the CBA outcome to variations in key variables/parameters (identification of switching values, volatility of benefits and costs, mitigation actions)

The goal of the economic analysis is to extract the range of parameter values enabling a positive outcome of the CBA and define actions to keep these variables in that range. Output indicators representing the CBA outcome include:

-Economic Net present value (ENPV): the difference between the discounted social benefits and costs. It provides an indication of the profitability of the project.

-Economic Internal rate of return (EIRR): the discount rate that produces a zero value for the ENPV. It provides an indication of the quality of the investment.

-B/C ratio, i.e. the ratio between discounted economic benefits and costs. It provides an indication of the efficiency of the project.

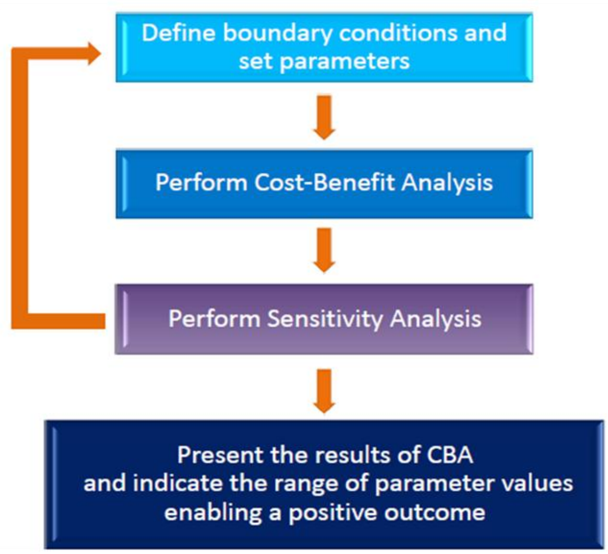

Figure 3 Cost-Benefit Analysis Framework

When conducting the CBA, it is also recommended to consider:

- √ Benefits should represent those actually resulting from the project.
- √ Benefits should be significant (meaningful impact), relevant to the analysis and transparent in their quantification and monetization.
- √ The individual benefit and cost variables should be mutually exclusive. In other words, avoid including one type of benefit as part of another type of benefit.
- √ The level of uncertainty associated to the benefit estimation should be clearly stated and documented.
- √ The beneficiaries (consumers, system operators, society, retailers etc.) associated with each benefit should be identified, if possible with a quantitative estimation of the corresponding share. In particular, we recommend performing a financial cost-benefit analysis at least for consumers and for the actor(s) implementing the project in order to

evaluate the financial viability of the investment (e.g. this is important to assess whether regulatory incentives are needed and appropriate)

- √ Use shadow prices wherever possible
- √ Make sure that transfers (including taxes) are not included in the analysis
- √ We recommend using a social discount rate of 4% [EC 2009]
- √ We recommend adopting a time horizon for the analysis of 20 years (the [EC 2008] recommends a time horizon of 15 years for ICT projects and 25 years for energy infrastructure projects)
- √ We recommend using the carbon prices projected both in the Commission reference and decarbonisation scenarios[5].

4.2 CBA – Appraisal of non-monetary impacts

As mentioned, in building the case for the economic viability of their project, project promoters can also provide a qualitative appraisal of other expected impacts that cannot be reliably monetized and included in the CBA. The goal is to give decision makers the whole range of elements for the evaluation of the project economic viability. We stress that the analysis of non-monetary impacts of the project will be treated very cautiously, especially when the analysis does not rely on quantitative indicators but on vague and subjective descriptive appraisals.

For this exercise, project promoters shall convincingly

(1) identify and express the expected non-monetary impacts (preferably) in physical terms or through a well-argued descriptive analysis.

(2) demonstrate the economic relevance of these impacts for the project.

Some project impacts included in this analysis might be directly related to the criteria and KPIs presented in chapter 3 (if they cannot be monetized and included directly in the CBA presented in section 4.1). For example, the project economic evaluation could include a qualitative appraisal of the economic impact of increased security of supply or of increased connectivity of network users.

[5] Annex 7.10 to Commission Staff Working Document SEC(2011) 288 final — 'Impact Assessment': http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF

Other project impacts included in this exercise might not be directly related to the criteria and KPIs but might still represent important social impacts, worth of being used to support the case for the economic viability of the project. In ANNEX IV, we provide a (non-exhaustive) list of project impacts that might be difficult to monetize and include in the CBA but that can however be considered (preferably expressed in physical units) in the economic analysis.

5 SUMMARY – PROJECT PROPOSALS AND EVALUATION PROCESS

CONTENT OF PROJECT PROPOSALS

Figure 4 summarizes the three main inputs that need to be included in the project proposals for project evaluation. To this end, project promoters shall duly fill in the submission forms /templates presented in ANNEX I.

Project promoters shall argue convincingly about the project compliance with the technical requirements, about the project contribution to policy objectives (KPI analysis) and about the project economic viability. The argumentation shall be supported by all relevant technical documentation, including quantifications in terms of KPIs and CBA.

Overlaps among the different assessment tools are possible. For example, environmental impacts might be considered in the KPI-analysis (consider the 'sustainability' criteria) and in the CBA (e.g. monetization of carbon costs). In presenting the expected impacts of their projects, project promoters are required to transparently highlight where overlapping in their project proposal might occur.

In summary, the project proposals shall include three main sections:

- ✓ **Compliance with technical requirements** – Project promoters shall argue convincingly for project compliance with the technical requirements presented in chapter 2. They shall fill in detail the checklist of minimum technical requirement reported in section A3 of ANNEX I and provide all necessary supporting technical documentation.
- ✓ **Project contribution to policy objectives** – Project promoters shall argue convincingly for project contribution to each of the six policy criteria (please refer to sections B2.1 – B2.6 of ANNEX I). The analysis of project performance against each criterion shall be supported by a reference to the corresponding KPIs. A quantitative evaluation of KPIs supported by clear exposition of performed analysis and calculation assumptions is required. However; if duly justified, also qualitative evaluation of KPIs will also be accepted. If a criterion or KPI is not relevant to the project, project promoters shall clearly demonstrate why. In any case, the analysis shall be technically sound, detailed and verifiable.

- ✓ **Project economic viability** - Project promoters shall argue convincingly that the societal benefits of the project outweigh its costs (please refer to sections B3 of ANNEX I). To this end, the case for economic viability and cost-effectiveness of the project should be supported as much as possible by a quantitative societal CBA and resulting economic indicators (e.g. ENPV). A reasonable estimate of the costs and benefits of the project, including positive and negative externalities, shall be carried out. The appraisal can also include a qualitative appraisal (preferably expressed in physical units) of all the impacts that cannot be reliably expressed in monetary terms. Project promoters shall include a detailed description of the methodology and of the calculation assumptions they have employed. Their proposed approach shall be technically sound, detailed and verifiable.
- ✓ Any other analysis and/or documentation (e.g. results from related pilot projects etc.) that may be used to support the case for the project.

The project proposal shall also include:

- ✓ A project plan, specifying roles and responsibilities of the different participants and highlighting, as a minimum, project key phases, milestones and interdependencies (e.g. through the use of a Gantt chart)
- ✓ An estimation of the necessary resources to complete the project on time and of the allocation of the resources among the different project participants
- ✓ The identification of the possible project risks and a description of the corresponding risk mitigation strategies

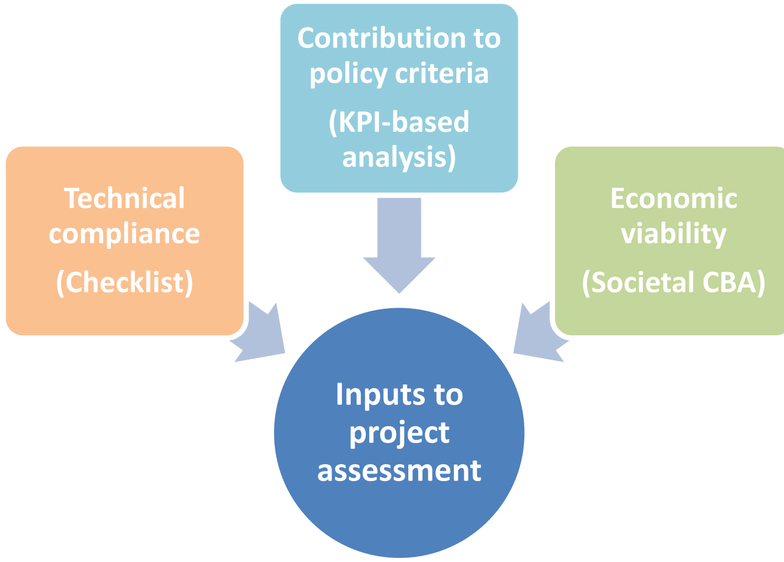

Figure 4 Inputs to project assessment to be included in the project proposal

PROJECT ASSESSMENT

As indicated in the Regulation Proposal, project proposals will be evaluated by an expert panel (Regional Group). Projects will be evaluated based on how they perform against the six criteria (discussed in chapter 3) and on how cost-effectively they can deliver the benefits associated with those criteria. The KPI-based analysis represents the core of the overall evaluation framework and priority will be given to projects significantly contributing to the objectives of Smart Grid implementation (see point 17 of the regulation recital and Article 4.2(c)). The compliance with the technical requirements will be considered as a prerequisite for further evaluation of the project proposal.

In the evaluation phase, a question arises over how to integrate the outcome of the KPI and of the economic analysis and come up with an overall project evaluation. It is also important to ensure that project proposals are evaluated against a common reference system.

To this aim, the 'Analytic Hierarchy Process' (AHP)[6] (see [Kendrick et Saaty 2007, Kumar 2004] for examples of application of this method to project evaluation), which is a widespread analytical tool to organize and analyse complex decisions, could be used by the project evaluators to combine projects' performances against the different criteria and according a common reference system. This method is intended to assess different alternatives with regard to multiple criteria. It enables the decision-maker to transparently implement weights as

[6] http://composite-indicators.jrc.ec.europa.eu/S6_weighting.htm

opposed to arbitrarily assign them. ANNEX V and VI present the details of the AHP method and illustrate a possible way to use it in the context of the assessment framework proposed in this document.

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ANNEX I TEMPLATE FOR PROJECT PROPOSALS AND FOR PROJECT MONITORING

<table>
<tr><th colspan="4">A-GENERAL DESCRIPTION OF THE PROJECT</th></tr>
<tr><th colspan="4">A1.ADMINISTRATIVE INFORMATION OF THE APPLICANT ORGANIZATION</th></tr>
<tr><td>Organization legal name (1)</td><td colspan="3"></td></tr>
<tr><td>Member State (1)</td><td colspan="3"></td></tr>
<tr><td rowspan="4">Leading organization legal status</td><td>Public undertaking/body</td><td>☐</td><td>Details:</td></tr>
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<tr><td>International organization</td><td>☐</td><td>Details:</td></tr>
<tr><td>Joint undertaking</td><td>☐</td><td>Details:</td></tr>
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<tr><td>Postal Code</td><td colspan="2"></td></tr>
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<tr><td>Country</td><td colspan="2"></td></tr>
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	Joint undertaking	☐	Details:
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	Postal Code		
	Town/City		
	Country		
Contact point	Name		
	Function		
	Street		
	Postal Code		
	Town/City		
	Country		
	Phone		
	Email		

A2. PROJECT GENERAL INFORMATION	
Project name	
Location/s of the physical implementation, specifying Member States (please provide also a map showing the grid under consideration, the consumption and generation areas and the main power flows)	
Project Website	
Name of leading organization(s)	
Name and email address of technical contact point(s)	
Other Participants (Names, Countries and Organization Type)	

Please provide an executive summary of the project (including main goals, participants and responsibilities, cross-border dimension, technical characteristics and expected impacts):

Please describe main needs addressed by the project:

Please describe in detail the expected cross-border impact of the project:

Please provide a project plan (including a graphic tool, e.g. Gantt chart), specifying roles and responsibilities of the different participants and highlighting, as a minimum, main project phases, milestones and interdependencies:

Please provide an estimation of the necessary resources to complete the project on time and of the allocation of the resources among the different project participants:

Please describe any major element of complexity of the project:

Please illustrate possible project risks and a description of the corresponding risk mitigation strategies:

Please describe briefly the main results of previous feasibility studies, pilot projects and/or technical studies undertaken for the project:

Has the project already received monetary support at National or European level? If yes please specify (e.g. support through tariffs or public funding etc.):

A3. COMPLIANCE WITH TECHNICAL REQUIREMENTS

Please describe in detail the technical characteristics of the project and of the portion of the grid impacted by the project (please provide any relevant technical documentation):

Please demonstrate clearly the "Smart Grid dimension" of the proposed project (i.e. clarifying why the proposed project can be considered a Smart Grid project) and provide details of the

Smart Grid features that will be implemented:

Please provide a summary of the project compliance with the technical requirements specified in the regulation proposal:

For each of the technical requirements reported below, please provide the corresponding project value and discuss in detail project compliance:

Criteria	**Reference value**	**Analysis of project compliance**	**Project value (synthetic outcome of analysis of project compliance)**
Voltage level(s) (kV):	>10kV		
Number of users involved (producers, consumers and prosumers):	>100000		
Consumption level in the project area (MWh/year):	300GWh/year		
% of energy supplied by non-Dispatchable resources (in terms of capacity)	>20%		
Projects involving transmission and distribution operators from at least two MS	-		

B-IMPACT OF THE PROJECT

B1. OVERVIEW OF EXPECTED PROJECT IMPACT

Please describe expected impacts on the project region and on neighbouring regions:

B2. PROJECT PERFORMANCE AGAINST SIX POLICY CRITERIA

Please provide an overview of the project performance against the six policy criteria (detailed below)

B2.1 – PROJECT PERFORMANCE AGAINST CRITERION 1 –LEVEL OF SUSTAINABILITY

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Reduction of greenhouse gas emissions	
Environmental impact of electricity grid infrastructure	

B2.2 – PROJECT PERFORMANCE AGAINST CRITERION 2 –CAPACITY OF TRANSMISSION AND DISTRIBUTION GRIDS TO CONNECT AND BRING ELECTRICITY FROM AND TO USERS

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Installed capacity of distributed energy resources in distribution networks	
Allowable maximum injection of power without congestion risks in transmission networks	
Energy not withdrawn from renewable sources due to congestion or security risks	

B2.3 – PROJECT PERFORMANCE AGAINST CRITERION 3 – NETWORK CONNECTIVITY AND ACCESS TO ALL CATEGORIES OF NETWORK USERS

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	
Operational flexibility for dynamic balancing of electricity in the network	

B2.4 – PROJECT PERFORMANCE AGAINST CRITERION 4 – SECURITY AND QUALITY OF SUPPLY

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Ratio of reliably available generation capacity and peak demand	
Share of electricity generated from renewable sources	
Stability of the electricity system	
Duration and frequency of interruptions per customer, including climate related disruptions	
Voltage quality performance	

B2.5 – PROJECT PERFORMANCE AGAINST CRITERION 5 – EFFICIENCY AND SERVICE QUALITY IN ELECTRICITY SUPPLY AND GRID

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Level of losses in	

transmission and in distribution networks	
Ratio between minimum and maximum electricity demand within a defined time period	
Demand side participation in electricity markets and in energy efficiency measures	
Percentage utilisation (i.e. average loading) of electricity network components	
Availability of network components (related to planned and unplanned maintenance) and its impact on network performances	
Actual availability of network capacity with respect to its standard value	

B2.6 – PROJECT PERFORMANCE AGAINST CRITERION 6 – CONTRIBUTION TO CROSS-BORDER ELECTRICITY MARKETS BY LOAD-FLOW CONTROL TO ALLEVIATE LOOP-FLOWS AND INCREASE INTERCONNECTION CAPACITIES

Please demonstrate convincingly project contribution to this criterion, referring to the KPIs reported below:

KPI	Estimated KPI value and calculation assumptions
Ratio between interconnection capacity of a Member State and its electricity demand	
Exploitation of interconnection capacities	
Congestion rents across interconnections	

B3. ECONOMIC APPRAISAL

Please demonstrate convincingly that benefits provided by the project outweigh their costs. The case for the economic viability and cost-effectiveness of the project should be supported as much as possible by (1) a quantitative societal CBA and resulting economic indicators (e.g. ENPV) and by (2) a qualitative appraisal (preferably expressed in physical units) of all the impacts that cannot be reliably expressed in monetary terms.

B3.1 SOCIETAL CBA

ASSUMPTIONS

VARIABLE	VALUE	RATIONALE FOR VALUE CHOICE
Demand growth		
Discount rate		
Time horizon		
Other		

Is the choice of the discount rate consistent with the Commission's or Member States' own guidance? If not, why?

Is the choice of the time horizon consistent with the recommended value? If not, why?

ESTIMATED BENEFITS

BENEFIT	VALUE	ESTIMATION APPROACH

ESTIMATED COSTS (CAPEX and OPEX)

COST	VALUE	ESTIMATION APPROACH
CAPEX		
OPEX		

SENSITIVITY ANALYSIS
Please describe the assumptions and critical variables considered in the sensitivity analysis:
Please provide CBA outcome (NPV and IRR) and provide the range of values of critical variables leading to a positive CBA outcome :
Please provide the switching values of critical variables and foreseen control/mitigation actions to keep critical variables under control and reduce CBA uncertainty:

B3.2 - APPRAISAL OF NON-MONETARY IMPACTS (see ANNEX IV)

Please provide a detailed appraisal of expected (positive and negative) impacts that cannot be monetized and included in the CBA. Preferably physical units shall be used. Qualitative descriptions of impacts could also be used but shall be convincingly supported.

Non-monetary impact	Estimation in physical units and/or description of expected impact

ANNEX II PROPOSED CALCULATION OPTIONS FOR KPIS MENTIONED IN THE REGULATION PROPOSAL

This ANNEX proposes ways to translate the key performance indicators put forward in the regulation proposal into computable metrics. It shall facilitate the preparation of project proposals by project promoters. However, project promoters can, if duly justified, propose other evaluation methods for the requested KPIs.

In following proposed calculation guidelines, we recommend to:

- ✓ Clearly define the particular local conditions (technical, regulatory) that affect the KPI calculation
- ✓ Clearly highlight the assumptions made in the calculation, the method of calculating the KPIs (e.g. details over the simulation model employed) and the grid boundary conditions considered in the analysis.
- ✓ Clearly illustrate how, in the design of the project, it has been foreseen a way to collect the data that are necessary to calculate the KPI in ex-post evaluation in the SG scenario. If field data for the evaluation of a KPI cannot be collected, please provide reasons and describe how this affects the KPI analysis.
- ✓ When using results from Smart Grid pilots to support assumptions in the calculation of KPIs, highlight clearly why the results are relevant and how they can be extended to the deployment project under consideration.
- ✓ In those cases where the project is simply enabling the improvement of a KPI, highlight clearly the external developments (i.e. developments that are beyond the control of the project promoters) that need to occur to actually improve that KPI.

1. LEVEL OF SUSTAINABILITY

a) Reduction of greenhouse gas emissions (GHG)

The quantification of this KPI requires the identification of all possible means of GHGs reduction (including CO_2 reduction) brought by the project, like:

-reduction due to reduced energy losses

-reduction due to energy savings

-reduction due to peak load reduction and displacement of fossil-based peak generation

- reduction due to higher integration of renewables with consequent displacement of fossil-based generation

Clearly, it is important to avoid overlapping with benefits in terms of CO2 reduction included in the CBA analysis.

The proposed KPI calculates the estimated variation of GHG emissions normalized to total energy demand in the portion of the grid affected by the project.

$$KPI_{1a} = \frac{GHG\_emissions_{BaU} - GHG\_emissions_{SG}}{Total\_Energy\_demand}$$

The KPI is expressed in [Ton/MWh].

The avoided GHG emissions can be calculated as follows:

$$GHG\_emissions_{BaU} - GHG\_emissions_{SG} = \frac{r_{emission}}{\eta_g} \times \Delta Energy$$

where:

r_{emission} [$\frac{kg}{MWhT}$] is the average GHG emission rate of the fossil-based energy mix in the region/country under consideration (MWhT represents thermal energy). The representative GHG content per MWh is based on assessments of the primary fuels typical energy and the GHG content as well as the typical efficiencies of power plants [ENTSOE 2009].

η_g [$\frac{MWh}{MWhT}$] is the average efficiency of the thermal power plants in the region/country under consideration (ratio between electricity produced per unit of thermal energy)

ΔEnergy [MWh] represents the amount of fossil-based energy displaced (e.g. via less losses, energy savings, replacement of fossil-based energy with renewable energy sources).

If feasible, instead of using average values, a more precise calculation can be carried out by estimating the emission rate of different fossil-based power plants (coal, gas etc.) and the amount of displaced fossil-base generation for each fossil fuel.

Also, as an alternative, it could be considered the emissions of the fossil-based power plants that would be displaced by peak shaving or the integration of renewables in the energy mix.

b) Environmental impact of electricity grid infrastructure

For the appraisal of the environmental viability of a Smart Grid project, we need to consider all environmental impacts that have not already been included in the KPI-analysis (under criteria 'level of sustainability') and in the CBA (e.g. monetization of CO2 costs or of noise reduction).

The environmental impact of Smart Grid projects should be evaluated against the "BaU" scenario, as in other typical licensing procedures for works of public interest. The policy goal of including an environmental evaluation of projects is, in fact, to preserve as much as possible the environment as it is before any intervention, or, if possible, to ameliorate it.

If numerical indicators cannot be calculated (e.g. decibel for sound level), the project appraisal might include a detailed well-argued description of the expected (positive or negative) impacts.

In the following we report a non-exhaustive list of possible areas of environmental impact that, wherever relevant, should be considered and assessed:

- √ Any anticipated or observed direct or indirect effects of the project on soil, water, air, climate
- √ Land use and landscape change (e.g. square meters per peak capacity of PV farm)
- √ Visual impact
- √ Emissions of air pollutants (except GHG, already included in the CBA and in the KPI analysis) and releases of toxic substances (e.g. heavy metals)
- √ Acoustic impact (e.g. decibel from wind farms per installed capacity)
- √ Electro-magnetic impact

2. CAPACITY OF TRANSMISSION AND DISTRIBUTION GRIDS TO CONNECT AND BRING ELECTRICITY FROM AND TO USERS

a) Installed capacity of distributed energy resources in distribution networks

This KPI is intended to capture the amount of additional capacity of distributed energy resources that can be safely integrated in the distribution grid thanks to the Smart Grid project.

As explained in [CEER 2011], 'the hosting capacity is the amount of electricity production that can be connected to the distribution network without endangering the voltage quality and reliability for other grid users'.

The calculation of this indicator might depend on specific national regulations (e.g. technical and economic conditions of curtailment of power/generation during periods of overproduction). It is recommended to clearly express the local conditions affecting the calculation of this KPI.

The contribution of a Smart Grid project to integrate DERs can be assessed by estimating, over a defined period of time (e.g. a year), the increase of DER energy injected in the distribution grid in safe conditions as a result of the Smart Grid implementation (e.g. through active management of distribution networks: control of transformer taps, innovative voltage regulation algorithms, reactive power management, innovative grid protection/monitoring etc.).

$$KPI_{2a} = \frac{EI_{SG} - EI_{BaU}}{E_{total}}$$

Where

EI_{SG} is the DER energy input (over a defined period of time, e.g. yearly) that can be integrated in safe conditions in the portion of the distribution grid under consideration in the SG scenario [MWh];

EI_{BaU} is the DER energy input (over a defined period of time, e.g. yearly) that can be integrated in safe conditions in the portion of the distribution grid under consideration in the BaU scenario [MWh];

E_{total} is the total energy consumption in the portion of the grid under consideration and is used as a normalization factor to keep into account the size of the project.

The installed DER capacity is affected by the short circuit level increase of the line, the voltage stability and the nominal current before and after the new installation. The protection (electrical) of the equipment is always taken in to account. Most of these values can be calculated by a power flow and short circuit analysis. Calculation hypothesis should be clearly explained and documented.

As highlighted in [Lo Schiavo 2011], both EI_{SG} and EI_{BaU} should be calculated with respect to the network structure, according to the Hosting Capacity approach discussed in [Deuse et al. 2008], regardless of the DG units actually connected to the network before and after the project. In this sense, this KPI can be calculated referring to the hosting capacity in the SG and BaU scenarios.

We remark that the contribution of DERs in terms of energy should be assessed cautiously and in accordance to local conditions. In fact, distributed energy resources can positively contribute to the system operations also by providing ancillary services, which in some cases can result in less energy generated. If that's the case, project promoters can include this analysis in their evaluation of this KPI.

b) Allowable maximum injection of power without congestion risks in transmission networks

As specified in [CEER 2011], 'this index can be considered as the transmission system equivalent of the hosting capacity. It can also be seen as the net transfer capacity from a (hypothetical) production unit to the rest of the grid. The condition "without congestion risks" should be interpreted as obeying the prescribed rules on operational security'.

This indicator can be calculated on an hourly basis, considering the actual availability of network components and the actual power flows through the network. This would result in an indicator whose value changes with time.

We recommend that the indicator be calculated as a fixed value under pre-defined worst-case power flows and a pre-defined outage level (e.g. n-1). The resulting value would give the largest size of production unit that can be connected without risking curtailment [CEER 2011].

$$KPI_{2b} = \frac{Pi_{\max SG} - Pi_{\max BaU}}{P_{ref}} \times 100$$

Where Pi_{max} represents the largest size of production unit that can be connected without risking curtailment in the pre-defined worst case scenario[MW].

P_{ref} is the power load in the grid under consideration in the pre-defined worst-case scenario (it is assumed constant before and after the project) [MW].

The choice of P_{ref} as normalisation factor is intended to reward projects having, for the same power load, a higher increase of the allowable maximum injection of power in absolute terms.

c) Energy not withdrawn from renewable sources due to congestion or security risks

"This indicator quantifies the ability of the network to host renewable electricity production. In that sense, it is similar to indicators like hosting capacity and allowable maximum injection of power. But whereas the latter two indicators only quantify the actual limits posed by the network, the energy not withdrawn quantifies to which extent the limits are exceeded" [CEER 2011].

This impact could be captured by estimating the percentage variation of RES energy curtailed as a result of the Smart Grid implementation.

$$KPI_{2c} = \frac{E\_RES\_curtailed_{BaU} - E\_RES\_curtailed_{SG}}{\mathrm{E\_RES_{tot}}}$$

Where

$E\_RES\_curtailed_{SG}$ is the RES energy curtailed (over a defined period of time, e.g. yearly) in the SG scenario [MWh];

$E\_RES\_curtailed_{BaU}$ is the RES energy curtailed (over a defined period of time, e.g. yearly) in the BaU scenario [MWh];

E_RES_{tot} is the total RES energy generated (over a defined period of time, e.g. yearly), assuming no variations between the BaU and SG scenario [MWh];

E_{total} is the total energy consumed in the grid under consideration in the defined period (it is assumed constant before and after the project) [MWh]. The calculation is done in the hypothesis that the same boundary conditions (e.g. load profile, generation mix, RES profile etc.) apply for both the BaU and in the SG scenarios.

If a reliable estimation of the total RES energy generated in the BaU and SG scenarios is possible, then the KPI could also be expressed as

$$KPI_{2c} = \frac{E\_RES\_curtailed_{BaU}}{E\_RES_{BaU}} - \frac{E\_RES\_curtailed_{SG}}{E\_RES_{SG}}$$

E_RES_{SG} is the total RES energy generated (over a defined period of time, e.g. yearly) in the SG scenario [MWh];

E_RES_{BaU} is the total RES energy generated (over a defined period of time, e.g. yearly) in the BaU scenario [MWh];

In this way, the higher the total RES energy enabled by the SG projects (in the SG scenario), the more emphasized is an improvement in the reduction of $E\_RES\_curtailed_{SG}$

The proposed KPI formulations are intended to capture the contribution of Smart Grids to reduce the instances where shedding of RES takes place. However, there might be cases where shedding of intermittent energy sources can provide substantial benefits in terms of network security and investment reduction and is in fact the best strategy to pursue. If, depending on local circumstance, the RES energy not withdrawn in those instances is not the same in both the BaU and the SG scenarios, then the KPI calculation should be accordingly corrected.

3. NETWORK CONNECTIVITY AND ACCESS TO ALL CATEGORIES OF NETWORK USERS

a) Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both

The implementation of Smart Grids provides a granular array of information that can be used by regulators to better allocate the costs of the electricity system among different users.

This KPI could be expressed qualitatively by listing the new information that can be measured and collected and by highlighting how this information can be used in defining more accurate methods of allocating costs.

b) Operational flexibility provided for dynamic balancing of electricity in the network

A possible metric for this KPI is:

$$KPI_{3b} = \frac{P_{disp_{SG}} - P_{disp_{BaU}}}{P_{Peak}} \times 100$$

Where $Pdisp_{SG}$ is the capacity of dispatchable resources (generation, storage and controllable loads) connected to the grid under consideration in the SG scenario

$Pdisp_{BaU}$ is the capacity of dispatchable resources (generation, storage and controllable loads) connected to the grid under consideration in the BaU scenario

Both $Pdisp_{SG}$ and $Pdisp_{BaU}$ should be corrected using a suitable simultaneity factor, taking into account that not all dispatchable resources can be operated at the same time.

P_{Peak} represent the average electricity demand in the BaU over the predefined period of time.

Other possible options for the quantification of the KPI include:

- comparing the needs in operating reserves before and after the project deployment

-Extent to which storage and DG are able to provide ancillary services as a percentage of the total offered ancillary services [Dupont et al. 2010]

-Percentage of storage and DG that can be modified vs. total storage and DG [MW/MW] [Dupont et al. 2010]

4. SECURITY AND QUALITY OF SUPPLY

a) Ratio of reliably available generation capacity and peak demand

The Reliably Available Capacity (RAC) on a power system is the difference between Net Generating Capacity and Unavailable Capacity [UCTE, 2009].

√ Net Generating Capacity of a power station is the maximum electrical net active power it can produce continuously throughout a long period of operation in normal conditions, where [UCTE, 2009]:

¨ "net" means the difference between, on the one hand, the gross generating capacity of the alternator(s) and, on the other hand, the auxiliary equipments' load and the losses in the main transformers of the power station;

¨ for thermal plants "normal conditions" means average external conditions (weather, climate…) and full availability of fuels;

¨ for hydro and wind units, "normal conditions" refer to the usual maximum availability of primary energies, i.e. optimum water or wind conditions.

√ Unavailable Capacity is the part of Net Generating Capacity that is not reliably available to power plant operators due to limitations of the output power of power plants [ENTSOE, 2009].

The Reliably Available Capacity is the part of Net Generating Capacity actually available to cover the load at a reference point [UCTE, 2009].

Let us consider, as reference point, the peak load point over a predefined period of time (for example over a year). The ratio between the reliably available generation capacity and the peak demand (P_{peak}) is representative of the system adequacy. The KPI could then be expressed as a percentage variation of this ratio in the BaU and in the SG scenarios.

$$KPI_{4a} = \frac{\left(\frac{RAC}{P_{peak}}\right)_{SG} - \left(\frac{RAC}{P_{peak}}\right)_{BaU}}{\left(\frac{RAC}{P_{peak}}\right)_{BaU}} \times 100$$

b) Share of electricity generated from renewable sources

This KPI can be quantified in terms of percentage variation of the share of electricity generated from renewable sources[7] that can be safely integrated in the system in the SG and in the BaU scenarios (over a defined period of time, e.g. over a year), assuming the same total amount of electricity generated in both scenarios:

$$KPI_{4b} = \frac{E\_RES_{SG} - E\_RES_{BaU}}{E_{total}}$$

Where

E_RES_{SG} and E_RES_{RES} represent the amount of electricity generated from renewable sources in the SG and in the BaU scenarios.

E_{total} is the total energy consumption in the distribution grid under consideration in the defined period (it is assumed constant before and after the project) [MWh].

The calculation of RES energy requires the estimation of the installed capacity [MW] and of the equivalent running hours of the different types of RES units considered [h/yr] (see e.g. [ENTSOE 2009]). We recommend highlighting clearly and transparently how the estimation has been carried out.

c) Stability of the electricity system

A preliminary analysis would identify whether the implementation of the Smart Grid project is able to remove the cause of possible system instabilities (typically in terms of voltage and frequencies) that were observed in the portion of the grid under consideration. The analysis could be conducted by defining contingency scenarios where the stability of the system is put under stress.

d) Duration and frequency of interruptions per customer, including climate related disruptions

This KPI is expressed by calculating the variations of reliability indexes in the Smart Grid and in the BaU scenario.

We recommend considering the following reliability indexes:

[7] As indicated in Directive 2003/54/EC , 'renewable energy sources' means renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases);

√ SAIDI is the System Average Interruption Duration Index [min] and represents the average outage duration for each customer served

√ -SAIFI is the System Average Interruption Frequency Index [units of interruptions per customer] and represents the average number of interruptions that a customer would experience.

The corresponding KPIs are:

$$KPI^{1}_{4d} = \frac{SAIDI_{BaU} - SAIDI_{SG}}{SAIDI_{BaU}} \times 100$$

$$KPI^{2}_{4d} \frac{SAIFI_{BaU} - SAIFI_{SG}}{SAIFI_{BaU}} \times 100$$

e)Voltage quality performance

The impact of the Smart Grid project on voltage quality performance can be assessed keeping track of short interruptions, voltage dips, flicker, supply voltage variation and harmonic distortions .

As mentioned in [CEER 2008], it is useful to group the different voltage disturbances mentioned above into continuous phenomena and voltage events. For each quality parameter to be regulated, it is important that it can be observed, quantified and verified.

√ Continuous phenomena are voltage variations that occur continuously over time. Continuous phenomena are mainly due to load pattern, changes of load or nonlinear loads. They occur continuously over time and can often be satisfactorily monitored during measurement over a limited period of time, e.g. 1 week.

√ Voltage events are sudden and significant deviations from normal or desired wave shape or RMS value. Voltage events are typically due to unpredictable events (e.g. faults) or to external causes. Normally voltage events occur only once in a while. To be able to measure voltage events, continuous monitoring and the use of predefined trigger values are necessary.

In order to assess the impact of the Smart Grid project over voltage quality performance, we recommend calculating the variation in the SG and BaU scenarios of:

1) Voltage line violations (over a predefined period of time, e.g. yearly), defined in accordance with the EN 50160 standard. The resulting KPI could be expressed in terms of number of voltage line violations over a predefined period of time:

$$KPI_{4e}^{1} = \frac{(Voltage\_violations)_{BaU} - (Voltage\_violations)_{SG}}{(Voltage\_violations)_{BaU}}$$

If feasible, the duration of voltage line violations in the BaU and SG scenarios can also be considered in this analysis.

Violations are calculated with reference to the following requirements:

-Variations in the stationary voltage RMS value are within an interval of +/-10% of the nominal voltage (in steady state)

-Number of micro-interruptions, sages and surges, assessing the number of events (MV-LV violations) recorded over a given time period (one year for example). Dips and surges are recorded when the voltage exceeds the threshold of +/-10% of its nominal value (in transient state).

2) Total harmonic distortion factor (THD).

The THD can be measured as defined in EN 50160. The KPI could be expressed as the percentage variation between the BaU and the SG scenarios.

$$KPI_{4e}^{2} = \frac{(THD)_{BaU} - (THD)_{SG}}{(THD)_{BaU}}$$

5. EFFICIENCY AND SERVICE QUALITY IN ELECTRICITY SUPPLY AND GRID OPERATION

a) Level of losses in transmission and in distribution networks

This KPI is expressed as:

$$KPI_{5b} = \frac{EL_{BaU} - EL_{SG}}{E_{tot}} \times 100$$

Where EL_{BaU} represent the yearly level of energy losses [MWh] in the portion of the grid under consideration in the BaU scenario;

EL_{SG} represent the yearly level of energy losses [MWh] in the portion of the grid under consideration in the SG scenario;

E_{tot} represents the total yearly energy consumption in the portion of the grid under consideration [MWh]. For sake of simplicity, it is assumed to be the same in the BaU and SG scenarios.

Project promoters should also highlight which local structural parameters (e.g. the presence of distributed generation in distribution grids and its production pattern) are affecting the value of the KPI. It is possible that energy losses might actually increase in the SG scenario due to higher penetration of DER. For example, if applicable, project promoters could analyse the ratio between energy losses and the amount of energy injected from DER in the SG and BaU scenarios and highlight that, even if the absolute value of losses has increased, a relative improvement with respect to the amount of injected DER energy is observed.

b) Ratio between minimum and maximum electricity demand within a defined time period

The KPI should calculate the variation in the ratio between minimum (P_{min}) and maximum (P_{max}) electricity demand (within a defined time period, e.g. one day, one week) as a consequence of the implementation of the project

$$KPI_{5b} = \frac{\left(\frac{P_{\min}}{P_{\max}}\right)_{SG} - \left(\frac{P_{\min}}{P_{\max}}\right)_{BaU}}{\left(\frac{P_{\min}}{P_{\max}}\right)_{BaU}} \times 100$$

Or alternatively:

$$KPI_{5b} = \frac{\Delta P_{BaU} - \Delta P_{SG}}{\left(P_{Peak}\right)_{BaU}}$$

Where ΔP_{BaU} represents the difference between minimum and maximum electricity demand (within a predefined period of time, e.g. one week or one year) in the BaU scenario,

ΔP_{SG} represents the difference between minimum and maximum electricity demand (within a predefined period of time, e.g. one week or one year) in the SG scenario,

P_{Peak} represents the peak electricity demand in the BaU over the predefined period of time.

The choice of P_{Peak} as normalisation factor is intended to reward projects for which the reduction between minimum and maximum electricity demand represents a higher share of the peak power load in the BaU.

As recommended in [ERGEG 2010; Task Force Smart Grids EG3 2011], in case of comparison, a structural difference in the indicator should be taken into account due e.g. to electrical heating and weather conditions, shares of industrial and domestic loads".

c) Demand side participation in electricity markets and in energy efficiency measures

We express demand side participation as the amount of load participating to demand side management. The KPI is expressed as variation of demand side participation in the BaU and SG scenarios normalized to the maximum electricity demand within a pre-defined time period (e.g. one day, one week):

The KPI can be then expressed as:

$$KPI_{5c} = \frac{(P_{DSM})_{SG} - (P_{DSM})_{BaU}}{P_{peak}} \times 100$$

where P_{DSM} represents the amount of load capacity participating in DSM in the BaU and SG scenarios, and P_{peak} represents the maximum electricity demand.

The choice of P_{peak} as normalization factor is intended to reward projects having, for the same peak electricity demand, a higher increase in P_{DSM} in absolute terms.

Project promoters shall clearly highlight the assumptions made in estimating P_{DSM} (e.g. for example highlighting the considered simultaneity factor).

A similar idea is proposed in [Dupont 2010], where one of the proposed KPI to assess Smart Grid progresses is the percentage of consumer load capacity participating in DSM.

d)Percentage utilisation (i.e. average loading) of electricity network components

It is expected that thanks to Smart Grid capabilities, it will be possible to make better use of grid assets in terms of capacity utilisation. Depending on local circumstances, average loading might increase or decrease in the Smart Grid scenario. It is up to project coordinators to demonstrate how the Smart Grid project, by affecting the average loading of the network components, is providing benefits (e.g. increased available capacity thanks to optimization of average loading; avoided investment costs thanks to better use of existing resources etc.).

We recommend highlighting clearly which national/local factors affect the analysis.

e)Availability of network components (related to planned and unplanned maintenance) and its impact on network performances

The Smart Grid implementation can have positive effects on the availability of network components. The implementation of Smart Grid capabilities potentially allows condition-based maintenance and reduces the stress of grid components. This might reduce the mean time between failures - MTBF (as components are operated at their optimal working point) and the mean time to repair - MTTR (thanks to faster identification of faults and to condition-based/proactive maintenance). For example, the possibility of remote control of MV devices reduces the need of intervention of work field teams and ensures short time failures. In distribution transformer stations and MV/BT transformer the constant monitoring of temperature, pressure, gas, intrusion, flood is important to anticipate problems.

In general, the availability of components is defined as

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

Where MTBF is the mean time between failures

And MTTR is the mean time to repair (including planned and unplanned maintenance)

For a given component, the KPI can be expressed as the percentage variation of its availability in the BaU and SG scenarios.

The indicator might be applied only to those components whose availability is indispensable for optimal grid performance and have a direct impact on output-based indicators like SAIDI and SAIFI (see KPI_{4d}). An alternative way to measure the impact of increased availability on network performances is to measure the increase in the network equipment lifespan in the SG scenario.

If some sort of estimation is feasible, it could also be carried out a comparison between the number of unplanned maintenance interruptions before ad after the project implementation.

f)Actual availability of network capacity with respect to its standard value

As clarified in [CEER, 2011], "There are two possible understandings of this type of indicator:

-The availability of network capacity compared to a reference value at national or local level; or

-The actual availability of network capacity in selected lines or network cross-sections compared to their nominal capacity (e.g. winter peak net transfer capacity), due to unavailability of some network components or actual operational conditions. "

In this document we recommend following the second approach. The resulting KPI can be expressed as:

$$KPI_{5f} = \frac{P_{SG} - P_{BaU}}{P_N}$$

Where P_{SG} and P_{BaU} represent the sum of the actual network capacities [MW] of the considered lines or network cross-sections, in the SG and BaU scenarios respectively. P_n is the sum of the nominal network capacities (standard value) of the considered lines or network cross-sections.

6. CONTRIBUTION TO CROSS-BORDER ELECTRICITY MARKETS BY LOAD-FLOW CONTROL TO ALLEVIATE LOOP-FLOWS AND INCREASE INTERCONNECTION CAPACITIES

a) Ratio between interconnection capacity of a Member State and its electricity demand

This ratio should have a value of at least 10%[8], i.e. the minimum interconnection capacity to ensure that, in case of significant events affecting one Country/zone electricity supply, at least 10% of the demand can be covered through imports. Calculation of the ratio (*r*) is usually carried out on yearly data as follows:

$$r_j = \frac{r\sum_i \mu_i(NTC_i)}{E_{tot\,j}} \times 100$$

Where i refers to each single interconnection from a Country/zone j to another Country/zone j and μ(NTC) is the average NTC (Net Transfer Capacity[9]) throughout the year per border i. $E_{tot\,j}$ represents the total electricity demand in Country/zone j.

It should be noted that this indicator is mostly significant for interconnections between Countries/zones where capacity calculation is based on ATC (Available Transfer Capacity). According to the Framework Guidelines for Congestion Management and Capacity Allocation, capacity in highly meshed networks should instead be calculated through flow-based calculation method[10], therefore a correct estimation of SG benefits on loop-flows should be assessed through a simulation of power flow change in the selected network branch.

In any event, the KPI should express the percentage variation of the aforementioned ratio in the SG and BaU scenarios.

$$KPI_{6a} = \frac{r_{BaU} - r_{SGproject}}{r_{BaU}} \times 100$$

b) Exploitation of interconnection capacities

[8] Presidency Conclusions of the Barcelona European Council (March 2002), where it has been agreed that "the target for Member States of a level of electricity interconnections [should be] equivalent to at least 10% of their installed production capacity by 2005".

[9] ENTSO-E Procedures for Cross-border transmission capacity assessment https://www.entsoe.eu/resources/ntc-values/

[10] Draft Framework Guidelines on Capacity Allocation and Congestion Management for Electricity - Initial Impact Assessment page 25

The exploitation of interconnection capacities can be calculated by comparing the yearly allocated NTC per border with the average yearly load flow on that same interconnection. These data are available through ENTSO-E Data Portal[11] for each European Interconnection. Actual load flow is measured conventionally every Wednesday at 03.00 am (proxy for off-peak load flow) and at 11.00 am (proxy for peak load flow). In order to calculate such Exploitation rate, the following formula can be used, where *i* stands for each interconnection and *μ* is the average of annual Load Flow values, measured as above:

$$ER_i = \frac{\mu_i(load\_flow)}{NTC_i} \times 100$$

Where ER_i is the exploitation rate for the interconnector i.

As above, the related KPI measures the percentage variation of the ratio in the SG and BaU scenarios:

$$KPI_{6a} = \frac{ER_{BaU} - ER_{SGproject}}{Er_{BaU}} \times 100$$

c) Congestion rents across interconnections

Congestion rents can be calculated both ex-ante and ex-post. For the purposes of evaluating projects before their actual implementation, as provided by the Proposal of Regulation on Guidelines for Trans-European energy infrastructure, the ex-ante estimation of congestion rent is the most appropriate. Ex-post evaluation will then be used in order to monitor the effectiveness of the Smart Grid project during and after its implementation.

Ex ante estimation of congestion rents (CR) can be derived by looking at the results of interconnection capacity auctions, i.e. how the market participants value that specific interconnection capacity in any on the selected interconnection i:

$$CR_i = \sum_i \left(\mathrm{Re}\,v_{yearly_i} + \mathrm{Re}\,v_{monthly_i} + \mathrm{Re}\,v_{daily_i}\right)$$

After the project is implemented, the ex-post calculation of congestion rents can be performed through calculating the sum of allocated interconnection capacity allocated on each interconnection i per single hour of the year, multiplied by the price differential per single hour on that same interconnection:

$$CR_i = \sum_i \left(MW_{AllocatedC_{h,i}} \times \Delta price_{h,i}\right)$$

[11] https://www.entsoe.eu/resources/data-portal/exchange/

The proposed Smart Grids projects should contribute to alleviate price differentials between two price zones/Countries. Moreover, the comparison of ex ante and ex post congestion rents in the same year and in previous years may also provide some relevant information on the actual SG impact on cross-zonal congestion.

ANNEX III A GUIDE TO THE CALCULATION OF BENEFITS

This annex provides a description of possible formulae for the calculation of benefits. The list is however not exhaustive, and project promoters may, if duly justified, use other calculation methods. Benefits should be calculated for each year of the time horizon of the analysis.

Other benefits, which might be not relevant for MV projects, refer more to the customers' side and include: reduced meter reading costs; reduced meter operation costs; reduced billing costs; reduced electricity theft; reduced call centre/customer care costs etc.

a. Reduced operations and maintenance cost

To calculate these benefits, the scenario should track the distribution operational and maintenance cost before and after the Smart Grid project takes place. These benefits will typically consist of different components, like reduced maintenance costs, reduced rate of breakdowns etc. The benefits refer to the cost reduction which is due to monitoring and real-time network information, quicker detection of anomalies and reduced amount of time between a breakdown and the restoring of the supply. The following formulae are proposed for the calculation of their monetary impact:

Reduced maintenance costs of assets

Value (€) = [Direct costs relating to maintenance of assets(€)]$_{Baseline}$ – [Direct costs relating to maintenance of assets (€)] $_{SGproject}$

Through remote control and monitoring of asset conditions and utilization (e.g. secondary substations LV), site visits could be avoided. However, it might also be the case that the installation of additional grid components increases the overall need for maintenance costs.

Reduced cost of equipment breakdowns

Value (€) = [Cost of equipment breakdowns (€)]Baseline – [Cost of equipment breakdowns (€/)] $_{SGproject}$

With a better knowledge of power flow and distributions of charge in the grid, less equipment (e.g. transformers) is likely to break down due to overcharge or maintenance failures. The benefit value can be estimated by considering the expected reduction in the number of equipment requiring replacement and the average cost of the equipment.

b. Deferred distribution capacity investments

The assumption underlying the monetization of this benefit is that the implementation of Smart Grid solutions will potentially allow reducing consumption and peak load or at least a reduction in their growth rate in cases where there are underlying industrial, economic or social reasons for growth in electricity demand.

Additionally the Smart Grid solutions are expected to enable the integration of distributed generation reducing the need of network reinforcements.

Taken cumulatively, these two effects would lead to a reduction of maximum installed capacity required and consequently to a deferral of investments. However it must be borne in mind that unless the two effects are entirely discretely measured, the savings calculated may not necessarily be treated as cumulative benefits.

Monetization of these benefits across a system can only be indicative and the more specific the deferral (pertaining to several specific networks affected by a Smart Grid project), the more accurate the projected savings.

A potential calculation method is the following.

The first step is to estimate the future incremental cost for the reinforcement of the grid due to the growing peak demand. Hence, it is necessary to estimate the incremental cost per MW of peak demand [€M/ΔMW]. This can be done considering the planned reinforcement projects to meet growing peak demand. Projections about growing peak demand are based on the projected growth rates. These rates can be determined on the basis of historical growth, economic, social and industrial factors.

The second step is to understand the reasons of peak reduction. We observe that peak reduction can be mainly achieved through two different ways: consumption reduction and peak load shifting.

Then it is necessary to distinguish the consumers whose consumption level can be affected by the Smart Grid project implementation. For example: In a smart metering project, we can assume that consumption reduction (e.g. 1%) should be applied only to the quota of peak demand due to domestic and small commercial loadings.

Separately, the potential for deferred cost of capacity (due to peak load shifting) needs to be calculated. This calculation should consider only those networks where the peak corresponds with the general peak (e.g. 6pm) when the potential for peak load shifting is higher.

The third step is the calculation of the benefit for both the consumption reduction and peak load shift. The benefit is calculated as a percentage of reduction on the Incremental cost per MW of peak demand. The formulas for the calculations are the following:

Deferred distribution capacity investments due to consumption reduction:

Value (€) = Peak demand reduction due to energy savings [MW]* Incremental cost per MW of peak demand [€M/ΔMW]

Deferred distribution capacity investments due to peak load shift:

Value (€) = Peak demand reduction due to peak load shift [MW]* *% of networks where the peak corresponds with general peak *Incremental cost per MW of peak demand [€M/ΔMW]

Where

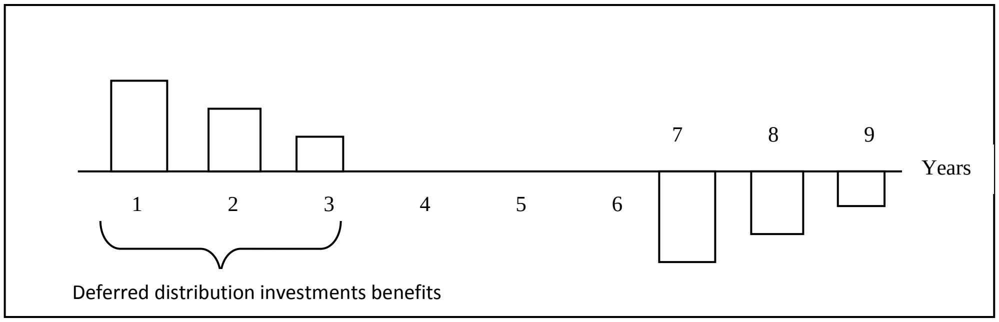
Peak demand reduction due to energy savings [MW] = % demand reduction * peak demand * % contribution of domestic and commercial load (or whatever load-type is influenced by the project in question)

The CBA calculation will then include:

The (discounted) avoided costs of the reinforcement project, allocated on the years where the reinforcement project was planned

The (discounted) costs of the reinforcement project, allocated to the years when the investment will take actually place after the deferral (provided that these costs are still within the time horizon of the CBA)

In the graph it is demonstrated an example of benefits due to deferred distribution investments allocated on the time horizon of the project. It can be observed the effect of discount rate on the net present values of benefit (decreasing benefits). It is assumed that investments have been deferred by six years, after which they are undertaken.



c. **Deferred transmission capacity investments**

For the calculation of this benefit, similar considerations made at the distribution level apply (see previous item). Similar monetization formulae can be used.

d. **Deferred generation capacity investments**

For the calculation of this benefit, we suggest considering the impact on the amount of generation capacity investments of peak load plants on the one hand and of spinning reserves on the other hand.

The underlying assumption concerning the monetization of this benefit is that the Smart Grid scenario will potentially allow reducing consumption and peak load and will provide demand side management tools to cope with supply variability. Taken cumulatively, these effects would lead to a reduction of maximum installed capacity and consequently to a deferral of investments.

Deferred generation investments for peak load plants:

Value (€) = Annual investment to support peak load generation (€/year) * Time deferred (# of years)

This takes into account the price of the marginal unit at peak and assumes that generation deferral is based on reducing peak demand.

Deferred generation investments for spinning reserves

Value (€) = Annual investment to support spinning reserve generation (€/year) * Time deferred (# of years)

e. **Reduced electricity technical losses**

As mentioned in the EPRI methodology, several Smart Grid functions can contribute to loss reductions, and scenarios that demonstrate more than one of them at once will see compounded effects. The total benefit of reduced power losses comprises different sub-categories of benefits. They are related to i) energy efficiency (consumption reduction and peak load transfer at the distribution level, ii) improved balancing between phases, iii) increased distributed (micro-generation); iv) voltage control and v) consumption reduction at the transmission level.

One way of estimating technical loss reductions is the use of simulators. Another possibility to determine loss reductions, e.g. on a distribution feeder, would be to measure and compare hourly load and voltage data from smart meters as well as hourly load and voltage data from the head end of the feeder at the substation [EPRI 2011].

Reduced electricity technical losses:

Value (€) = Reduced losses via energy efficiency (€) + Reduced losses via voltage control (€) + Reduced losses at transmission level (€)

As an example, in this formula we include the estimated loss reductions via energy efficiency and via voltage control at distribution level and the estimated loss reductions at transmission level.

f. Electricity cost savings

For the calculation of this benefit, the impact of consumption reduction and peak load transfer on electricity cost savings have been considered. The following formulae are suggested for the calculation of the monetary impact of this benefit:

Consumption reduction:

Value (€) = Energy Rate (€/MWh) * Total energy consumption (MWh) * Estimated % of consumption reduction with Smart Grid scenario (%/100)

In ex ante calculations, a confident estimate of consumption reduction is difficult. Assumptions on consumption reduction can be done by analyzing international benchmarks and recent studies.

Peak Load Transfer:

Value (€) = Wholesale margin difference between peak and non-peak generation (€/MWh) * % Peak load transfer (%/100) * Total energy consumption (MWh)

The introduction of new tariff plans and detailed real-time information about consumption is expected to incentivize clients to shift part of their consumption to off-peak periods. The percentage of peak load transfer needs to be estimated. One way of monetizing this benefit is to use the price difference of the electricity wholesale margin between peak and off-peak periods (€/MWh).

g. Reduced outage times

Customer outage time can typically be measured by smart metering or outage management systems. This data can then be compared with average hourly loads to estimate the load that was not served during the outage. The value of the decreased load not served as a result of a particular asset and its functions must be attributed to that asset's contribution to the reduction in outage duration.

Reduced outage time can be achieved through monitoring and real-time network information, quicker detection of anomalies, remote management and automatic network reconfiguration. Since the % decrease in outage time varies across endpoints depending on the infrastructure installed, the value of service needs to be calculated separately for different installed assets (e.g. smart meters, distribution transformer controllers).

In principle, the estimated value of outage costs might go beyond the immediate lost load cost and reflect also other societal impacts which are difficult to quantify (e.g. uncertainty, negative perception etc.). In this perspective, the outage penalty cost set by regulators could be used, as it reflects the ultimate cost to society in the local context.

We suggest the following three formulae to calculate the monetary impact of this benefit:

Value of service:

Value (€) = Total energy consumed (MWh)/ Minutes per year (#/year) * Average non-supplied minutes/year ((#/year) * Value of Lost Load (€/kWh) * % Decrease in outage time (%)

For the calculation of this value, it is necessary to adopt an index to measure technical service quality (e.g. Interruption Time Equivalent to Installed Capacity-TIEPI) and use a target in a BaU scenario (e.g. 100 minutes/year) as a reference. The value of lost load, which is typically set as a reference by national regulators, represents an estimated cost for the economy per kWh of electricity not supplied.

Note: When estimating the load not served (average non-supplied minutes), it is important to bear in mind the potential impact of load control and the energy efficiency on load not served. The average number of non-supplied minutes could decrease after the implementation of the scenario, e.g. as a result of customers using less electricity, without any actual improvement in reliability, i.e. outage duration.

Recovered revenue due to reduced outages:

Value (€) = Annual supplier revenue (€)/ Minutes per year (#/year) * Average non-supplied minutes/year (#/year) * % Decrease in outage time (%)

While the value of service benefit is a benefit associated with society at large, as it measures the cost of outages for the economy, this benefit refers to increased supplier's revenue due to a reduction in outage time.

Reduced cost of client compensations:

Value (€) = Average annual client compensations (€) * % Reduction of client compensations

This benefit refers to a reduction of client compensations relating to losses or injuries incurred by power outages.

h. Reduced CO_2 emissions and reduced fossil fuel usage

CO2 reduction can be achieved through different means, such as the incorporation of additional renewable sources or increased energy efficiency through the implementation of the roll-out scenarios. These values are, however, complex to calculate and should be evaluated on a case by case basis.

Another possible source of CO2 emissions is related to the reduction of the total mileage of DSOs' operational fleet and the consequent savings on liters of fuels and CO2 emissions due to remote meter readings and remote network operations.

In those cases where the analysis permits the calculation of carbon costs, it is recommended to use the projected EU Emission Trading Scheme carbon prices in the

Commission reference scenario up to 2050 as a minimum lower bound, assuming implementation of existing legislation, but not decarbonisation.[12]

Benefit of reduced CO_2 emissions due to reduced line losses:

Value (€) = [Line losses (MWH) * CO2 content (tons/MWH) * Value of CO2 (€/ton)]Baseline -[Line losses (MWH) * CO2 content (tons/MWH) * Value of CO2 (€/ton)]$_{SGproject}$

This calculation monetizes the reduced CO2 emissions due to reduced line losses. If feasible, the estimation of this benefit should be integrated with a clear and transparent explanation of the value chosen for the CO2 content of the electricity produced (tons/MWH). In the definition of this value, the generation sources that are affected by the reduction of line losses should typically be taken into account.

Reduced CO2 emissions due to wider diffusion of low carbon generation sources

Value (€) = [CO2 Emissions (tons) * Value of CO2 (€/ton)] Baseline - [CO2 Emissions (tons) * Value of CO2 (€/ton)]$_{SGproject}$

This benefit captures the emission reductions due to a wider diffusion of renewable energy sources and distributed generation. This benefit is extremely challenging to capture. Its estimation should be integrated with a clear and transparent explanation of the link between the SMD and the wider diffusion of low carbon generation sources.

Benefit of reduced CO2 emissions:

Value (€) = Avoided # liter of fossil fuel (#) * Cost per liter of fossil fuel avoided (€)

This calculation monetizes the reduced CO2 emissions due to fuel savings. It is necessary to define the reduction of fleet mileage, the average consumption (liter/100km), the CO2 emissions per liter of fuel and a monetary value to CO2 emissions (€/metric ton of CO_2)

Benefit of reduced fossil fuel usage:

Value (€) = Avoided # liter of fossil fuel (#) * Cost of one liter of fossil fuel (€)

[12] Annex 7.10 of SEC (2011) 288 final- COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF

For this calculation, it is necessary to define the reduction of fleet mileage, the average consumption (liter/100km) and the price (€/liter) of fossil fuel.

i. Reduction of air pollution (Particulate Matters, NOx, SO2)

For the 'cost of air pollutants' (particulate matters, NOx, SO2), it is recommended to consult the Clean Vehicles Directive - Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles, and the "CAFÉ" (Clean Air For Europe) air quality benefits' quantification process.

Reduced air pollutants emissions due to reduced line losses

For each pollutant:

Value (€) = [Line losses (MWh) * air pollutant content (unit/ MWh)* cost of air pollutant (€/unit)] $_{Baseline}$ ***-***

Line losses (MWh) * air pollutant content (unit/MWh)* cost of air pollutant (€/unit)] $_{SGproject}$

Reduced air pollutants emissions due to wider diffusion of low carbon generation sources (enabled by the Smart Grid project)

For each pollutant:

Value (€) = [air pollutant Emissions (unit) * cost of air pollutant(€/unit)] $_{Baseline}$ ***— [air pollutant Emissions (unit) * cost of air pollutant(€/unit)]*** $_{SGproject}$

ANNEX IV – POSSIBLE ADDITIONAL PROJECT IMPACTS TO ARGUE FOR THE ECONOMIC VIABILITY OF THE PROJECT

In the following we provide a (non-exhaustive) list of project impacts that might be difficult to monetize and include in the CBA. These impacts might be used to support the case for economic viability and cost-effectiveness of the project proposal. As much as possible, expected additional impacts should be expressed in physical units. Their economic relevance should be discussed.

✓ Network user/consumer inclusion

For Smart Grids to be economically and socially sustainable, consumers need to be engaged through understanding, trust and clear tangible benefits, like economic benefits, increased market choice, and greater awareness.

In this context, it is worth mentioning that the Task Force has put forward three consumer-related criteria [EC 2010c] that have not been included in the regulation proposal:

- ✓ Enhanced consumer awareness and participation in the market by new players
- ✓ Consumer bills are either reduced or upward pressure on them is mitigated
- ✓ Create a market mechanism for new energy services such as energy efficiency or energy consulting for customers

These indicators could be used in the assessment of project impact in terms of consumer inclusion and empowerment.

During the project, the adverse impact on network users should be minimized. Any expected or potential adverse impact should be discussed with the impacted network users.

✓ Employment

In this area, one important challenge is to evaluate the impact on jobs along the whole value chain, and identify the segments where jobs might be lost and the segments where jobs might be produced.

The analysis might include an estimation of the number of jobs in the supply and operation value chain. The first direct impact is on utility jobs created by Smart Grid projects that require new skills and on utility positions which are retrained for other roles. A second direct impact is on new jobs for service providers working to the implementation of the project.

Other categories that might be impacted include direct and indirect utility suppliers (supply chain providers like manufacturers, communication providers, integrators etc.), aggregators entering the market to provide energy services, new industry players (renewable energy suppliers, electric vehicle manufacturers and suppliers etc.).

This criterion should be considered together with the improvement in skills endowment of all stakeholders (see below).

- ✓ **Safety**

This analysis might take into account new possible sources of hazard or of reduction of hazard exposure (e.g. fewer field workers due to remote reading through smart meters).

It is important that companies are responsible to ensure that both direct employees and workers from third-parties have the adequate training and skills. Third parties should be appropriately vetted for competence and compliance including health and safety standards. Moreover, each project application should present clearly what are the safety standards applicable to any component of the project, and prove that HSE management systems are put in place to ensure compliance.

If feasible, a quantitative indicator might be an estimation of the reduction in the risk of death or serious injuries.

- ✓ **Social acceptance**

In several instances, social acceptance is critical for the successful implementation of Smart Grid projects. Social resistance might arise due to concerns over transparency, over fair benefit sharing or over environmental impact. (e.g. [Wolsink 2012]). The consequences of the project on this subject should be assessed and mitigation strategies proposed.

- ✓ **Enabling new services and applications and market entry to third parties**

This analysis should try to assess which new services and applications might be enabled by the implementation of the Smart Grid project under consideration. It should assess the impact of the project in creating new opportunities for third parties (e.g. aggregators, telecommunication companies) to enter the electricity market. The analysis could also assess whether the project contributes to minimize any risk for a monopoly player to use its monopoly position to obtain an advantage on an open market.

- ✓ **Time lost/saved by consumers and network users**

The analysis might try to capture and quantify (e.g. in terms of minutes) the impact of the implementation of Smart Grid technologies on time saved/lost by network users/consumers.

- ✓ **Ageing work force – gap in skills and personnel**

This analysis might address the impact of the project in terms of reducing the gap in skills and personnel due to "Greying workforce”, i.e. shortages of qualified technical personnel due to retirement of skilled technicians. It might also analyze the impact of the project in terms of creation of new skills and knowledge that might increase know-how and competitiveness.

- ✓ **ICT system performances**

The analysis might quantify the impact brought by the project in terms of ICT system performances (e.g. increased network availability, reduced latency, improved communication rate etc.) and related potential new applications and services.

This analysis might also address the foreseen activities to develop measures to ensure data protection and cyber-security related to the implementation of ICT systems. It might qualitatively include the additional costs that are foreseen to implement preventing measures or the benefits resulting from reduced risks.

- ✓ **Dissemination of the results**

A further criterion could be the extent to which experience from the project and any results from the project and from experiments performed during the project are disseminated over a wide audience. A dissemination plan could be submitted together with the project proposal and the level of dissemination could be considered as a further impact of the project.

ANNEX V – MULTI-CRITERIA DECISION ANALYSIS USING THE ANALYTIC HIERARCHY PROCESS (AHP) METHOD

The Analytic Hierarchy process is a multi-criteria decision analysis. It consists in systematically extracting judgment by means of pair-wise comparisons, by firstly posing the question “which of the two is more important?” and secondly “by how much?”. The strength of preference per pairs is expressed on a semantic scale of 1 (equality) to 9 (i.e. an indicator can be voted to be 9 times more important than the one to which it is being compared).

The first step of the procedure consists in applying this process to calculate the relative weights of the different criteria (see table 2). The hypothetical example reported in table 3 indicates that criterion B is considered to be weakly more important than criterion A (3 in a scale of 10) and very strongly more important than criterion C (7 in a scale of 10).

Objective	Criterion A	Criterion B	Criterion C
Criterion A	1	1/3	1
Criterion B	3	1	7
Criterion C	1	1/7	1

Table 2: Comparison matrix of three criteria (semantic scale)

The second step is to make pair-wise comparisons of project alternatives with respect to each of the criteria (which project scores higher with regard to this criterion?). In this way it is possible to come up with the relative strengths of each project alternative with respect to each criterion. The hypothetical example in table 3 indicates that, with respect to criterion 1, project C is as good as project A (1 in a scale of 10) and strongly better than project B (5 in a scale of 10).

Project alternative with respect to criterion 1	Project A	Project B	Project C
Project A	1	1/4	1
Project B	4	1	1/5
Project C	1	5	1

Table 3: Comparison matrix of three project alternatives with respect to criterion 1 (semantic scale)

By combining the weights calculated in step 1 and step 2, it is possible to come up with a ranking of the different project alternatives with respect to all the criteria. For sake of clarity, annex VI reports an illustrative example of implementation of the AHP method. More details can be found in [Saaty T. 2008].

Application of the AHP to project appraisal and ranking

The AHP is intended to support the project evaluators (i.e. the regional group, as defined in the Regulation Proposal) to apply their expert judgement in a structured way.

We stress that the AHP evaluation is based on the parallel (or joint) comparison of projects against the set of criteria, rather than the individual evaluation of each project against each of the criteria.

Therefore it allows to have a common reference system and to come up with a ranking of the proposed projects.

For the purpose of comparing and evaluating project proposals against the six policy criteria and against the economic criterion, we propose to use the AHP three times, in three separate steps (see figure 6).

First, the AHP will be used to evaluate project scores against the six policy criteria (AHP_1). The outcome of this first step is a ranking of the project proposals based on the six policy criteria. In this first phase, the six policy criteria could all be weighted the same.

In the second step, the AHP will be used to evaluate project scores against the economic criterion (AHP_2). The outcome of this second step is a ranking of project proposals based on the economic criterion.

In the third step, the AHP will again be used to combine the scores of projects against the policy and economic criteria and come up with the final ranking of project proposals (AHP_3).

By applying the AHP in this way, we aim at maximizing the transparency of the evaluation process. In fact, project proposals are ranked against the policy criteria first and then against the economic criterion, before coming up with an overall project ranking.

Alternatively, the AHP can be used in a single step to combine the project performance against the policy criteria and the economic criterion at the same time.

Figure 7 summarizes the overall proposed project evaluation process, in the case where a multi-criteria decision analysis approach like AHP is chosen. The KPI and economic analysis performed by each project promoter are the inputs for the multi-criteria analysis (application of AHP in three steps) to be performed by the project evaluators through pair-wise comparisons of projects.

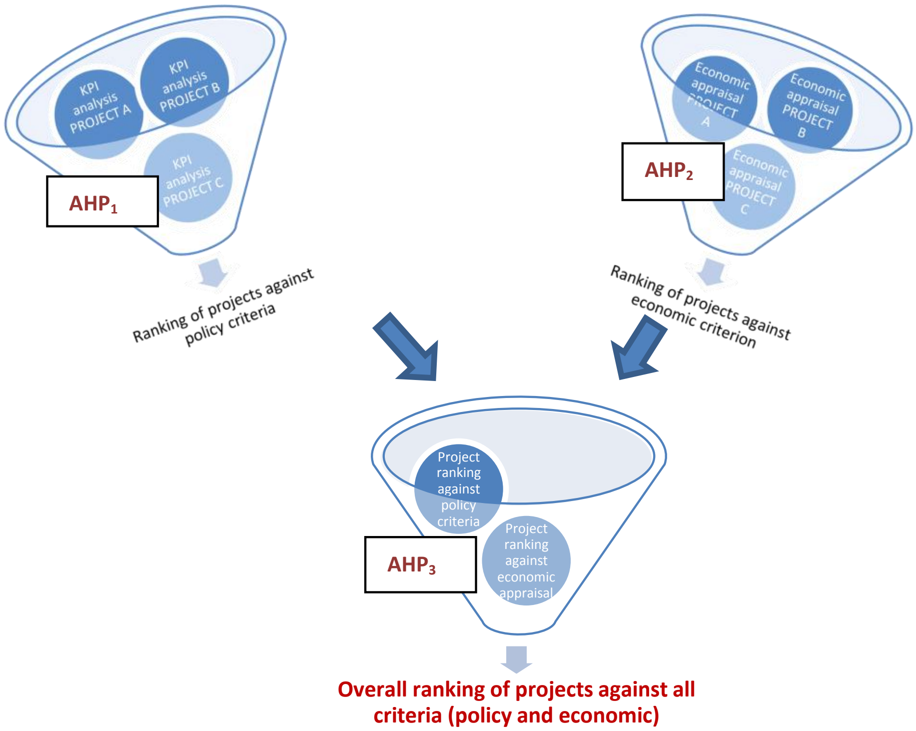


Figure 6 –Three-step implementation of the AHP (performed by project evaluators): 1)ranking of projects against policy criteria (AHP_1); 2)ranking of projects against the economic criterion (AHP_2); 3)ranking of projects against all criteria (AHP_3)

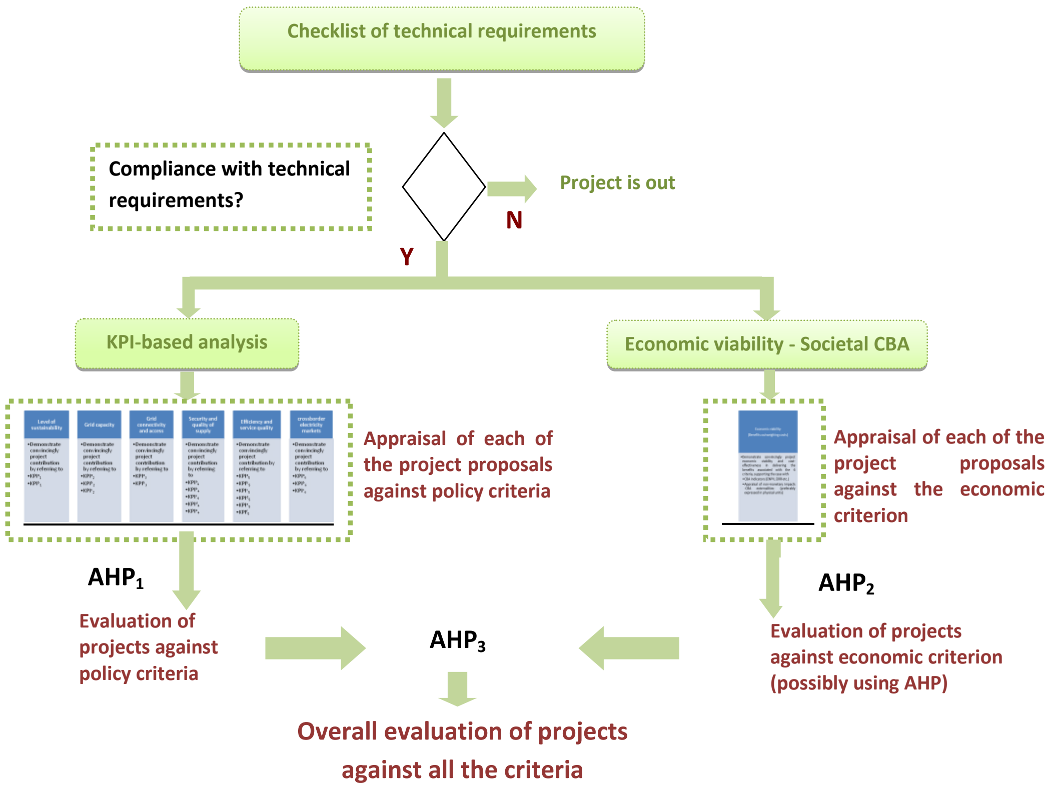


Figure 7 Flowchart of the evaluation process when the AHP approach is chosen

ANNEX VI – EXAMPLE TO ILLUSTRATE THE ANALYTIC HIERARCHY PROCESS (AHP) METHOD

In the following, we provide an illustrative example of applying the Analytic Hierarchy Process (AHP) in the assessment of three hypothetical Smart Grid projects named A, B and C. Please bear in mind that the values and the calculations provided in this example do not refer to a realistic project scenario. They have been chosen for the sole purpose of illustrating the AHP method.

As detailed in Annex V, project evaluation could be conducted by applying three times the AHP:

a) AHP for ranking the projects against the policy criteria (AHP_1)

b) AHP for ranking the projects against the economic criterion (AHP_2)

c) AHP for ranking overall the projects (AHP_3)

The same result can be achieved combining these three individual AHPs in one AHP for the overall ranking of the projects. Applying the AHP three times is intended to facilitate and make more transparent the project evaluation. Firstly, in this way, the decision-maker can have a separate appraisal of the project performance against the policy criteria and against the economic criterion before making the final- overall ranking of the projects. Secondly, in terms of structure it is more convenient to split the process into two initial steps [(a) and (b)] and one final step (c) which has as input the output of steps (a) and (b). By increasing the granularity of the process, it should be easier to allocate weights to the policy and to the economic criteria.

The main aim of this annex is to provide an illustrative example of how to apply the AHP. For sake of brevity only AHP_3 will be presented. Thus we consider steps (a) and (b) completed and we use their output (i.e. projects' ranking in AHP_1 and AHP_2) as an input to the final AHP_3 in step c. As mentioned, in step (a) the AHP is used for ranking the projects against the six policy criteria while in (b) the AHP is used for ranking the projects against one economic criterion. The resulting scores of AHP_1 and AHP_2 are reported in table 4.

CRITERIA/PROJECTS	PROJECT SCORES AGAINST THE SIX POLICY CRITERIA (OUTPUT OF AHP_1)	PROJECT SCORES AGAINST THE ECONOMIC CRITERION (OUTPUT OF AHP_2)
Project A	0.4	0.6
Project B	0.8	0.3
Project C	0.12	0.15

Table 4: Output of AHP1 (project scores against the 6 policy criteria) and AHP2 (project scores against the economic criterion)

Three basic steps should be followed for applying AHP process in the assessment of the three projects:

- 1st Step: Assess the relative weights of the different criteria.
- 2nd Step: Make pair-wise comparisons of project alternatives with respect to each of the criteria.
- 3rd Step: This final step consists of the synthesis of 1st and 2nd step in order to get the overall priorities for each alternative.

✓ **First step**

The first step of the procedure is to assess the relative weights of the different criteria. To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one criterion is over another criterion with respect to the objective they are compared. Table 5 details the scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	Experience and judgement slightly favour one activity over another
3	Moderate importance	
4	Moderate plus	Experience and judgement strongly favour one activity over another
5	strong importance	
6	Strong plus	An activity is favoured very strongly over another; its dominance demonstrated in practice
7	Very strong or demonstrated importance	
8	Very, very strong	The evidence favouring one activity over another is of the highest possible order of affirmation
9	Extreme importance	
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity j, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1 – 1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities

Table 5: Scale of relative weights

Taking into consideration the above scale, the relative weights of the different decision criteria are filled in table 6.

Objective	Decision Criterion 1 (policy criterion)	Decision Criterion 2 (economic criterion)
Decision Criterion 1	1	1/4
Decision Criterion 2	4	1

Table 6: Relative weights among the two criteria (policy and economic)

The above table indicates that Criterion 1 (project scores against the 6 policy criteria) is 4 times more important than Criterion 2 (project scores against the economic criterion).
The three steps for calculating the priorities are:

i. Calculate the sum of each column:

In the first column we made the calculation: Σ= 1+ 4= 5
In the second column we made the calculation: Σ= 1/4+ 1= 5/4

ii. Then divide each element of the matrix with the sum of its column:

For Example the new values in the first column are: 1/5, 4/5
In the second column: 4/20, 4/5

As it can be observed the sum of each column is 1.

iii. The normalized principal priority vector (V) can be obtained by averaging across the rows. The priority vector shows relative weights among the things that we compare.

$$V = 1/2 * \begin{bmatrix} 1/5 + 4/20 \\ 4/5 + 4/5 \end{bmatrix} = \begin{bmatrix} 0.2 \\ 0.8 \end{bmatrix}$$

- ✓ **AHP - Second step**

The second step of the AHP method consists of the pair-wise comparisons of project alternatives with respect to each of the criteria.

Decision Criterion 1

	Project A	Project B	Project C
Scores	0.4	0.8	0.12

Table 7: Score of each project according to criterion 1

Project alternative with respect to decision criterion 1	Project A	Project B	Project C
Project A	1	1/2	1/3
Project B	2	1	2/3
Project C	3	3/2	1

Table 8: Pair-wise comparison matrix of the three projects with respect to the 1st criterion

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one project is over another project with respect to the criterion they are compared. Table 5 shows the scale. Table 8 shows the comparison of the economic viability of projects. One compares a project indicated on the left with another indicated at the top and answers the question: How many times more, or how strongly more is the one project than the one at the top? One then enters the number from the scale that is appropriate for the judgment: for example enters 2 in the (Project B, Project A) position meaning that Project B economic performance is 2 times better than Project A economic performance. It is automatic that 1/2 is what one needs to use in the (Project A, Project B) position.

Calculating the priorities for each criterion after completing the table with the scores includes the three steps that were also described in the First step of the AHP method. These are:

i. Calculate the sum of each column.
ii. Then divide each element of the matrix with the sum of its column.
iii. Finally, calculate priority vector by averaging across the rows.

Following all the above steps we calculate the principal priority vector (V)

$$V=1/3*\begin{bmatrix}1/6+1/6+1/6\\2/6+1/3+2/6\\3/6+3/6+1/2\end{bmatrix}=\begin{bmatrix}0.17\\0.33\\0.50\end{bmatrix}$$

Project alternative with respect to decision criterion 1	Project A	Project B	Project C	PRIORITIES
Project A	1	1/2	1/3	0.17
Project B	2	1	2/3	0.33
Project C	3	3/2	1	0.50

Table 9: Priorities of each project with respect to decision criterion 1

Decision Criterion 2:

	Project A	Project B	Project C
Scores	0.6	0.3	0.15

Table 10: Score of each project according to criterion 2

Project alternative with respect to decision criterion 2	Project A	Project B	Project C
Project A	1	2	4
Project B	1/2	1	2
Project C	1/4	1/2	1

Table 11: Pair-wise comparison matrix of the three projects with respect to criterion 2

Following the three steps (i, ii, iii) for the calculation of priorities we get:

$$V=\begin{bmatrix}0.57\\0.29\\0.14\end{bmatrix}$$

Project alternative with respect to decision criterion 2	Project A	Project B	Project C	PRIORITIES
Project A	1	2	4	0.57
Project B	1/2	1	2	0.29
Project C	1/4	1/2	1	0.14

Table 12: Priorities of each project with respect to decision criterion 2

- ✓ **AHP - Third step**

CRITERIA/PROJECTS	CRITERION 1	CRITERION 2
	0.2	*0.8*
Project A	0.17	0.57
Project B	0.33	0.29
Project C	0.50	0.14

Table 13: Overall Priorities of projects

This final step of the assessment consists of the synthesis of first and second step. It can be observed that table 13 contains the priorities of each project with respect to the two criteria (step 2). Additionally, the table contains the priority of each criterion with respect to the objective being assessed (step 1). For getting the final priorities (overall priority column) one has to multiply each priority criterion with the project priority. For getting the overall priority for each Project we should make the following calculations:

Priority of Project A= (0.2*0.17) + (0.8*0.57) = 0.49
Priority of Project B= (0.2*0.33) + (0.8*0.29) = 0.298
Priority of Project C= (0.2*0.50) + (0.8*0.14) = 0.212

Project A gets the higher score (0.49) while Project B comes second with a score of 0.298 and Project C comes third with a score equal to 0.212.

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