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Assessment framework for projects of common interest in the field of smart grids

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Title *Assessment framework for projects of common interest in the field of smart grids*

Abstract
The document presents an update of the assessment framework, a methodology to assess smart grid projects of common interest, in line with Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure. In this context, every 2 years the European Commission establishes an EU-wide list of projects of common interest (PCIs), consisting of key energy infrastructure projects in the EU. These are essential for completing the European internal energy market and reaching the EU's energy policy objectives of affordable, secure and sustainable energy. The assessment framework for smart grid PCI candidates is based on Annex V to the Regulation and it consists of: i) a checklist to verify project compliance with the general criteria, set out by the Regulation in Article 4(a) and (c); ii) a cost–benefit analysis to argue the economic viability of the project; and iii) key performance indicators (KPIs) based analysis for evaluation of the non-monetary impacts. The assessment methodology is intended to guide project promoters in preparing their project proposals and assist the Smart Grid Regional Group in proposing smart grid projects of common interest.

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Executive summary

Projects of common interest (PCIs) are key energy infrastructure projects essential for completing the European internal energy market and for reaching the EU's energy policy objectives of affordable, secure and sustainable energy. This report supports the implementation of the EU Regulation on trans-European energy infrastructure (Regulation (EU) No 347/2013) and in particular, the development of an assessment framework for the evaluation of candidate projects of common interest in the field of smart grids. It presents an update of the 2014 JRC assessment framework (European Commission, 2014a), which includes significant adjustments in both the methodological approach of the project's compliance with the general criteria laid out in the Regulation and in the evaluation of the project's contribution to the smart grid specific criteria of the Regulation.

It is intended to guide and support project promoters in preparing their proposals and assist the Smart Grid Regional Group (comprised of ministries, national regulatory authorities, electricity transmission operators, project promoters, the European Network of Transmission System Operators (ENTSO-E), the Agency for Cooperation of Energy Regulators (ACER), and the European Commission) in proposing projects of common interest in the area of smart grids.

Key conclusions

The document presents an update of the methodological approach for assessing smart grid project candidates, with regard to both the evaluation of project compliance in line with the general criteria laid out in Article 4 of Regulation (EU) No 347/2013, and the evaluation of a project's contribution to the smart grid specific criteria of the same Regulation.

The assessment framework builds upon verification of project compliance with the general criteria of the Regulation, which includes three steps:

- the project shall prove necessary for the smart grid thematic priority area;
- the potential benefits of the project, assessed according to the respective smart grid specific criteria, shall outweigh its costs, including in the longer term and;
- the project shall meet any of the following criteria: a) it involves at least two Member States by directly crossing the border of two or more Member States; b) it is located on the territory of one Member State and has a significant cross-border impact, as set out in point (1) of Annex IV to the Regulation; and c) it

crosses the border of at least one Member State and a European Economic Area country.

In this context, the update of the assessment framework expands upon the interpretation of the general criteria, in particular points (1)(a) and (c) of Article 4, and provides further clarification on general criterion 1(b) and specifically on the additional criteria for significant cross-border impact laid out in point (1) of Annex IV to the Regulation.

The updated framework also stresses the need for a robust cost–benefit analysis (CBA) from a societal perspective, where all costs and benefits are transparently assessed and presented according to the smart grid specific criteria outlined in the Regulation. Additionally, quantified non-monetary impacts are assessed using analysis based on key performance indicators (KPI).

Main findings

The update of the assessment framework builds on the JRC assessment framework (European Commission, 2014a) developed within the Smart Grid Task Force, expert group on smart grid infrastructure deployment, as well as comments received by the Smart Grid Regional Group. The major adjustments relate to the interpretation of the general criteria of Regulation (EU) No 347/2013 for smart grid projects of common interest as follows:

- Article 4(1)(c)(i): 'the project involves at least two Member States by directly **crossing the border** of two or more Member States' and (iii): 'the project **crosses the border** of at least one Member State and a European Economic Area country'. While in the context of electricity transmission and gas projects 'crossing the border' would imply deployment of an interconnector, for smart grids project candidates this may refer to the development and installation of cross-border ICT infrastructure for coordinated control and monitoring of the electricity network on both sides of the border, with the aim to increase exploitation of interconnection capacity, voltage enhancement, etc.
- Article 4(2)(c) on contribution to the smart grid specific criteria and point (4) of Annex IV on the KPIs used for evaluation of the project's contribution to the smart-grid-specific criteria: the assessment framework update centres on the smart grid specific criteria of Article 4(2)(c), whereas the KPIs mentioned in point (4) of Annex IV are used for assessing the project's contribution to the smart grid specific criteria. On this note, the assessment framework focuses on societal cost–benefit analysis, where the benefits are assessed according to the specific criteria and using the KPIs of point (4) of Annex IV. Additionally, positive impacts (benefits) that

cannot be expressed in monetary terms are quantitatively or qualitatively expressed using the KPI-based analysis.

Related and future JRC work

The JRC supports the European Commission's energy union strategy to make energy more secure, affordable and sustainable, and foster sustainable and efficient transport in the EU. A modern energy infrastructure is crucial for an integrated energy market and to enable the EU to meet its broader climate and energy goals. This requires considerable investment in the existing electricity and gas networks, and rapid development of their interconnections and ICT-based infrastructure. In order to face these challenges, JRC research includes desktop and experimental studies on ways to integrate renewable energy sources into the power grid. It also investigates grid interoperability with, for instance ICT and transport systems. The EU's list of projects of common interest is updated every 2 years and the JRC aims to continue supporting energy infrastructure development policies in general and smart grid deployment policies in particular.

Quick guide

To assist the development of an integrated EU energy market, every 2 years the European Commission adopts a list of key energy infrastructure projects — known as projects of common interest. This report presents an update of the assessment framework used to evaluate smart grid project proposals, after which the projects may be included in the 2017 Union list of projects of common interest. This framework aims to serve as guidance for project promoters to prepare their PCI proposals and for the Smart Grid Regional Group to propose and review projects of common interest based on the guidelines outlined in this document.

1. Introduction

1.1. Objectives

This report presents an update of the assessment framework for identification and evaluation of candidate PCIs in the area of smart grids, in line with the requirements put forward in Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure ([1]), hereinafter referred to as 'the Regulation'. It builds on the 2014 JRC assessment framework (European Commission, 2014a) and includes significant adjustments in the methodological approach of both the project's compliance with the general criteria laid out in the Regulation and in the evaluation of the project's contribution to the smart grid specific criteria of the Regulation. The assessment framework for smart grid PCI candidates is based on Annex V to the Regulation, with an aim to guide project promoters in preparing their project proposals.

The Regulation identifies 'smart grids deployment' as one of its 12 priority infrastructure corridors and thematic areas, 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. In this context, Article 2(7) of the Regulation defines a smart grid as '*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*'. Also, point (1)(e) of Annex II to the Regulation specifies a smart grid infrastructure as '*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*'.

1.2. Background

With the objective to promote a more resource-efficient, sustainable and competitive economy, the European Commission has put the energy infrastructure at the forefront by underlining the need to urgently upgrade the EU's networks and connect them at the continental level; in particular to integrate and increase the penetration of renewable energy

([1]) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:en:PDF sources.

For electricity projects falling under the categories set out in point (1) of Annex II to the Regulation, each regional group shall be composed of representatives from the Member States, national regulatory authorities, transmission system operators (TSO), as well as the Commission, ACER and ENTSO-E ([2]). The Smart Grid Regional Group represents the priority thematic area on smart grids deployment, as defined in Annex I, point (10) to the Regulation, and focuses on the adoption of 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.

In this context, PCI proposals in the area of smart grids shall comply with the general criteria set out in Article 4(1) of the Regulation and clearly demonstrate their contribution to the specific criteria, as defined in Article 4(2)(c). The assessment framework presented in this document shall thus provide project promoters with the tools to conduct the necessary assessment to apply for the status of 'project of common interest'. Furthermore, the assessment serves as a basis for the selection of smart grid projects of common. The selected projects will become part of the Union-wide list of projects of common interest; these projects are, under certain conditions ([3]), eligible for co-financing from the Connecting Europe Facility and shall become an integral part of the national ten-year network development plans.

1.3. General overview

Table 1 summarises the evaluation criteria of the smart grid assessment framework and highlights the proposed tool to perform the evaluation. It consists of the following steps:

1. Evaluation of the project set-up for the smart grid priority thematic area (compliance with eligibility requirements):
    a. the project shall be necessary for the energy infrastructure priority area;
    b. the project shall either involve at least two Member States by directly crossing the border of two or more Member States or cross the border of at least one

([2]) Each group shall determine its assessment method on the basis of the aggregated contribution to the criteria referred to in Article 4(2) of the Regulation; this assessment shall lead to a ranking of projects for the internal use of the group. However, for smart grids projects falling under the energy infrastructure category set out in point (1)(e) of Annex II, the ranking shall only be carried out for those projects that affect the same two Member States, and due consideration shall also be given to the number of users affected by the project, the annual energy consumption and the share of generation from non-dispatchable resources in the area covered by these users.

([3]) See Article 14 of the Regulation.

Member State and a European Economic Area country;

c. alternatively, it shall be located on the territory of one Member State and have a significant cross-border impact ([4]).

2. The potential overall benefits, assessed according to the six specific criteria outlined in Article 4(2)(c) of the Regulation, outweigh its costs, including in the longer term (monetary assessment). Each specific criterion shall be assessed against a set of KPIs set out in point (4) of Annex IV to the Regulation.

3. Appraisal of non-monetary impacts using KPI-based analysis.

Table 1 illustrates the assessment framework's stepwise approach. First, the project shall prove to be necessary for the smart grid priority thematic area and as such, project promoters shall clearly demonstrate the smart grid dimension of the project under the priority thematic area on smart grid deployment. Second, each project candidate shall demonstrate its compliance with the general criteria of the Regulation (Article 4(1)(c)). Third, the overall project benefits, assessed according to the respective specific criteria of the Regulation (Article 4(2)(c)), need to outweigh the project costs. This includes a societal cost–benefit analysis, where each specific criterion is assessed against a set of KPIs, as outlined in point (4) of Annex IV to the Regulation. Finally, positive impacts (benefits) that cannot be reliably expressed in monetary terms are evaluated using KPI-based analysis.

To this end, the KPIs serve as a basis for evaluation of the monetary project impacts included in the societal CBA and assess the impacts that cannot be expressed in monetary terms (e.g. electricity system stability and voltage quality performance). These are quantitatively or qualitatively expressed and included in the KPI-based analysis.

([4]) Cross-border impact as set out in point (1)(e) of Annex IV to the Regulation.

Assessment steps	Assessment tool
1. Necessity for the smart grid priority thematic area	**Checklist**
2. Compliance with the general criteria under Article 4(1)(c)	**Checklist**
3. Overall benefits outweigh costs by significant contribution to the six specific criteria	**Societal cost–benefit analysis (CBA)**
4. Appraisal of non-monetary impacts, assessed according to the specific criteria	**Analysis of key performance indicators (KPI) and corresponding metrics**

Table 1. Requirements of the smart grid project assessment

More details on the set of tools that make up the assessment framework are provided in the next sections. Chapter 2 discusses the evaluation of the project set-up, namely, the project's compliance with the general criteria of the Regulation, outlined under points 1 and 2 of Table 1. Chapter 3 presents the impact assessment, in line with the project's contribution to the specific criteria of the Regulation under Article 4(2)(c), including cost–benefit analysis guidelines to capture the economic impact of candidate projects and KPI-based analysis for assessing the non-monetary impacts. Finally, Chapter 4 summarises the content of project proposals required for the evaluation process.

The assessment framework is intended to guide and support the project promoters in preparing their proposals. It is, however, up to the project promoters to clearly and convincingly build the case for their projects. For this purpose, the project information template in Annex I should be accurately filled in by all project promoters. In particular, the project proposal needs to convincingly argue about the project's contribution to the specific criteria outlined in Article 4(2)(c) of the Regulation by making reference to the corresponding KPIs. As much as possible, the argumentation regarding the project's contribution to a particular criterion (e.g. network security, system control and quality of supply) needs to be supported by a quantification of the corresponding KPIs (e.g. ratio of reliably available generation capacity and peak demand, duration and frequency of interruption per customer, etc.).

Likewise, the project proposal should argue convincingly about the economic viability of the project by discussing how the benefits achieved outweigh the costs. These arguments should be credibly supported by quantification of monetary impacts (societal CBA) of both the benefits and the costs and use of economic indicators (e.g. economic net present value (ENPV), economic internal rate of return (EIRR) and benefit/cost ratio (B/C)) to argue about the project's economic viability.

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 the KPIs and the monetary benefits of the CBA.

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 of the calculation methods and the assumptions employed.

All assessment shall be carried out in view of the following two scenarios:

- Business as usual (BAU) scenario. This is the scenario without deployment of the smart grid project and it only considers planned maintenance. This is the reference scenario used 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 boundary conditions (load profile, generation mix, renewable energy sources profile, etc.) should be clearly illustrated and supported with reliable references.

2. Evaluation of the smart grid project set-up

Project promoters should demonstrate that the project set-up complies with the general criteria of the Regulation, as outlined in Article 4(1) (a), (b) and (c). First, project promoters need to demonstrate the project's necessity for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation) by discussing its relevance to this priority thematic area.

Second, the project promoters need to define whether the project:

a) involves at least two Member States by directly crossing the border of two or more Member States; or

b) is located on the territory of one Member State and has a significant cross-border impact ([5]); or.

c) crosses the border of at least one Member State and an European Economic Area country.

For smart grid project candidates defined under category a) or c), a project proposal needs to demonstrate in detail the role/involvement of the project promoters (a transmission system operator (TSO) or distribution system operator (DSO) from two or more Member States, or from at least one Member State and a European Economic Area country, respectively) . 'Involvement' should be understood as the participation of active promoters on both sides of the border — at least one on each side of the border having the role of a DSO or a TSO. As an indication, 'involvement' should include significant investments for each project promoter and a tangible impact on the network operations of the project promoters. If a project consists of two DSO project partners, special attention will be paid to the trans-European dimension of the project.

Additionally, project promoters shall demonstrate how the project directly impacts cross-border capacity through the smart grid project deployment. For example, smart grid investments may address the development and installation of cross-border ICT infrastructure for coordinated control and monitoring of the electricity network (at high voltage and medium voltage distribution or transmission network level; or alternatively at both). Activities may include data exchange in order to perform advanced load flow calculations on both sides of the border, and integration of such information in the TSO and DSO supervisory control and data acquisition systems, dynamic line rating, etc. These activities may result in increased exploitation of the interconnection capacity (either at DSO or TSO levels), voltage

([5]) Significant cross-border impact as set out in point (1)(e) of Annex IV to the Regulation.

enhancement due to coordinated voltage control, and energy loss optimisation, etc. These are only indicative examples; the project promoters shall argue their case with regard to compliance with the general criteria.

Project proposals falling under category (b) take place on the territory of one Member State. Given the reduced scope of investments, the project shall demonstrate a significant cross-border impact, as set out in point (1)(e) of Annex IV to the Regulation. This requires project compliance with the following requirements:

1. the project is designed for equipment and installations at high voltage and medium voltage levels of 10 kV or more;

2. the project involves transmission and distribution system operators from at least two Member States;

3. the involved transmission and distribution system operators cover at least 50 000 users that generate or consume electricity, or do both;

4. the involved transmission and distribution system operators cover a consumption area of at least 300 GWh/year, of which at least 20 % originates from renewable resources that vary in nature ([6]).

Project promoters shall argue the project's compliance with these requirements. The project proposal shall clearly demonstrate the network voltage level where the investments will take place. With regard to the second requirement, a project promoter shall describe in detail the role(s) of a project participant(s) (DSO, TSO or both), on whose territory the project will take place, and demonstrate the involvement of the TSO(s) and/or DSO(s) in the other Member State. The involvement of a TSO and/or DSO in the other Member State needs to be demonstrated to enable an assessment of the significant cross-border impact on the project's territory. However, the involvement of the DSO(s) or TSO(s) does not necessitate significant investments on the side of the involved participant. With regard to the third and fourth requirements, both requirements shall be based on a reasonable forecast, supported with relevant referenced data and clearly presented in Section A3 of Annex I to this document.

([6]) Variable renewable power plants rely on resources that fluctuate on a timescale of seconds to days, and do not include some forms of integrated storage (e.g. wind power, wave and tidal power, run-of-river hydropower, and solar photovoltaics) (International Energy Agency, 2008).

3. Project contribution to smart grid specific criteria

The benefits of the project shall be assessed according to specific criteria, outlined in Article 4(2)(c) of the Regulation. In this regard, the selected PCIs are expected to contribute to the following criteria:

1. integration and involvement of network users with new technical requirements with regard to their electricity supply and demand;
2. efficiency and interoperability of electricity transmission and distribution in day-to-day network operation;
3. network security, system control and quality of supply;
4. optimised planning of future cost-efficient network investments;
5. market functioning and customer services; and
6. involvement of users in management of their energy usage.

Moreover, point (4) of Annex IV to the Regulation specifies that each specific criterion shall be evaluated against a set of KPIs ([7]), namely:

- **KPI_1**: reduction of greenhouse emissions;
- **KPI_2**: environmental impact of electricity grid infrastructure;
- **KPI_3**: installed capacity of distributed energy resources in distribution networks;
- **KPI_4**: allowable maximum injection of electricity without congestion risks in transmission networks;
- **KPI_5**: energy not withdrawn from renewable sources due to congestion or security risks;
- **KPI_6**: methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both;
- **KPI_7**: operational flexibility provided for dynamic balancing of electricity in the network;
- **KPI_8**: ratio of reliably available generation capacity and peak demand;
- **KPI_9**: share of electricity generated from renewable sources;

([7]) The KPIs are derived from the criteria of point (4) of Annex IV: level of sustainability; capacity of transmission and distribution grids; network connectivity; security and quality of supply; efficiency and service quality; and contribution to cross-border electricity markets.

- **KPI_{10}**: stability of the electricity system;
- **KPI_{11}**: duration and frequency of interruptions per customer, including climate-related disruptions;
- **KPI_{12}**: voltage quality performance;
- **KPI_{13}**: level of losses in transmission and distribution networks;
- **KPI_{14}**: ratio between minimum and maximum electricity demand within a defined time period;
- **KPI_{15}**: demand side participation in electricity markets and in energy efficiency measures;
- **KPI_{16}**: percentage utilisation (i.e. average loading) of electricity network components;
- **KPI_{17}**: availability of network components (related to planned and unplanned maintenance) and its impact on network performances;
- **KPI_{18}**: actual availability of network capacity with respect to its standard value;
- **KPI_{19}**: ratio between interconnection capacity of a Member State and its electricity demand;
- **KPI_{20}**: exploitation of interconnection capacities;
- **KPI_{21}**: 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)). A positive project impact on any of the aforementioned criteria is referred to as a 'benefit'.

Some of these KPIs can be used to support the evaluation of the project's economic viability, illustrated in the next chapter (e.g. KPI_{13} can further be used for monetisation of the benefit 'reduced electricity technical losses', see Annex III 5a) of the present document).

Additionally, project impacts that cannot be expressed in monetary terms shall be subject to quantitative or qualitative appraisal (by referring to the respective KPIs) and further consideration in the overall project analysis. It is, however, up to project promoters to build a convincing case for their project according to the specific criteria indicated above, taking into account all of the corresponding KPIs. In this regard, the project promoters can choose a single KPI or a set of KPIs that better capture the project's impact against a specific criterion. Clearly, some KPIs may contribute to more than one specific criterion. For instance, a smart grid project implementing dynamic line rating and variable access for wind generation may have a positive impact on $\mathbf{KPI_5}$: 'energy not withdrawn from renewable sources due to congestion or security risks' and therefore contribute to the specific criterion on 'optimised planning of future cost-efficient network investments' (e.g. due to reduced need for building new network lines). The same positive KPI may enable 'market functioning and customer services' (e.g. variable wind access contracts may incentivise commercial parties to engage in demand response and storage activities), while also enabling 'integration and involvement of network users with new technical requirements with regard to their electricity supply and demand' (e.g. demand response and storage).

Similarly, $\mathbf{KPI_{14}}$: 'ratio between min and max electricity demand within a defined time period' may have an impact on both, 'efficiency and interoperability of electricity transmission and distribution in day-to-day network operation', and 'network security, system control and quality of supply', due to peak loss reduction and controllable load enabled by the project.

Likewise, $\mathbf{KPI_{15}}$: 'demand side participation in electricity markets and in energy efficiency measures' could contribute to criteria 'market functioning and customer services' and 'involvement of users in management of their energy usage'.

The outcome of this analysis shall be presented as a detailed explanation of how the project contributes to each of the six specific 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. If a KPI is not directly relevant or applicable to the project, project promoters shall clearly demonstrate why in their proposal.

Moreover, promoters can argue the project's impact on certain criterion by proposing additional KPIs, and by describing the project's positive impact on promoting cooperation, replicability and innovation.

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. In any case, project promoters need to make sure that their KPI assessment is technically sound and verifiable.

We have underlined three main issues regarding the project performance according to the different KPIs.

Specific criteria and KPIs might pull in opposite directions

The KPIs evaluate the impact of smart grid technologies from different perspectives. It is possible that some projects will perform well against a certain KPI and less well against others. For instance, specific criterion 1 (integration and involvement of network users with new technical requirements), specific criterion 2 (efficiency and interoperability of electricity transmission and distribution in day-to-day network operation), and specific criterion 3 (network security, system control and quality of supply) may pull in opposite directions. For example, the integration of distributed energy resources might be at odds with a reduction in the level of energy losses or in the level of voltage harmonic distortion. Such possible contradictory scores against different KPIs shall be clearly highlighted and duly substantiated.

Influence of local conditions on the project evaluation

Secondly, we remark that in many instances, the comparison of different projects against a certain KPI might not be straightforward because of specific local conditions that affect the outcome of the calculation (e.g. different smart grid starting conditions, 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 grid deployment should proceed at a similar pace in the different Member States (European Commission, 2011). This is 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 the smart grid is not an end in itself but rather a means to an end, the proposed assessment framework aims at highlighting the projects in the EU that most contribute to improving network conditions with smart solutions, while ensuring stability at both distribution and transmission network levels, and ultimately contributing to the development of the EU internal market for electricity.

KPIs influenced by developments beyond the control of project promoters

Finally, certain projects create conditions that allow them to perform well on some of the

KPIs; however, the project's implementation might also depend on external developments beyond the control of project promoters. For example, the criterion 'integration and involvement of network users with new technical requirements' might also depend on investments by external actors (e.g. generation companies investing in renewable energy sources) or on regulatory and policy developments (e.g. incentive schemes for DGs, approval and enforcement of connection codes). In this context, project promoters shall: (1) clearly demonstrate how their project is enabling the future fulfilment of certain KPIs; (2) explain clearly which external developments need to take place for the actual fulfilment of a KPI; and (3) discuss how these external developments might take place in the near future in the project area.

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

3.1. Economic viability — Cost–benefit analysis

The Regulation (Article 4(1)(b)) underlines that the potential overall benefits of the project shall outweigh its costs, including in the longer term. This is assessed by evaluating the project's contribution to the specific criteria using the KPIs illustrated in the previous chapter.

In this regard, project promoters shall argue convincingly about the economic viability of the project ([8]) by performing a societal cost–benefit analysis, which goes beyond the costs and benefits incurred by the project promoter. They should support their analysis as much as possible with monetary quantification of costs and benefits (see section B3.1 of Annex I of the present document). Positive and negative externalities shall also be included. Calculation assumptions shall be clearly and transparently indicated.

We recommend following the CBA guidelines defined in (European Commission, 2012) ([9]), by offering a structured evaluation of the societal costs and benefits of different smart grid solutions. However, if duly justified, project promoters can propose alternative quantification formulas, provided that their rationale is clearly and convincingly illustrated.

The benefits of implementing the smart grid project will be measured against the business as usual scenario, i.e. without the project being in place.

As shown in Figure 1, the proposed approach to CBA is composed of three main parts (European Commission, 2012):

([8]) Please note that 'economic viability' is not to be mistaken with 'commercial viability'. Once a project obtains the status of 'project of common interest' it may apply for co-financing under the Connecting Europe Facility, providing it demonstrates its commercial non-viability, among other things (see Article 14 of the Regulation).

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

- 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 that enable a positive CBA outcome and to define actions that will 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.

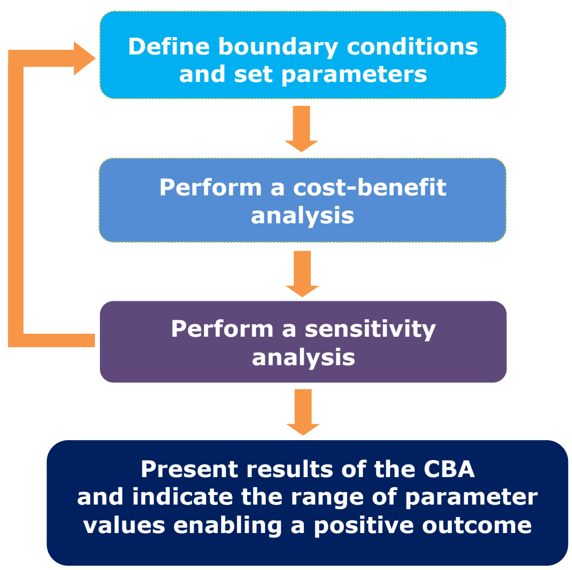

Figure 1. Cost–benefit analysis framework

When conducting the CBA, project promoters shall also consider the following:

- 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 monetisation.
- The individual benefit and cost variables should be mutually exclusive. In other

words, promoters shall 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 as a minimum for the 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 of shadow prices wherever possible.
- Transfers (including taxes) shall not be included in the analysis.
- Use of a social discount rate of 4 % (European Commission, 2009).
- All costs and benefits need to be discounted to the present year, whereas the period of analysis (i.e. time horizon) starts with the commissioning date of the project and extends to a time frame covering the lifecycle of the assets.
- Use of a time horizon of 20 years for the CBA ((European Commission, 2014b) recommends a time horizon of 15-25 years for energy infrastructure projects and 15-20 years for ICT projects).
- Use of carbon prices projected both in the Commission reference and in decarbonisation scenarios ([10]).

Finally, project promoters shall also perform a sensitivity analysis by:

- including the list of critical variables (e.g. load growth, discount rate, electricity prices, carbon prices, cost of energy not supplied) and underlying assumptions;
- including a range of values of critical variables leading to a positive CBA outcome; and
- switching values of critical variables and foreseen control/mitigation actions to keep critical variables under control and reduce CBA uncertainty.

([10]) 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).

3.2. Appraisal of non-monetary impacts

A fully monetised CBA cannot cover all of the specific criteria mentioned in Article 4(2)(c) of the Regulation, since some of these cannot be quantified financially in an objective manner (market functioning and customer services, involvement of users in management of their energy use, etc.). Such impacts can be evaluated using a KPI-based analysis, according to the following:

- **green colour**: a positive impact has been assessed with sufficient level of confidence;
- **yellow colour:** some positive impact has been assessed with some confidence, however uncertainties might persist (in the information provided or in the assumptions made);
- **red colour**: limited impact has been assessed or stronger impact could not be assessed with a sufficient level of confidence due to a significant lack of information.

As previously mentioned, some of the benefits included in the CBA are expected to be directly related to the KPIs (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's economic evaluation could include the monetary value of reduced CO_2 emissions, whereas the KPI analysis might just refer to the amount of CO_2 reduction expressed in tons. In this context, benefits which are quantified using the KPI analysis and later monetised in the CBA can both be presented, principally, to provide more complete information, however they shall not be accounted twice in the overall impact assessment. In this sense, the KPI-based analysis can be seen as a complementary approach, providing increased transparency and adding an additional level of detail.

Other project impacts included in this exercise might not be directly related to the criteria, but might still represent important social impacts worthy of being used to support the case for the economic viability of the project (e.g. employment impact, safety, social acceptance). In Annex IV we provide a (non-exhaustive) list of project impacts that might be difficult to monetise and include in the CBA, but however, can be considered (preferably expressed in physical units) as part of the project evaluation.

4. Summary — Project proposals and evaluation process

Figure 2 summarises the three main inputs that must be included in the project proposals for evaluation. Each proposal shall be prepared by filling in the submission form/template presented in Annex I.

Project promoters shall argue convincingly about: 1) project compliance with the eligibility requirements; 2) project economic viability by demonstrating the project's contribution to the specific criteria; and 3) additional non-monetary impacts linked to the specific criteria, using KPI-based analysis. The argumentation shall be supported by all relevant technical documentation, including quantifications in terms of KPIs and CBA.

In summary, the project proposals shall include three main sections (Figure 2):

- **Compliance with eligibility requirements (evaluation of the project set-up) —** Project promoters shall demonstrate the project's compliance with the eligibility requirements presented in Chapter 2, as a prerequisite for further evaluation of the project proposal. They shall fill in the checklist of eligibility requirements reported in section A3 of Annex I and provide all of the required technical documentation.
- **Project economic viability (societal CBA) —** Project promoters shall argue the project economic viability by demonstrating that the societal benefits of the project outweigh its costs (please refer to section B3 of Annex I of this document). To this end, the case for economic viability of the project should be supported as much as possible by a quantitative societal CBA and resulting economic indicators (e.g. ENPV, EIRR and B/C). A reasonable estimate of the costs (both investment and operational) and benefits of the project, assessed according to the six specific criteria of the Regulation (Article 4(2)(c)), including positive and negative externalities, shall be carried out. The analysis of the project performance against each specific criterion shall be supported by a reference to the corresponding KPIs, including the calculation formulas and assumptions, and the monetary value used for calculating the monetised benefit. If a certain criterion or KPI is not relevant to the project, project promoters shall clearly demonstrate why.
- **Evaluation of non-monetary impacts (KPI-based analysis) —** The appraisal can also include a qualitative or quantitative (non-monetary) appraisal of all of the impacts that cannot be reliably expressed in monetary terms, using the KPI-based analysis. Project promoters shall include a detailed description of the methodology, including calculation formulas and assumptions that they have employed. Their

demonstration shall be technically sound, detailed and verifiable.

- Any other analysis and/or documentation (e.g. results from related pilot projects) that may be used to support the case for the project).

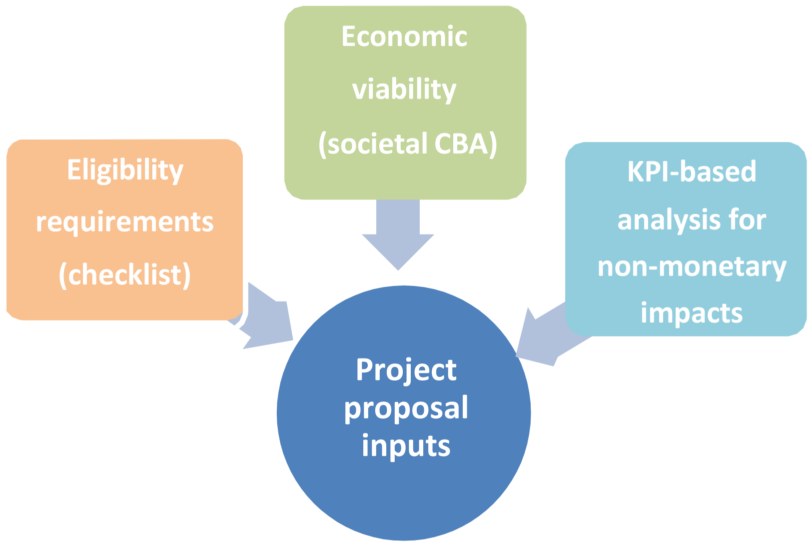

Figure 2. Inputs to be included in the project proposal

The project proposal shall also include:

- a project plan specifying the 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 possible project risks and a description of the corresponding risk mitigation strategies;
- an Excel sheet with the complete cost–benefit analysis and all assumptions considered for the calculations.

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List of abbreviations and definitions

ACER	Agency for Cooperation of Energy Regulators
BAU	business as usual
B/C	benefit/cost ratio
CBA	cost–benefit analysis
DSO	distribution system operator
EIRR	economic internal rate of return
ENPV	economic net present value
ENTSO-E	European Network of Transmission System Operators
KPI	key performance indicator
PCI	project of common interest
RMS	root mean square
SG	smart grid
TSO	transmission system operator

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Annex I — Template for project proposals

<table>
<tr><th colspan="4">A — General description of the project</th></tr>
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<tr><td>Legal name of organisation (1)</td><td colspan="3"></td></tr>
<tr><td>Member State (1)</td><td colspan="3"></td></tr>
<tr><td rowspan="4">Legal status of leading organisation</td><td>Public undertaking/body</td><td>☐</td><td>Details:</td></tr>
<tr><td>Private undertaking/body</td><td>☐</td><td>Details:</td></tr>
<tr><td>International organisation</td><td>☐</td><td>Details:</td></tr>
<tr><td>Joint undertaking</td><td>☐</td><td>Details:</td></tr>
<tr><td rowspan="4">Legal address</td><td>Street</td><td colspan="2"></td></tr>
<tr><td>Postal code</td><td colspan="2"></td></tr>
<tr><td>Town/City</td><td colspan="2"></td></tr>
<tr><td>Country</td><td colspan="2"></td></tr>
<tr><td rowspan="8">Contact point</td><td>Name</td><td colspan="2"></td></tr>
<tr><td>Function</td><td colspan="2"></td></tr>
<tr><td>Street</td><td colspan="2"></td></tr>
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<tr><td>Email</td><td colspan="2"></td></tr>
</table>

Legal name of organisation (2)			
Member State (2)			
Legal status of leading organisation	Public undertaking/body	☐	Details:
	Private undertaking/body	☐	Details:
	International organisation	☐	Details:
	Joint undertaking	☐	Details:
Legal address	Street		
	Postal code		
	Town/City		
	Country		
Contact point	Name		
	Function		
	Street		
	Postal code		
	Town/City		
	Country		
	Phone		
	Email		

A2. General information	
Project name	
Location/s of the physical implementation, specifying Member States (please also provide a map showing the grid under consideration, the consumption and generation areas and the main power flows)	
Project website	

Name of leading organisation(s)	
Name and email address of contact point(s)	
Other participants (names, countries and organisation 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 the main needs addressed by the project:
Please provide a project plan (including a graphic tool, e.g. Gantt chart), specifying the roles and responsibilities of the different participants and highlighting, as a minimum, the 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 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 the national or European level? If yes, please specify (e.g. support through tariffs or public funding):

A3. Compliance with general criteria

Please describe in detail the technical characteristics of the project and the portion of the grid impacted by the project (please provide any relevant technical documentation):
Please demonstrate the project's necessity for the smart grid deployment thematic area (according to section 4, point (10) of Annex I to the Regulation) by referring to the smart grid elements and the trans-European dimension of the proposed project, and its compliance with the energy infrastructure category (point (1)(e) of Annex II to the Regulation):
Please demonstrate the project's compliance with Article 4(1)(c) of the Regulation. For projects falling under Article 4(1)(c)(i) and (iii), demonstrate in detail the role of the project promoters from each Member State; for projects falling under Article 4(1)(c)(ii) elaborate on the impact of the project in the other Member State:
If the project is located on the territory of one Member State, it needs to demonstrate a significant cross-border impact (Article 4(1)(c)(ii) of the Regulation), in accordance with the following: For each of the technical requirements reported below (point (1) of Annex IV to the Regulation), please provide the corresponding project value and demonstrate project compliance in detail.

Criteria	**Reference value**	**Confirmation of project compliance**	**Verification and analysis of project compliance**

Voltage level(s) (kV):	≥ 10		
Number of users involved (producers, consumers and prosumers):	≥ 50 000		
Consumption level in the project area (GWh/year):	≥ 300		
% of energy supplied by variable renewables [11]	≥ 20		
Projects involving transmission and distribution operators from at least two Member States	-		

([11]) Variable renewable power plants rely on resources that fluctuate on the timescale of seconds to days, and do not include some forms of integrated storage (e.g. wind power, wave and tidal power, run-of-river hydropower, and solar photovoltaics) (International Environment Agency, 2008).

B — Impact of the project

B1. Overview of expected project impact

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

B2. Project performance against six specific criteria

Please provide an overview of the project's performance against the six specific criteria set out in Article 4(2)(c) of the Regulation, assessed according to the following KPIs, as outlined in Annex IV to the Regulation:

- **KPI_1**: reduction of greenhouse emissions;
- **KPI_2**: environmental impact of electricity grid infrastructure;
- **KPI_3**: installed capacity of distributed energy resources in distribution networks;
- **KPI_4**: allowable maximum injection of electricity without congestion risks in transmission networks;
- **KPI_5**: energy not withdrawn from renewable sources due to congestion or security risks;
- **KPI_6**: methods adopted to calculate charges and tariffs, as well as their structure for generators, consumers and those that do both;
- **KPI_7**: operational flexibility provided for dynamic balancing of electricity in the network;
- **KPI_8**: ratio of reliably available generation capacity and peak demand;
- **KPI_9**: share of electricity generated from renewable sources;
- **KPI_{10}**: stability of the electricity system;
- **KPI_{11}**: duration and frequency of interruptions per customer, including climate-related disruptions;
- **KPI_{12}**: voltage quality performance;
- **KPI_{13}**: level of losses in transmission and distribution networks;

- **KPI_{14}**: ratio between minimum and maximum electricity demand within a defined time period;
- **KPI_{15}**: demand side participation in electricity markets and in energy efficiency measures;
- **KPI_{16}**: percentage utilisation (i.e. average loading) of electricity network components;
- **KPI_{17}**: availability of network components (related to planned and unplanned maintenance) and its impact on network performances;
- **KPI_{18}**: actual availability of network capacity with respect to its standard value;
- **KPI_{19}**: ratio between interconnection capacity of a Member State and its electricity demand;
- **KPI_{20}**: exploitation of interconnection capacities;
- **KPI_{21}**: congestion rents across interconnections.

It is up to project promoters to build a convincing case for their project according to each of the six specific criteria mentioned below, taking into account all of the corresponding KPIs. In this regard, the project promoters can choose a single KPI or a set of KPIs that better capture the project's impact against a specific criterion. Nevertheless, all KPIs need to be addressed for evaluating the overall project impact against the six specific criteria (Regulation (EU) No 347/2013 (point (4) of Annex IV)).

B2.1 — Project performance against criterion 1 — Integration and involvement of network users with new technical requirements with regard to their electricity supply and demand

Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.

KPIs	Estimated KPI value and calculation assumptions

B2.2 — Project performance against criterion 2 — Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation	
Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.	
KPIs	**Estimated KPI value and calculation assumptions**

B2.3 — Project performance against criterion 3 — Network security, system control and quality of supply	
Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.	
KPIs	**Estimated KPI value and calculation assumptions**

B2.4 — Project performance against criterion 4 — Optimised planning of future cost-efficient network investments	
Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.	
KPIs	**Estimated KPI value and calculation assumptions**

B2.5 — Project performance against criterion 5 — Market functioning and customer services	
Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.	
KPIs	**Estimated KPI value and calculation assumptions**

B2.6 — Project performance against criterion 6 — Involvement of users in management of their energy usage	
Please describe the project's contribution to this criterion, indicating which KPIs from the above-mentioned list were used to measure the project's impact on this criterion. Additionally, please indicate the calculation approach and the underlying assumption of each KPI used.	
KPIs	**Estimated KPI value and calculation assumptions**

B3. Economic appraisal

Please demonstrate convincingly that the overall benefits provided by the project outweigh the project costs. The case for the economic viability of the project should be supported by a quantitative societal CBA and resulting economic indicators (ENPV, EIRR, B/C), where all the benefits shall be assessed according to the specific criteria outlined in the Regulation.

Please demonstrate the calculation method of all of the benefits in the estimation approach column by clearly referring to the respective KPIs used for calculating the benefits.

Also, please provide a complete cost–benefit analysis Excel sheet, including all the costs

and benefits per individual year and assumptions for the calculation.

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 **(capital expenditure (CAPEX) and operating expenditure (OPEX))**		
Cost	Value	Estimation approach

CAPEX		
OPEX		
Sensitivity analysis		
Please describe the assumptions and critical variables considered in the sensitivity analysis:		
Please provide the CBA outcome (ENPV, EIRR and B/C) and provide the range of values of critical variables which lead 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 additional non-monetary impacts		
Please provide a detailed appraisal of expected (positive and negative) impacts that cannot be monetised and included in the CBA, and are not captured by the KPI-based analysis. Preferably physical units shall be used. Qualitative descriptions of impacts could		

also be used but must be convincingly supported.	
Non-monetary impact	Estimation in physical units and/or description of expected impact

Annex II — Proposed calculation options for the KPIs mentioned in the Regulation

This annex proposes ways to translate the key performance indicators put forward in the Regulation 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 the following 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 of the simulation model employed) and the grid boundary conditions considered in the analysis.
- Clearly illustrate how, in the design of the project, the collection of data necessary to calculate the KPI in the SG scenario has been planned. 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 the KPIs, clearly highlight why the results are relevant and how they can be extended to the deployment project under consideration.
- In cases where the project is simply enabling the improvement of a KPI, clearly highlight the external developments (i.e. developments that are beyond the control of the project promoters) that need to occur to actually improve that KPI.

KPI_1: Reduction of greenhouse gas emissions

The quantification of this KPI requires the identification of all possible means of greenhouse gas (GHG) emissions reduction (including CO_2 reduction) brought by the project, such as:

- 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 the resulting displacement of

fossil-based generation.

It is important to avoid overlapping with benefits in terms of CO_2 reduction included in the CBA.

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

$$KPI_1 = \frac{GHG_{emissions\ BaU} - GHG_{emissions\ SG}}{energy\ demand}$$

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:

- $r_{emission}\left[\frac{kg}{MWhT}\right]$ 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 fuel's typical energy and GHG content, along with the typical efficiencies of power plants (ENTSO-E, 2009).
- $\eta_g\left[\frac{MWh}{MWhT}\right]$ is the average efficiency of the thermal power plants in the region/country under consideration (ratio between electricity produced per unit of thermal energy). $\Delta Energy$ (MWh) represents the amount of fossil-based energy displaced (e.g. via fewer 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-based generation for each fossil fuel.

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

KPI_2: Environmental impact of electricity grid infrastructure

For the appraisal of the environmental viability of a smart grid project, promoters need to consider all of the environmental impacts that have not already been included in the CBA.

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 the environment as much as possible before any intervention, or, if possible, to improve it.

If numerical indicators cannot be calculated (e.g. decibels for sound level), the project appraisal could include a well-argued and detailed description of the expected (positive or negative) impacts. Here is 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, etc.;
- land use and landscape change (e.g. square metres per peak capacity of photovoltaic 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. decibels from wind farms per installed capacity);
- electromagnetic impact.

KPI_3: 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 into the distribution grid because of 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). Therefore, project promoters need to clearly express the local conditions affecting the calculation of this KPI.

The contribution of a smart grid project to the integration of DERs can be assessed by estimating, over a defined period of time (e.g. yearly), the increase of DER energy injected into 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; and innovative grid protection/monitoring).

$$KPI_3 = \frac{EI_{SG} - EI_{BaU}}{E_{total}}$$

Where:

- EI_{SG} is the DER energy input (over a defined period of time, e.g. yearly) that can be safely integrated into 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 safely integrated into 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 normalisation 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 into account. Most of these values can be calculated by power flow and short-circuit analysis. The calculation hypothesis should be clearly explained and documented.

As highlighted in (Lo Schiavo et al., 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). In this sense, this KPI can be calculated by 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 with local conditions. In fact, distributed energy resources can positively contribute to system operations 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.

KPI_4: Allowable maximum injection of power into transmission networks without congestion risks

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 is calculated as a fixed value under predefined worst-case power flows and a predefined 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).

$$KPI_4 = \frac{P_{imax(SG)} - P_{imax(BaU)}}{P_{ref}} \times 100$$

Where:

- P_{imaxSG} (MW) and $P_{imaxBaU}$(MW) represent the largest size of production unit that can be connected without risking curtailment in the predefined worst case scenario, with and without the project, respectively;
- P_{ref} (MW) is the power load in the grid under consideration in the predefined worst-case scenario (it is assumed constant before and after the project).

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

KPI_5: 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. However, 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.

$$KPI_5 = \frac{E_{REScurtailed(BaU)} - E_{REScurtailed(SG)}}{E_{RES(tot)}}$$

Where:

- $E_{REScurtailed(SG)}$(MWh) is the RES energy curtailed (over a defined period of time, e.g. yearly) in the SG scenario;
- $E_{REScurtailed(BaU)}$(MWh) is the RES energy curtailed (over a defined period of time, e.g. yearly) in the BAU scenario;
- $E_{RES(tot)}$ (MWh) is the total RES energy generated (over a defined period of time, e.g. yearly), assuming no variations between the BAU and SG scenarios.

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

$$KPI_5 = \frac{E_{REScurtailed(BaU)}}{E_{RES(BaU)}} - \frac{E_{REScurtailed(SG)}}{E_{RES(SG)}}$$

Where:

- $E_{RES(SG)}$ (MWh) is the total RES energy generated (over a defined period of time, e.g. yearly) in the SG scenario;
- $E_{RES(BaU)}$ (MWh) is the total RES energy generated (over a defined period of time, e.g. yearly) in the BAU scenario.

In this way, the higher the total RES energy enabled by the SG projects (in the SG scenario), the higher the emphasis given on the reduction of $E_{REScurtailed(SG)}$.

The proposed KPI formulations are intended to capture the contribution of smart grids to the reduction of 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 the local circumstances, the non-withdrawn RES energy in those instances is not the same in both the BAU and SG scenarios, then the KPI calculation should be corrected accordingly.

KPI_6: 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 with the project deployment and by highlighting how this information can be used in defining more accurate methods of allocating costs.

KPI_7: Operational flexibility provided for dynamic balancing of electricity in the network

A possible metric for this KPI is:

$$KPI_6 = \frac{P_{disp(SG)} - P_{disp(BaU)}}{P_{peak}} \times 100$$

Where:

- $P_{disp(SG)}$ is the capacity of dispatchable resources (generation, storage and controllable loads) connected to the grid under consideration in the SG scenario;
- $P_{disp(BaU)}$ is the capacity of dispatchable resources (generation, storage and controllable loads) connected to the grid under consideration in the BAU scenario;
- P_{peak} represents the average electricity demand in the BAU over the predefined period of time.

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

Other possible options for the quantification of the KPI include:

- comparing the needs in operating reserves before and after project deployment;
- level of storage and distributed generation (DG) 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).

KPI_8: 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 (ENTSO-E, 2009b).

a. The net generating capacity (NTC) of a power station is the maximum electrical net active power it can produce continuously over a long period of operation in normal conditions, (ENTSO-E, 2009b):

   – 'net' means the difference between, on the one hand, the gross generating capacity of the alternator(s) and, on the other hand, the auxiliary equipment's 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.

b. Unavailable capacity is the part of the NTC that is not reliably available to power plant operators due to limitations of the output power of power plants (ENTSO-E, 2009a).

The reliably available capacity is the part of net generating capacity actually available to cover the load at a reference point (ENTSO-E, 2009b).

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

$$KPI_8 = \frac{\left[\frac{RAC}{P_{peak}}\right]_{SG} - \left[\frac{RAC}{P_{peak}}\right]_{BaU}}{\left[\frac{RAC}{P_{peak}}\right]_{BaU}} \times 100$$

KPI_9: 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 ([12]) that can be safely integrated in the system in the

([12]) 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).

SG and BAU scenarios (over a defined period of time, e.g. yearly), assuming the same total amount of electricity generated in both scenarios:

$$KPI_9 = \frac{E_{RES(SG)} - E_{RES(BaU)}}{E_{total}} \times 100$$

Where:

- $E_{RES(SG)}$ (MWh) and $E_{RES(BaU)}$ (MWh) represent the amount of electricity generated from renewable sources in the SG and BAU scenarios respectively;
- E_{total} (MWh) is the total energy consumption in the distribution grid under consideration in the defined period (it is assumed constant before and after the project).

The calculation of RES energy requires an estimation of the installed capacity (MW) and the equivalent running hours of the different types of RES units considered (h/year) (see for example: ENTSOE, 2009a). Project promoters need to clearly and transparently highlight how the estimation has been carried out.

KPI_{10}: 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.

KPI_{11}: 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 BAU scenarios.

We recommend considering the following reliability indexes:

a. SAIDI is the system average interruption duration index (min) and represents the average outage duration for each customer served;

b. 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:

$$KPI_{11a} = \frac{SAIDI_{BaU} - SAIDI_{SG}}{SAIDI_{BaU}} \times 100$$

$$KPI_{11b} = \frac{SAIFI_{BaU} - SAIFI_{SG}}{SAIFI_{BaU}} \times 100$$

KPI_{12}: Voltage quality performance

The impact of the smart grid project on voltage quality performance can be assessed by 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 and they 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 root mean square (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 on the voltage quality performance, we recommend calculating the voltage variation in the SG and BAU scenarios:

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

$$KPI_{12a} = \frac{V_{violations_{BaU}} - V_{violations_{SG}}}{V_{violations_{BaU}}}$$

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 a steady state).

- The number of micro-interruptions, sages and surges, and assessing the number of events (MV-LV violations) recorded over a given time period (1 year for example). Dips and surges are recorded when the voltage exceeds the threshold of +/- 10 % of its nominal value (in a transient state).

b. Total harmonic distortion factor (THD).

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

$$KPI_{12b} = \frac{THD_{BaU} - THD_{SG}}{THD_{BaU}}$$

KPI_{13}: Level of losses in transmission and distribution networks

This KPI is expressed as:

$$KPI_{13} = \frac{EL_{BaU} - EL_{SG}}{E_{tot}} \times 100$$

Where:

- EL_{BaU} (MWh) represents the yearly level of energy losses in the portion of the grid under consideration in the BAU scenario;
- EL_{SG} (MWh) represents the yearly level of energy losses in the portion of the grid under consideration in the SG scenario;
- E_{tot}(MWh) represents the total yearly energy consumption in the portion of the grid under consideration and 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 this 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.

KPI_{14}: Ratio between minimum and maximum electricity demand within a defined time period

This 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. 1 day, 1 week) as a consequence of the implementation of the project, namely:

$$KPI_{14} = \frac{\left[\frac{P_{min}}{P_{max}}\right]_{SG} - \left[\frac{P_{min}}{P_{max}}\right]_{BaU}}{\left[\frac{P_{min}}{P_{max}}\right]_{BaU}} \times 100$$

Or alternatively:

$$KPI_{14} = \frac{\Delta P_{BaU} - \Delta P_{SG}}{P_{peak(BaU)}}$$

Where:

- ΔP_{BaU} represents the difference between the minimum and maximum electricity demand (within a predefined period of time, e.g. 1 week or 1 year) in the BAU scenario;
- ΔP_{SG} represents the difference between the minimum and maximum electricity demand (within a predefined period of time, e.g. 1 week or 1 year) in the SG scenario;
- $P_{peak(BaU)}$ represents the peak electricity demand in the BAU over the predefined period of time.

The choice of $P_{peak(BaU)}$ as the 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.

The boundary conditions (e.g. electrical heating, weather conditions, shares of industrial and domestic loads) need to be clearly stated and taken into account in the KPI interpretation (ERGEG, 2010).

KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures

The demand side participation is expressed as the amount of load participating to demand side management (DSM). The KPI is expressed as the variation of demand side participation in the BAU and SG scenarios, normalised to the maximum electricity demand within a predefined time period (e.g. 1 day, 1 week).

The KPI can then be expressed as:

$$KPI_{15} = \frac{P_{DSM(SG)} - P_{DSM(BaU)}}{P_{peak}}$$

Where:

- $P_{DSM(SG)}$ 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 the normalisation 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. highlighting the simultaneity factor).

A similar idea is proposed in (Dupont, 2010), where one of the proposed KPIs to assess the smart grid impact is the percentage of consumer load capacity participating in P_{DSM}.

KPI$_{16}$: Percentage utilisation (i.e. average loading) of electricity network components

Owing to the capabilities of a smart grid, it will be possible to make better use of the grid's 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 the project promoters to demonstrate how the smart grid project, by affecting the average loading of the network components, is providing benefits (increased available capacity thanks to optimisation of average loading; avoided investment costs thanks to better use of existing resources, etc.).

Moreover, project promoters need to clearly highlight which national/local factors affect the analysis.

KPI$_{17}$: Availability of network components (related to planned and unplanned maintenance) and its impact on network performance

Smart grid implementation is expected to have positive effects on the availability of network components, by potentially allowing for condition-based maintenance and thereby reducing the stress on the 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 for field team intervention and ensures shorter duration of network failures. In this context, it is important to constantly monitor the temperature, pressure, gas, intrusion and flooding in distribution transformer stations and MV/LV transformers in order to anticipate relevant 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 only be applied to components whose availability is indispensable for optimal grid performance and which have a direct impact on output-based indicators like SAIDI and SAIFI (see KPI_{11a} and KPI_{11b}). An alternative way to measure the impact of increased availability on network performance is to measure the increase in the network equipment lifespan in the SG scenario. If some sort of estimation is feasible, a comparison between the number of unplanned maintenance interruptions before and after the implementation of the project could also be carried out.

$\mathbf{KPI_{18}}$: Actual availability of network capacity with respect to its standard value

(CEER, 2011) indicates two possible interpretations of this type of indicator:

- the availability of network capacity compared to a reference value at national or local levels; 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 the 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:

$$KPI_{18} = \frac{P_{SG} - P_{BaU}}{P_N}$$

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.

KPI_{19}: Ratio between interconnection capacity of a Member State and its electricity demand

This ratio should have a value of at least 10 % ([13]), i.e. the minimum interconnection capacity to ensure that, in case of significant events affecting one country/zone's 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:

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

Where i refers to each single interconnection from a country/zone j to another country/zone j and $\mu_i(NTC_i)$ is the average NTC ([14]) throughout the year per border i, where r stands for the number of hours per year. E_{totj} 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 the flow-based calculation method ([15]). 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.

$$KPI_{19} = \frac{r_{SG} - r_{BaU}}{r_{BaU}} \times 100$$

KPI_{20}: Exploitation of interconnection capacities

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.

([13]) 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'.
([14]) ENTSO-E, Procedures for cross-border transmission capacity assessments, https://www.entsoe.eu/publications/market-reports/Documents/entsoe_proceduresCapacityAssessments.pdf
([15]) ACER, Framework guidelines on capacity allocation and congestion management for electricity, http://www.acer.europa.eu/en/Electricity/FG_and_network_codes/Electricity%20FG%20%20network%20codes/FG-2011-E-002.pdf

These data are available through the ENTSO-E Data Portal ([16]) for each European interconnection. Actual load flow is measured conventionally every Wednesday at 3.00 a.m. (proxy for off-peak load flow) and at 11.00 a.m. (proxy for peak load flow). In order to calculate the exploitation rate, the following formula can be used, where *i* stands for each interconnection and *μ* is the average of annual load flow values, i.e.:

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

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 ([17]):

$$KPI_{20} = \frac{ER_{BaU} - ER_{SG}}{ER_{BaU}} \times 100$$

KPI$_{21}$: 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 outlined in the Regulation, 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 of the selected interconnection i:

$$CR_i = \sum_i \left(Rev_{yearly(i)} + Rev_{monthly(i)} + Rev_{daily(i)}\right)$$

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

([16]) https://transparency.entsoe.eu/
([17]) The increased exploitation of the interconnection capacity may result either from increased average power flow at the interconnection (enhanced use of the interconnector) or increased net transfer capacity. In this sense, the project's impact on this KPI shall be seen as an absolute value of the difference between the SG and BAU scenarios, relative to the BAU scenario.

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

The proposed smart grid projects should contribute to alleviating 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 the benefits gained through the smart grid project. The list is, however, not exhaustive and project promoters may, if duly justified, use other calculation methods providing that they are clearly stated in their proposals. Benefits should be calculated for each year of the time horizon of the analysis.

1. Reduced operations and maintenance costs

To calculate these benefits, the scenario should track the distribution's operational and maintenance costs before and after the smart grid project takes place. These benefits will typically consist of different components, such as reduced maintenance costs and 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 the reduced amount of time between a breakdown and the restoration of the supply. The following formulae are proposed for the calculation of their monetary impact:

a) Reduced maintenance costs of assets

Value (€) = (Direct costs related to maintenance of assets (€)) $_{Baseline}$ ***— (Direct costs related to maintenance of assets (€))*** $_{SGproject}$

Through remote control and monitoring of asset conditions and utilisation (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.

b) Reduced cost of equipment breakdowns

Value (€) = (Cost of equipment breakdowns (€)) $_{Baseline}$ ***— (Cost of equipment breakdowns (€))*** $_{SGproject}$

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

2. Deferred distribution capacity investments

The assumption underlying the monetisation of this benefit is that the implementation of smart grid solutions will potentially give way to the reduction of 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, thereby reducing the need for network reinforcements.

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

Monetisation 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.

Here is a potential calculation method:

- The first step is to estimate the future incremental cost for the reinforcement of the grid due to growing peak demand. Thus, it is necessary to estimate the incremental cost per MW of peak demand (€M/ΔMW). This can be done by considering the reinforcement projects that are planned 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, and economic, social and industrial factors.
- The second step is to understand the causes of peak reduction. We have observed that peak reduction can mainly be achieved in two different ways: consumption reduction and peak load shifting. It is then necessary to distinguish the consumers whose consumption level can be affected by the implementation of the smart grid project. For example, in a smart metering project, we can assume that consumption reduction (e.g. 1 %) should only be applied 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) also needs to be calculated. This calculation should only consider the networks where the peak corresponds with the general peak (e.g. 6 p.m.) when the potential for peak load shifting is higher.
- The third step is the calculation of the benefit for both consumption reduction and

peak load shifting. The benefit is calculated as a percentage of reduction on the incremental cost per MW of peak demand. The formulas for the calculations are as follows:

a) 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)

b) Deferred distribution capacity investments due to peak load shifting:

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

The figure below demonstrates an example of benefits gained due to deferred distribution investments within the time horizon of the project. The effect of the discount rate on the net present values of benefit (decreasing benefits) can be observed. It is assumed that the investments have been deferred by 6 years, after which they are undertaken.

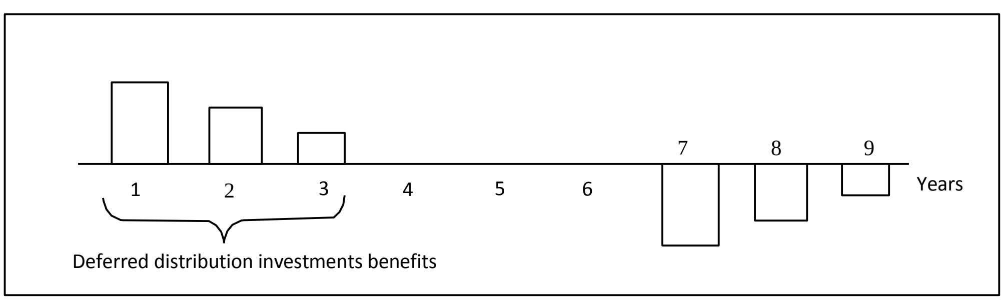

Figure 3. Illustrative example of deferred distribution investments

3. Deferred transmission capacity investments

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

4. 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 along with the impact on the spinning reserves.

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

a) 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 it assumes that generation deferral is based on reducing peak demand.

b) Deferred generation investments for spinning reserves:

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

5. Reduced electricity technical losses

As mentioned in the EPRI methodology (EPRI, 2015), several smart grid functions can contribute to loss reduction, and scenarios that demonstrate more than one of them at a time will see compounded effects. The overall benefit of reduced power loss consists of different subcategories 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 and micro-generation; iv) enhanced voltage control; and v) consumption reduction at the transmission level.

One way of estimating technical loss reductions is through 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, 2015).

a) **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.

6. 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:

a) **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 analysing international benchmarks and recent studies.

b) **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 incentivise clients to shift part of their consumption to off-peak periods. The percentage of peak load transfer needs to be estimated. One way of monetising this benefit is to use the price difference of the electricity wholesale margin between peak and off-peak periods (€/MWh).

7. 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 real-time network monitoring and control, resulting in quicker detection of anomalies, remote management, and automatic network reconfiguration. Since the percentage decrease in outage time varies across endpoints depending on the infrastructure installed, the value of the service needs to be calculated separately for different installed assets (smart meters, distribution transformer controllers, etc.).

In principle, the estimated value of outage costs might go beyond the immediate cost of lost load and also reflect other societal impacts which are difficult to quantify (e.g. uncertainty, negative perception). 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:

a) Value of service:

Value (€) = Total energy consumed (MWh)/Minutes per year (#/year) * Average non-supplied minutes/year (#/year) * Value of lost load (€/MWh) * % 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.

NB: 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 SG project, e.g. as a result of customers using less electricity without any actual improvement in reliability, i.e. outage duration.

b) 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.

c) Reduced cost of client compensation:

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

This benefit refers to a reduction in client compensation related to losses or injuries incurred by power outages.

8. Reduced CO_2 emissions and reduced fossil fuel usage

CO_2 reduction can be achieved through different means, such as the deployment of additional renewable sources or increased energy efficiency through the implementation of the SG project. 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 the DSOs' operational fleet and the consequent savings on litres of fuel and CO2 emissions due to remote meter readings and remote network operations.

In cases where the analysis permits the calculation of carbon costs, project promoters shall use the projected EU emission trading scheme's carbon prices in the Commission's reference scenarios up to 2050 as a minimum lower bound, assuming the implementation of the existing legislation ([18]).

([18]) Annex 7.10. to Commission staff working document — Impact assessment (SEC(2011) 288 final) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF).

a) Benefit of reduced CO_2 emissions due to reduced line losses:

Value (€) = Line losses (MWh) * CO_2 content (tons/MWh) * Value of CO_2 (€/ton)$_{Baseline}$ – Line losses (MWh) * CO_2 content (tons/MWh) * Value of CO_2 (€/ton)$_{SGproject}$

This calculation monetises the reduced CO_2 emissions due to reduced line losses. The estimation of this benefit should be integrated with a clear and transparent explanation of the value chosen for the CO_2 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.

b) Reduced CO_2 emissions due to wider diffusion of low-carbon generation sources:

Value (€) = CO_2 emissions (tons) * Value of CO_2 (€/ton)$_{Baseline}$ — CO_2 emissions (tons) * Value of CO_2 (€/ton)$_{SGproject}$

This benefit captures the emissions reductions due to a wider diffusion of renewable energy sources and distributed generation.

c) Benefit of reduced CO_2 emissions as a result of fuel savings:

Value (€) = Avoided # litres of fossil fuel (#) * CO_2 emissions per litre of fuel (tons/litre) * Value of CO_2 (€/ton)

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

d) Benefit of reduced fossil fuel usage:

Value (€) = Avoided # litres of fossil fuel (#) * Cost per litre of fossil fuel (€/litre)

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

9. Reduction of air pollution (particulate matters, NOx, SO_2)

For the cost of air pollutants (particulate matters, NOx, SO_2), it is advisable to consult the clean vehicles directive (Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles) and the clean air for Europe programme's (CAFÉ) air quality benefits quantification process.

a) **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)$_{SGproject}$

b) **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 impacts relevant to the fulfilment of the specific criteria

Below we provide a (non-exhaustive) list of project impacts that might be difficult to monetise and include in the CBA; however they may prove relevant to further support the project's contribution to the smart grid specific criteria. Where possible, these impacts should be expressed in physical units and their economic relevance needs to be discussed.

Network user/consumer inclusion

For smart grids to be economically and socially sustainable, consumers need to be engaged through clear and tangible benefits such as economic benefits and increased market choice, and through greater awareness.

In this context, additional impacts that are relevant to the fulfilment of the specific criteria, however not captured by the current KPIs, may be demonstrated in the project proposal, such as:

- enhanced consumer awareness and participation in the market by new players;
- reduced consumer electricity bills;
- creation of a market mechanism for new energy services such as energy efficiency or demand response.

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

Employment

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

The analysis could include an estimation of the number of jobs in the supply and operations value chain. The first direct impact is on utility jobs created by the smart grid projects that require new skills and on utility positions that require retraining for other roles. A second direct impact is the creation of new jobs for service providers working on the implementation of the project.

Other categories that might be impacted include direct and indirect utility suppliers, manufacturers, communication providers, aggregators, etc.

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

Safety

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

It is important that companies 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 clearly present what the safety standards applicable to any component of the project are, and prove that health, safety and environment 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 should be proposed.

Enabling new services and applications and market entry to third parties

This analysis shall address which new services and applications might be enabled through the implementation of the smart grid project under consideration. It should assess the impact of the project on 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 minimising 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 may 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 may address the impact of the project in terms of reducing the gap in skills and personnel due to a 'greying workforce', i.e. shortages of qualified technical personnel due to the retirement of skilled technicians. It can also analyse the impact of the project in terms of the creation of new skills and knowledge that may increase know-how and competitiveness.

ICT system performances

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

This analysis may also address the activities anticipated to develop measures to ensure data protection and cyber-security related to the implementation of ICT systems. Additional costs that are foreseen to implement preventative measures or the benefits resulting from reduced risks can be quantitatively assessed and included in the analysis.

Dissemination of the results

A further criterion could be the extent to which experience from the project, and any results from the project and experiments performed during the project, are disseminated to a wider 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.

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