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Evaluation of Smart Grid projects for inclusion in the third Union-wide list of Projects of Common Interest

Evaluation of candidate projects in the TEN-E priority thematic area of smart grids deployment

Vasiljevska, J., Gras, S., Flego, G.

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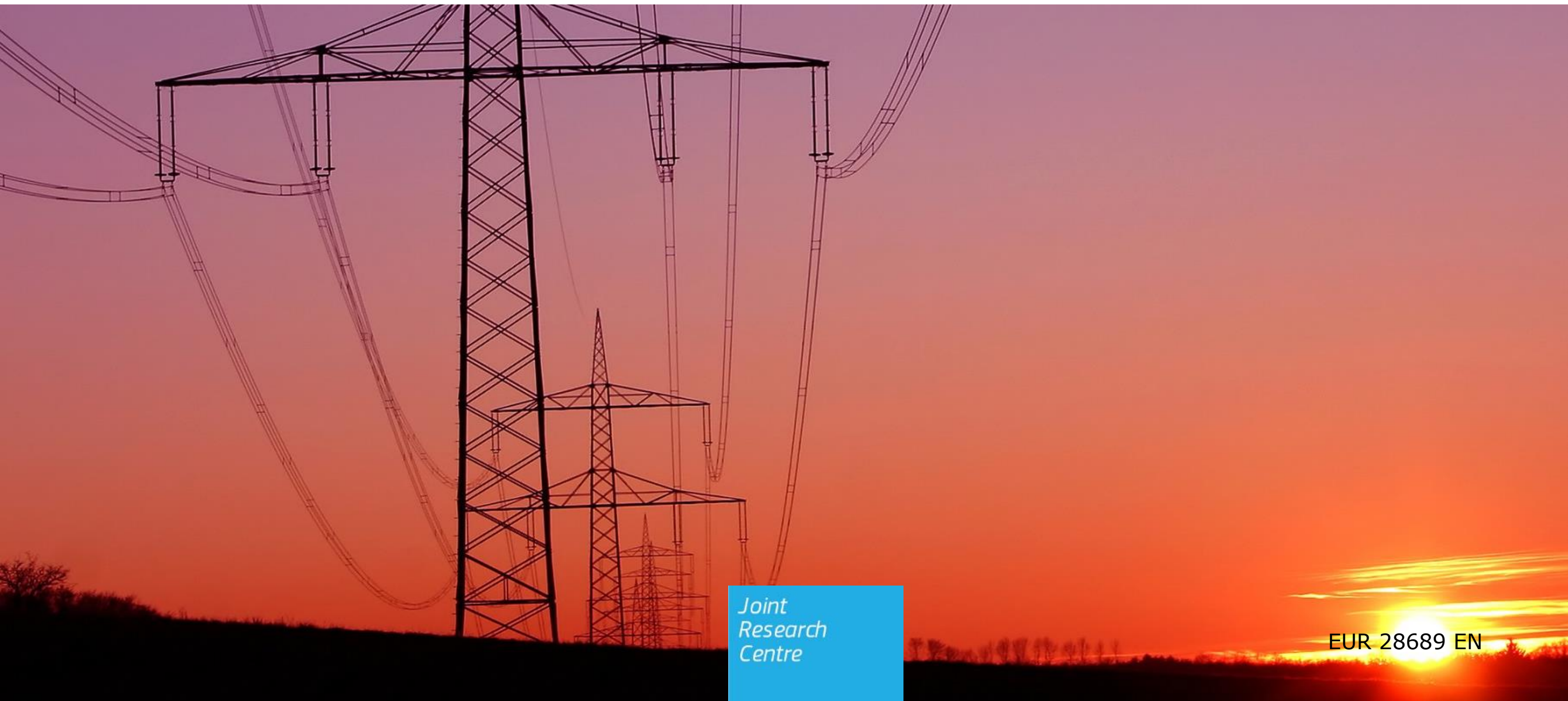

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Title
Evaluation of Smart Grid projects for inclusion in the third Union-wide list of Projects of Common Interest – Evaluation of candidate projects in the TEN-E priority thematic area of smart grids deployment

Abstract
The document presents the outcome of the evaluation process of candidate Projects of Common Interest in the priority thematic area of 'smart grids deployment', as set out in the trans-European energy infrastructure regulation. The evaluation follows the guidelines of the assessment framework for smart grid Projects of Common Interest, 2017 update, developed by the JRC and adopted within the smart grid Regional Group.
The report aims to assist the smart grids Regional Group in proposing projects of common interest in the area of smart grids deployment to be included in the 3rd Union list of Projects of Common Interest.

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Executive summary

Policy context

This report supports the implementation of the Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure (herein referred as the Regulation) and in particular the assessment of candidate Projects of Common Interest in the priority thematic area of smart grids deployment. Projects of Common Interest are energy infrastructure projects, essential for completing the European internal energy market and for meeting the EU's energy policy objectives of affordable, secure and sustainable energy.

Projects of Common Interest may benefit from accelerated planning and permit granting, a "one-stop-shop" for obtaining permits, improved regulatory treatment, streamlined environmental assessment processes, increased public participation, and increased visibility to investors.

Once a project is selected as a Project of Common Interest (PCI), it may also be eligible for financial assistance under the Connecting Europe Facility in the form of grants for works under certain conditions. Such assistance may be granted if the project promoters can demonstrate significant positive externalities generated by the project and the lack of commercial viability, according to the business plan and other assessments carried out, notably by possible investors or creditors or, where applicable, a national regulatory authority.

To be selected as PCI, a project must have a significant impact on the energy markets and market integration in at least two EU countries, increase energy market competition and contribute to the EU's energy security, and climate and energy goals by diversifying energy sources and integrating renewables. The selection process aims at projects in priority corridors and areas, as identified in the Regulation, where 'smart grids deployment' is identified as one of the 12 priority infrastructure corridors and thematic areas.

This report is intended to assist the TEN-E Regional Group for Smart Grids Deployment (herein referred as the Regional Group), which includes Ministries, national regulatory authorities, electricity transmission operators, project promoters, ENTSO for Electricity, ACER, and the European Commission, in selecting Projects of Common Interest in the priority thematic area of 'smart grids deployment', to be included in the 3rd Union list of Projects of Common Interest.

Key conclusions

The report presents the outcome of the evaluation process of projects in the area of 'smart grids deployment' which have applied to be selected as PCI, based on the *assessment framework for smart grid Projects of Common Interest, 2017 update*, developed by the Regional Group, with the support of the JRC.

Four (4) candidate projects have been submitted to the Commission and evaluated accordingly, namely: ACON project (Member States: Czech Republic and Slovak Republic), ALPGRID project (Member States: Austria and Italy), Smart Border Initiative project (Member States: France and Germany) and SINCRO.GRID project (Member States: Croatia and Slovenia).

All four project proposals were carefully analysed and assessed, based on the information provided by the project promoters, and with regard to both, the project compliance with the general criteria laid out in Article 4 (1) of the TEN-E Regulation, and the evaluation of a project's contribution to the smart grid specific criteria of Article 4 (2) of the same Regulation. In this regard, all the four projects' proposals were evaluated against the following steps: *1) verification of the project's necessity for the 'smart grids deployment' priority thematic area; 2) verification of the project's economic viability, according to the outcome of a societal cost-benefit analysis, where the overall projects' benefits are* *assessed according to the six specific criteria outlined in Article 4(2)(c) of the Regulation and against a set of KPIs as derived from the criteria in Annex IV (4) to the Regulation* and *3) verification of the project's compliance with the general criteria of Article 4 (1) (c), namely: 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 Member State and a European Economic Area country; alternatively, it shall be located on the territory of one Member State and have a significant cross-border impact.*

The ACON project, notwithstanding the conventional elements proposed in the project, consists of technologies and solutions which prove necessary for the smart grid deployment thematic area (Annex I, 4(10) to the Regulation). The ACON project involves DSOs from two Member States, while TSOs are also expected to be involved and benefit from more efficient and reliable operation of the distribution networks in the project area. In this respect, the project complies with Article 4 (1) (c) (i) of the Regulation. The ACON project demonstrates significant contribution to the six smart grid specific criteria, outlined in Article 4(2)(c) of the Regulation and positive outcome of the project's societal cost-benefit analysis.

The ALPGRID project includes deployment of both, mature smart grid technology elements and an innovative, cross-border flexibility platform operated jointly in both Member States providing leverage for market players (aggregators, generation units, storage operators, etc.) to offer flexibility to both, the DSOs and TSOs. The ALPGRID project proves necessary for the smart grid deployment priority thematic area (Annex I, 4 (10) to the Regulation) and it complies with the general criterion 1(c)(i) of Article 4 of the Regulation. The ALPGRID project demonstrates overall positive contribution to the six smart grid specific criteria, outlined in Article 4 (2) of the Regulation and positive outcome of the project's societal cost-benefit analysis.

The Smart Border Initiative (SBI) project presents an innovative approach of addressing common cross-border energy challenges in the project area by integrating the electricity grid with electric mobility and district heating and cooling systems. The SBI project aims to develop a cross-border data management system and common standards for optimisation of the electricity distribution. The SBI project complies with the general criterion 1(c)(i) of Article 4 of the Regulation and it proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation). The SBI project has not yet reached a high level of maturity therefore a quantitative societal cost-benefit analysis could not be conducted at the current stage of the project's development. Consequently, the economic appraisal of the project's expected benefits is demonstrated in qualitative terms. However, the project is expected to contribute positively to the six smart grid specific criteria, outlined in Article 4(2)(c) of the Regulation.

The SINCRO.GRID project is a mature project with clear objectives and a well-defined set of necessary actions to achieve these objectives. It is driven by existing challenges, mainly related to voltage and frequency regulation at the transmission network level. The SINCRO.GRID project develops, among other elements, a Virtual Cross-Border Control Centre (VCBCC) to effectively support various voltage and frequency control processes and enhance voltage profiles in the project area, while enabling increased integration of RES and secure and reliable supply of electric power to the end-users. The SINCRO.GRID project proves necessary for the 'smart grid deployment' thematic area (Annex I, 4 (10) to the Regulation) and it complies with the general criterion 1(c)(i), as well as with 1 (c) (ii) of Article 4 of the Regulation. The SINCRO.GRID project proposal is very well articulated and documented and demonstrates a significant positive contribution to the six smart grid specific criteria outlined in Article 4 (2) of the Regulation and a positive outcome of the project's societal cost-benefit analysis.

Quick guide: To develop an integrated EU energy market and ensure fulfilment of EU's policy objectives of affordable, secure and sustainable energy, every two years the European Commission adopts a list of key energy infrastructure projects - known as Projects of Common Interest. Since 2013 and the establishment of the first Union-wide list of Projects of Common Interest, JRC supports the implementation of the TEN-E Regulation in the priority thematic area of 'smart grid deployment'.

This report presents the outcome of the evaluation process of candidate projects in the area of 'smart grids deployment', to be included in the 3rd Union list of Projects of Common Interest. The evaluation process relies on thorough analysis of the information provided in the submitted project proposals, following the *JRC assessment framework for Projects of Common Interest in the field of smart grids, 2017 update*.

The report shall assist the TEN-E Regional Group on Smart Grids Deployment in proposing smart grid projects to be included in the 3rd Union list of Projects of Common Interest.

1 Introduction

1.1 Objectives

This report presents the outcome of the technical evaluation of smart grid project proposals, carried out for the Regional Group on Smart Grids Deployment ([1]) and in line with the Assessment framework for Projects of Common Interest in the field of Smart Grids (Vasiljevska and Gras, 2017), which is intended to guide project promoters in preparing their project proposals.

The Assessment Framework closely follows the requirements put forward in Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure ([2]), hereinafter referred to as 'the Regulation'. It builds on a methodological approach for verification of project's compliance with the general criteria laid out in the Regulation (Article 4) and in the evaluation of the project's contribution to the smart grid specific criteria of Article 4 of the Regulation and in line with Annex IV (4) to the Regulation.

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*'.

In this context, the report aims to assist the Regional Group in proposing Projects of Common Interest (PCI) in the area of smart grids deployment to be included in the 3rd Union list of Projects of Common Interest.

1.2 Policy context

To facilitate the development of an integrated EU energy market, since 2013 and every two years, the European Commission draws up a list of key energy infrastructure projects, known as Projects of Common Interest, essential for meeting the EU's energy policy objectives of affordable, secure and sustainable energy.

Projects of common interest shall meet the following general criteria, according to Article 4 (1) of the Regulation:

a) the project shall be necessary for at least one of the energy infrastructure priority corridors and areas;

b) 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. Each specific criterion shall be assessed against a set of KPIs as derived from the criteria in point (4) of Annex IV to the Regulation.

([1]) The Regional Group on Smart Grids Deployment is one of the 12 Regional Groups as set out in Annex III.1 of the Regulation, and it includes representatives of Ministries, national regulatory authorities, electricity transmission operators, project promoters, ENTSO for Electricity, ACER, and the European Commission. The membership of each Group is based on each priority corridor and area and their respective geographical coverage as set out in Annex I to the Regulation.

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

c) 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 Member State and a European Economic Area country; alternatively, it shall be located on the territory of one Member State and have a significant cross-border impact ([3]).

In the context of point b) above, each Project of Common Interest shall significantly contribute to the six specific policy criteria of Article 4(2)(c), namely:

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

Moreover, point (4) of Annex IV to the Regulation specifies that each specific criterion mentioned above shall be criteria (who have been translated into KPIs in the applicable Assessment Framework) ([4]), 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;
- **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;

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

([4]) 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_{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.

To facilitate the assessment of projects that could be eligible as Projects of Common Interest and that may be included in a regional list, each Regional Group shall assess the project's contribution to the implementation of the same priority corridor or area in a transparent and objective manner, and in line with the assessment framework for Projects of Common Interest in the field of Smart Grids (Vasiljevska and Gras, 2017).

A fully monetised cost-benefit analysis (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 (e.g. market functioning and customer services, involvement of users in management of their energy use, etc.). Such impacts are evaluated according to a KPI-based analysis (Vasiljevska and Gras, 2017), 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**: stronger impact could not be assessed with a sufficient level of confidence due to a significant lack of information or negative impact has been assessed.

For smart grids projects falling under the energy infrastructure category set out in Annex II.1 (e), a ranking of projects shall be carried out only 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.

2 Evaluation of project proposals

In line with the Regulation's requirements and upon official request for information launched by the European Commission, the following projects were submitted for inclusion in the 3rd Union list of PCIs:

- **A**gain **CO**nnected **N**etworks (ACON) – Member States involved: Czech Republic and Slovak Republic
- **ALPGRID** – Member States involved: Italy and Austria
- **S**mart **B**order **I**nitiative (SBI) – Member States involved: Germany and France
- **SINCRO.GRID** – Member States involved: Slovenia and Croatia

The sections below illustrate the evaluation of these four projects.

2.1 Again COnnected Networks (Czech Republic and Slovak Republic)

2.1.1 General overview

The ACON project is mainly driven by the necessity in the project area to significantly improve the efficiency of the distribution networks in both Member States, while strengthening cooperation between the Czech and Slovak Republic and delivering benefits to the broader territorial cohesion of the Eastern European region. The project will leverage on the existing cross-border connections at distribution network level (at 110 kV and 22 kV) of once historically connected region (therefore the name of the project) and further enhance the network security by strengthening the existing cross-border connections and constructing additional ones. In this context, the project addresses smart grid and conventional elements, both necessary for strengthening the network operational security. Current 110 kV and 22 kV cross-border connections at the distribution network level are mainly used in non-standard operational conditions. On the other hand, future regional needs – mainly taking care of growing RES integration while ensuring network security and quality of supply - would lead to increasing interregional flows at the distribution network level. The construction of additional 110 kV and 22 kV interconnection capacity is expected to secure efficient energy exchanges between the involved Member States, particularly in case of increased transfer capacity needs at the DSO level, while maintaining network stability. The smart grid elements introduced by the project include smart metering and control functionalities, installed mainly at medium voltage (MV) and high voltage (HV) distribution network levels, nevertheless some part of the equipment will be also installed at low voltage (LV) network level.

Main project goals:

- Enhancement of network security and quality of supply;
- Improvement of distribution and transmission network operational efficiency;
- Enabling growing penetration level of RES in the region;
- Leveraging the benefits of increased cross-border co-operation and connectivity.

2.1.2 Compliance with the general criteria of Article 4 (1) (c) of the Regulation

The ACON project involves distribution system operators (DSOs) from two Member states (E.ON Distribuce and Západoslovenská distribučná in the Czech and Slovak Republic, respectively), responsible for carrying out the project’s investments at each side of the project area. An impact is also expected at the transmission network level in the involved countries and the project entails the cooperation with the concerned Czech and Slovak Transmission System Operators (TSO)s (ČEPS and Slovenská elektrizačná prenosová sústava, respectively). The project has a direct impact on the cross-border capacity of the involved Member States as it addresses cross-border connections at 110 kV and 22 kV network level and as such it complies with the general criterion 1(c)(i) of Article 4 of the Regulation.

2.1.3 Project's necessity for the 'smart grid deployment' thematic area

The ACON project aims to support integration of all users connected to the grid and facilitate growing penetration of renewable energy sources. Smart grid technologies addressed in the project allow for improved network observability and control and ultimately lead to enhanced network operational efficiency and higher quality and security of supply. Smart grid elements deployed in the project would enable cross-border data exchange and lead to increase of the regular operational capacity of the cross-border interconnections, while improving network reliability and quality of supply. This will ultimately facilitate utilisation of different flexibility services for enhanced network reliability and quality of supply. Smart grid technologies cover Advanced Meter Management (AMM) devices, mainly installed at MV and HV network level, including smart meters with integrated ripple control functionality ([5]), concentrators and additional communication supporting elements using fibre optics or Long-Term Evolution (LTE), installed at LV network levels. The AMM technology is expected to optimise the energy balance in the distribution grid, particularly in MV and LV network areas where overvoltages are present due to large amount of growing PV capacity and enable demand side management services provided to both DSOs and TSOs. Additionally, smart grid technologies will be installed at MV/LV distribution transformer stations for enhanced grid steering and monitoring to be able to accommodate future customer needs.

In addition to the smart grid elements, the ACON project also includes conventional investments necessary to address current and future needs in the project area. Such investments address enhancement of the existing 22 kV and 110 kV cross-border lines and construction of new cross-border interconnections (at 22 kV and 110 kV network level).

The ACON project is mainly driven by the current and future needs of the distribution networks in the project area, and as such DSOs of both Member states are the main project promoters. Nevertheless, the project is expected to have positive impact on the transmission networks of both Member States, as increase network observability and control enabled by the ACON project would lead to better management of the power flows in the distribution networks, and consequently power flows coming from the distribution into the transmission networks. Additionally, demand side management solutions enabled by the ACON project and future use of dynamic tariffs could lead to new type of ancillary services provided to the TSOs. In this regard, the project proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation.

2.1.4 System architecture and deployed assets

The main technologies addressed by the ACON project are the following:

- Smart grid technologies including new substation dispatching control and protection system – installation of new local advanced (supervisory control and data acquisition) SCADA system, voltage regulation, remotely controlled transformation stations, installation of smart switches (reclosers) and fault locators on the MV power lines, intelligent algorithms for automation, etc.

([5]) Ripple control presents unidirectional direct load control for enabling demand-side management, widely used in the Czech Republic. The customer's consent for the control of specified appliances by the distribution-system operator is included in the connection contracts and the customers are compensated for deferred consumption in the form of a lower rate for electricity distribution and, in most cases, also lower price of the actual electricity.

- Smart communication and control technologies, including smart metering devices – optic wires, high speed PLC communication, new network dispatching model, etc.

- Modernisation of current cross-border MV and HV power lines – installation of automated remote controls for MV power lines and distribution transformer stations, deployment of optic wires for real (or close to real) time data communication on the current network status, looping and cabling of MV power lines, etc.

- Construction of new cross-border distribution network interconnections and 110/22 kV transformer station with the aim to improve network operational efficiency, security and quality of supply and increase network capacity while accommodating future needs of all network users.

2.1.5 Contribution to the smart grid specific criteria

The benefits of the ACON project are assessed according to the specific criteria, outlined in Article 4(2)(c) of the Regulation, and captured by a set of 21 Key Performance Indicators (KPIs), as derived from the criteria in Annex IV to the Regulation. In this context, the ACON project promoters argue the project impact on each of the six specific criteria, selecting a set of KPIs to better capture the project's impact against a specific criterion.

Table 1 – Table 6 set forth the KPIs selected for capturing the project's impact against each specific criterion, and the estimation approach used. Depending on the current degree of uncertainty in the information provided by the promoters and on the assumptions made, the JRC has used an approach based on colour-coding (Vasiljevska and Gras, 2017) to evaluate the project's contribution to each specific criterion.

Policy criterion 1: Integration and involvement of network users with new technical requirements with regard to their electricity supply and demand

The project is expected to effectively integrate growing integration of distributed renewable sources and involve controllable load in provision of more efficient distribution network operation. To this end, the promoters select the following KPIs in addressing the project's impact on this criterion.

Table 1 ACON: evaluation of project's impact against the first specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{14}: Ratio between minimum and maximum electricity demand within a defined time period	The ratio between the minimum and maximum electricity demand within a defined time period is expected to decrease as a result of better involvement of network users (and their controllable load) for network management, enabled by the ACON project deployment. The proposed project solution, in terms of data information and promotion of dynamic tariffs, is expected to facilitate demand side management and reduce the difference between Pmax and Pmin. Based on this expectation, this KPI is quantified and positively assessed to nearly 11 %, using the formula proposed in the assessment framework.	

KPI_7: Operational flexibility provided for dynamic balancing of electricity in the network	The project is expected to significantly increase the operational flexibility for electricity network dynamic balancing, as a result of effective integration and involvement of network users in managing their load. This would, on the other hand, potentially lead to growing integration of distributed renewable energy sources. ACON promoters report increase of nearly 33 % of the network operational flexibility, using the formula proposed in the assessment framework.	

Policy criterion 2: Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation

The promoters report an increase in the distribution and transmission network efficiency (and consequently reduced level of network losses), due to the enhanced network monitoring and control and the larger demand side participation enabled by the project, which would, in turn, lead to lower environmental impact.

In this respect, the promoters select the KPIs presented in Table 2 to capture the project's impact on this specific criterion.

Table 2 ACON: evaluation of project's impact against the second specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_1: Reduction of greenhouse gas emissions	The project is expected to increase distribution and transmission network efficiency (e.g. lower network losses) due to increased network observability and controllability, increase RES and enable effective demand side management enabled by the project's solutions. ACON promoters positively quantify this KPI, using the formula proposed in the assessment framework and report reduction of 68.7 kg/MWh of GHG emissions due to the project deployment.	
KPI_2: Environmental impact of electricity grid infrastructure	Enhanced network management and control, enabled by the project deployment could possibly lead to lesser need of building overhead lines and in that respect, reduce the environmental impact of such grid infrastructure. Furthermore, the ACON project proposes replacement of selected overhead power lines with underground cables, thus reducing long-term environmental impact, in terms of visual impact, soil occupation, threat to endangered animal species, etc.	
KPI_3: Installed capacity of distributed energy resources in distribution networks	Enhanced network management and control capabilities (e.g. innovative voltage regulation algorithms, reactive power management, innovative grid protection/monitoring) enabled by the ACON project would allow for increased DER capacity that could be safely integrated in the distribution grids. The ACON promoters report an increase in DG hosting capacity of around 15 %, using the formula proposed in the assessment framework.	

KPI_{13}: Level of losses in transmission and distribution networks	ACON promoters are expected to respond to the 7% of network losses decrease in the region, as set by the Regulator, which otherwise would be difficult to achieve in the absence of smart grid technologies. In this context, ACON project would facilitate the decrease of network losses through enhanced network observability and access to more detailed information for all grid users. In this respect, the promoters positively assess this KPI to around 1.17 %, using the formula proposed in the assessment framework.	

Policy criterion 3: Network security, system control and quality of supply

The promoters anticipate a positive impact of the project on this policy criterion, due to enhanced network management and control using advanced network reconfigurations and voltage regulation at the substations and provision of new types of ancillary services enabled by the project. Additionally, extension of the 110 kV and deployment of a new 22 kV cross-border interconnection line would also allow for enhanced network control and management and ultimately growing level of DER.

The following KPIs are selected by the promoters to address the project's contribution to the third specific criterion.

Table 3 ACON: evaluation of project's impact against the third specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_4: Allowable maximum injection of power into transmission networks without congestion risks	The ACON project mainly addresses the distribution network and in this case the KPI indicates the increased distribution network hosting capacity in the project area, thus allowing for increase of DER in the region without compromising the operation of the transmission network. The ACON promoters positively quantify this KPI to nearly 35 % in terms of DER energy increase as a result of increase in the distribution network hosting capacity due to extension of the 110 kV line and deployment of new 22 kV line. Moreover, smart grid elements deployed within the project would allow for enhanced network control and management and ultimately growing level of DER.	
KPI_8: Ratio of reliably available generation capacity and peak demand	The ACON project is expected to increase the reliably available generation capacity due to enhanced network management and control and lower the peak demand as a result of demand side management and introduction of dynamic tariffs, enabled by the project. The reliably available capacity is the part of net generating capacity actually available to cover the peak load (ENTSO-E, 2009b) and as such is an indicator of the system's adequacy. As ACON project mainly addresses the distribution network level, the promoters use an alternative approach and positively quantify this KPI as nearly 10 % increase in the renewable energy connected to the grid due to better network operational and load management, and therefore, lower difference between the Pmin and Pmax.	

KPI_{10}: Stability of the electricity system	The promoters expect positive impact on this KPI as the ACON project would deal with possible under/over voltage situations using advanced network reconfigurations and voltage regulation at the substations, provision of new types of ancillary services (e.g. DSM), while enabling larger connection of new network users. In this respect some positive impact is anticipated, nevertheless uncertainties still persist in the information provided to access positive impact with sufficient level of confidence.	
KPI_{11}: Duration and frequency of interruptions per customer, including climate-related disruptions	The ACON project is expected to increase network reliability due to various smart grid elements deployed within the project (voltage regulation, remotely controlled transformation stations, installation of smart switches and fault locators on the MV power lines, etc.). In this regard, the promoters positively quantify the project's impact on both reliability indices, reporting anticipated increase of SAIDI and SAIFI of 4.2 % and 8 %, respectively, using the formula proposed in the assessment framework. This improvement is expected to bring significant benefits to both, the customers and the DSOs (in terms of avoided costs for repairs and service interventions).	
KPI_{12}: Voltage quality performance	The promoters report positive impact on this KPI, in terms of voltage line violations (over a predefined period of time) defined in accordance with the EN 50160 standard and using the formula proposed in the assessment framework. The KPI is quantified as reduced frequency of voltage line violations by nearly 5.5 % over a period of one year owing to the project deployment.	
KPI_{20}: Exploitation of interconnection	As the project mainly addresses the distribution network level, the promoters estimate this KPI as increase in the MV cross-border capacity due to modernisation and installation of new MV cross-border lines along with deployment of smart grid elements in the project area. In this regard, the exploitation of the distribution interconnection is expected to increase as well, however uncertainties still persist in the information provided to access positive impact with sufficient level of confidence.	

Policy criterion 4: Optimised planning of future cost-efficient network investments

The promoters anticipate positive impact on this specific criterion as increased data availability related to network operation and maintenance, enabled by the project, would lead to optimised planning of network investments. Moreover, higher percentage utilisation of electricity network components would potentially lower the cost of distribution network management and ultimately enhance planning of future cost-efficient network investments. In this respect, the promoters capture the project's impact on this criterion using the following KPIs.

Table 4 ACON: evaluation of project impact against the fourth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{18}: Actual availability of network capacity with respect to its standard value	The promoters select the actual availability of network capacity to address future cost-efficient investment. In this context, the ACON project is expected to increase the network capacity with respect to its nominal value, as a result of the expected extension and enhancement of the 110 kV and deployment of a new 22 kV cross-border interconnection. The KPI is positively assessed to ca. 25 % increase of network capacity with respect to its standard value using the formula proposed in the assessment framework.	
KPI_{17}: Availability of network components (related to planned and unplanned maintenance) and its impact on network performance	The project is expected to have positive impact on this KPI as increased data availability related to network operation and maintenance, enabled by the project, will lead to optimised planning of network investments. The implementation of smart grid capabilities will allow for condition-based maintenance and ultimately reduce the mean time between network failures (as a result of optimal loading conditions of network components) and the mean time to repair (due to faster fault identification). The KPI is positively assessed, owing to expected increase of around 16.5 % in the availability of network components using the formula proposed in the assessment framework and based on existing network failure reports from both DSOs and similar pilot projects.	
KPI_{16}: Percentage utilisation (i.e. average loading) of electricity network components	The promoters anticipate positive impact on this KPI due to increased distribution network capacity and improved network stability enabled by the ACON project. This would ultimately lead to enhanced utilisation of the TSO-DSO interconnection, in terms of power flows coming from the transmission network and increase the lifetime and reliability of network components and equipment at the TSO-DSO interconnection point (HV/MV transformer). In this respect some positive impact is anticipated, nevertheless uncertainties still persist in the information provided to access positive impact with sufficient level of confidence.	

Policy criterion 5: Market functioning and customer services

The project would enable increased involvement of end-users (both consumers and prosumers) in effective management of the grid operation, which is critical for market functioning and introduction of new customer services. Complementary increase of the physical cross-border interconnection enabled with the ACON project is expected to have positive impact on the market development in the project area.

Table 5 illustrates the KPIs selected to address the project's impact on the fifth specific criterion.

Table 5 ACON: evaluation of project's impact against the fifth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	The promoters use this KPI to capture the project's impact on this specific criterion, as involvement of end-users (both consumers and prosumers) in effective management of the grid operation is critical for retail market functioning and introduction of different customer services. In this regard, the ACON project is expected to lower the renewable energy not withdrawn due to network congestion or security risks as a result of increase of controllable load subject to demand side management. At this stage of the project development, promoters do not consider RES curtailment in the project area and therefore the KPI is positively assessed as potential increase of nearly 46 % of RES without congestion/security risks, in view of growing controllable load, subject to demand side participation.	
KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	The ACON project is expected to provide a more granular array of information available to better allocate the electricity costs among different network users. Such information typically includes: automatic and (close to) real-time energy consumption and/or generation data, detailed analysis of consumer/prosumer data in the form of clear tables and graphs used for customer energy bills, etc. Moreover, this level of informational detail would further promote the introduction of dynamic pricing, and potentially engage end-users in more effective management of their energy consumption. Finally, more detailed information flows would allow regulators to assess RES contribution to the provision of ancillary services to both DSOs and TSOs, and move the market forward in the setup of new customer services.	
KPI_{19}: Ratio between interconnection capacity of a Member State and its electricity demand	The promoters use this KPI to capture the project's impact on this specific criterion, as cross-border interconnections and cross-border cooperation have a critical impact on market functioning. Increase of physical cross-border interconnection at distribution network level, enabled with the ACON project, is expected to have a marginal, but positive impact on market development in the project area. Since the ACON project is mainly developed at the distribution network level, this positive impact is quantified as increase in the distribution network net transfer capacity resulting from the modernisation of the existing cross-border lines and installation of new 110 kV and 22 kV lines. Additionally, the deployment of smart grid elements on both sides of the border would allow for integration of additional DER and enable ancillary services available to the DSO. Although this KPI is positively quantified as the increase in the ratio of the interconnection capacity at distribution	

	network level and energy demand in the project area, the impact on the ratio of total interconnection capacity in each Member State and their energy demand is expected to be limited.	
KPI_{21}: Congestion rents across interconnections	Well interconnected energy markets provide sufficient capacity for all market participants and in this regard, the level of congestion rents strongly affects the functioning of the market itself. The promoters anticipate lower probability/frequency of distribution network congestion due to the project deployment. However, this KPI cannot be positively assessed with sufficient level of confidence due to significant lack of information at this stage of project development.	

Policy criterion 6: Involvement of users in management of their energy usage

The ACON project is expected to increase the involvement of end-users in more effective management of their energy usage (through demand–side participation and energy efficiency measures) and consequently enable increase in the share of electricity generated from RES. Table 6 presents the KPIs, selected by the promoters, in order to assess the ACON project's contribution to this specific criterion.

Table 6 ACON: evaluation of project's impact against the sixth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_9: Share of electricity generated from renewable sources	The promoters choose this KPI to address the project contribution to the 6th specific criterion, as the share of electricity generated from RES is expected to increase due to more effective involvement of end-users in the management of their energy usage. The promoters positively asses this KPI due to anticipated increase of nearly 10 % renewable energy in the project area, enabled by the smart grid elements introduced in the project.	
KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures	This KPI is closely linked to the involvement of users in the effective management of their energy usage. In this respect, the ACON project is expected to increase the load participating in demand-side management and energy efficiency measures in comparison to the business as usual (BaU) scenario. The KPI is therefore positively assessed to around 9%, using available data from the dispatch centres of both DSOs for the BaU scenario, and expected increase in additional sources subject to DSM, coming from similar pilot projects in the region.	

2.1.6 Economic appraisal

The following section presents the societal benefits of the ACON project along with the cost elements (capital and operational expenditure), subject to societal CBA performed and communicated by the promoters. Furthermore, the outcome of the societal CBA, in terms of economic indicators such as NPV, IRR, and B/C, are used to verify whether for this project, the overall benefits outweigh the costs and, therefore, if the project complies with the general criteria of the Regulation (Article 4 (b)).

The promoters assumed the following values for the variables used in the societal CBA:

- **Demand growth**: an average annual demand growth of 0.843 % has been assumed for the project area;
- **Discount rate**: a value of 4% has been used as social discount rate (6);
- **Time horizon**: a period of twenty-five years has been chosen as time horizon (as the project also considers traditional investments);
- **Peak demand reduction**: a value of 293.6 MW has been assumed for the project area due to expected peak load shift and energy savings;
- **Electricity price for losses**: a value of 27 €/MWh has been assumed for evaluating the project impact on the level of technical losses;
- **Electricity market price**: 36 €/MWh, however, it is expected that electricity prices will increase within the considered time horizon (European Commission, 2016);
- **Cost of energy not supplied**: 11 €/kWh (7);
- **Carbon prices**: 40 €/t (8);
- **Fuel prices**: 1€/litre.

The project reports positive outcome of the economic cost-benefit analysis (NPV equal to 41.8 million € and B/C of 1.6) with the main monetised benefits and costs listed below.

2.1.6.1 Main monetised benefits

The ACON project is expected to deliver a set of positive impacts and in that respect the following monetised benefits are communicated by the project promoters:

- Reduced maintenance costs of assets;
- Reduced cost of equipment breakdowns;
- Deferred distribution capacity investments due to consumption reduction;
- Deferred distribution capacity investments due to peak load shift;
- Reduced electricity technical losses;
- Electricity savings due to consumption reduction;

(6) (Vasiljevska and Gras, 2017), available at http://europa.eu/!XT96FU
(8) (Commission Staff Working Document, 2016)
(8) (Commission Staff Working Document, 2011)

- Electricity savings due to peak load transfer;
- Increased value of service due to reduced outage times;
- Recovered revenue due to reduced outages;
- Reduced CO_2 emissions due to reduced losses;
- Reduced CO_2 emissions due to wider diffusion of low carbon generation sources;
- Reduced fossil fuel usage.

2.1.6.2 Main costs

The main costs associated with the project deployment are:

- Smart technologies related to new substation dispatching control and protection system (remote control, cabling, voltage regulation, intelligent metering system, smart distribution board, reclosers, platform for demand side management, etc.);
- Smart technologies related to communication and network management, including smart meters (new dispatching model, optic wires, smart meters, high speed PLC communication, intelligent algorithms for network management, etc.);
- Modernisation of current cross-border MV and HV power lines, and construction of new cross-border MV power lines for increase of network capacity for new network users, removing under-voltage situations, etc.

2.1.6.3 Sensitivity analysis

The NPV of the project varies with the variation of the following critical variables:

- **Peak demand reduction**: lowering the value of assumed peak demand reduction due to both energy savings and peak load shifting by 33 % lowers the project NPV by 11 %. Increasing the value of assumed peak demand reduction due to both energy savings and peak load shifting by 10 % increases the project NPV by ca. 3 %.
- **Electricity price for losses:** Lowering the value of electricity losses (compensated by the regulator) by 25 % lowers the project NPV by around 30 %. Increasing the value of electricity losses (compensated by the regulator) by 20 % increases the project NPV by ca. 22 %.
- **Electricity market price:** Lowering the electricity market price by 25 % lowers the project NPV by 12.4 %. Increasing the electricity market price by 20 % increases the project NPV by 10 %.
- **CO_2 price:** The switching value of CO_2 between positive and negative NPV is calculated to be at a level of 21.77 €/ton.
- **Value of lost load:** The switching value of VOLL between positive and negative NPV is calculated to be at a level of 5556.66 €/MWh.
- **Discount rate:** Increasing the discount rate value from 4 % to 5.5 % lowers the calculated project NPV by 73 %.

2.1.7 Additional non-monetised benefits

The project proposal also includes a set of additional non-monetary impacts, such as:

- Reduced air pollutants emissions (particulate matter, SO_x, $NO_{x,}$ and CO) due to reduced line losses;

- Reduced air pollutants emissions (dust particles, SO_x, $NO_{x,}$ and CO) due to wider diffusion of low carbon generation sources;

- Reduced soil occupation;

- Lower threat to animal species;

- Reduced visual impact.

2.1.8 Summary of the ACON project's evaluation

The ACON project responds to the need to significantly improve the efficiency of the distribution networks in the project area, while increasing the cross-border capacity at DSOs' level. It capitalises on existing cross-border distribution network interconnection (currently only used for non-standard operational activities) and proposes further enhancement of the existing cross-border connections by deployment of smart grid solutions and installation of additional 22 kV and 110 kV cross-border lines, necessary for addressing future grid stability and reliability issues in presence of growing level of RES. Notwithstanding the conventional elements proposed in the project (deployment of MV and HV cross-border distribution network interconnectors), necessary to support the energy needs in the project area, the ACON project consists of smart grid technology and solutions and as such, it proves necessary for the smart grid deployment thematic area (Annex I, 4(10) to the Regulation).

The project addresses a cross-border region at distribution network level and in this sense, it involves DSOs from two Member States, nevertheless, TSOs are also expected to be involved and benefit from more efficient and reliable operation of the distribution networks in the project area. The cross-border dimension includes deployment of cross-border connection of two-way real- or close to real-time digital communication, allowing for interactive and intelligent monitoring and management of the electricity network through better involvement of network users in management of their energy usage. This would ultimately create favourable conditions for utilisation of demand-side flexibility and development of innovative customer services. In this respect, the project complies with Article 4 (1) (c) i) of the Regulation.

The ACON project demonstrates significant contribution to the six smart grid specific criteria, outlined in Article 4 (2) of the Regulation and positive outcome of the project's societal cost-benefit analysis.

2.1.9 General overview

The ALPGRID project develops an innovative cross-border flexibility platform operated jointly by aggregators in Austria and Italy. It builds on the deployment of mature technologies for distribution networks monitoring and control, whereas market players (generators, storage, etc.) provide flexibility and aggregators from the project area offer their flexibility to DSOs and TSOs.

In the recent years, the Austrian and Italian electricity systems have been increasingly challenged by major trends impacting the regional performances of both electricity systems, such as:

- Increasing penetration of RES, mainly connected at distribution network level;

- Lower electricity consumption due to the economic crisis;

- Changing load profiles, resulting from electrification of the transport sector of and consumers' value chains;

- Strict power quality needs for industrial processes (refineries, microelectronics factories, etc.)

- Congestion on the single interconnector between Austria and Italy, resulting from price spreads between the two adjacent control zones.

As a result, in the coming years the Italian and Austrian distribution networks will likely observe growing voltage and power quality issues and, consequently, constraints on the connection of new RES. This situation may lead to increasing need for provision of flexibility solutions to the electricity systems by aggregators and storage operators.

The project includes DSOs from Italy (e-distribuzione) and Austria (KNG-Kärnten Netz and Wiener Netze) and aggregators and energy storage operators from Italy (Enel Green Power and Enel Produzione) and Austria (VERBUND Solutions).

Main project goals:

- Enhancement of network security, reliability and quality of supply;

- Enabling a growing penetration level of RES in the region;

- Increasing the system's operational efficiency, as a result of a joint cross-border systemic approach;

- Development of a market for provision of flexibility services.

2.1.10 Compliance with the general criteria of Article 4 (1) (c) of the Regulation

The main idea of the ALPGRID project revolves around development of a cross-border flexibility platform being able to aggregate flexibilities from different market players on both sides of the border and offer these services to the DSOs and TSOs in the project area. In presence of an increasing share of RES, lower electricity consumption and changing load profiles, the region will likely observe growing network voltage and power quality issues. To this end, the Italian and Austrian DSOs, in collaboration with the respective TSOs in the region have started to address this issue separately, in their respective control zones. Nevertheless, uncoordinated actions taken at the distribution level in each control zone separately may negatively impact the performance of the single interconnector and the electricity system in the region, potentially leading to repeated investments to keep the electricity system operating within the admissible ranges. To this end, the involved Austrian and Italian DSOs together with aggregators and storage operators in the project area jointly propose the development of a common cross-border flexibility platform for increasing system security, reliability and operational efficiency and maximise the investment impacts in the project region. As such, the project complies with the general criterion 1(c)(i) of Article 4 of the Regulation. The DSOs benefit from advanced, yet mature technologies allowing for enhanced observability and controllability of their distribution network assets, while solving network operational issues in a more coordinated and optimal way by considering cross-border flexibility services. Ultimately, such coordinated approach is expected to positively impact the single interconnector between the two Member States, in terms of increased net transfer capacity (NTC) and cross-border participation in electricity markets.

2.1.11 Project’s necessity for the ‘*s*mart grid deployment’ thematic area

The ALPGRID project includes various smart grid elements, such as real-time power monitoring and fault detection devices, power flow and power quality control devices installed at primary and secondary substations for improving power quality and network reliability issues. The project also envisages installation of forecasting and control technologies for the non-dispatchable distributed renewable plants in order to maximise the flexibility offered to the grid, while supporting growing penetration level of such power sources. Additionally, the deployment of a virtual cross-border coordination platform between the Italian and Austrian aggregators will significantly increase the flexibility resources, while effectively responding to the network operational needs in the region.

The project is also expected to contribute to a better management of the existing interconnection between the two Member States and therefore maximise the NTC and reduce the Reliability Security Margin (RSM). Additionally, implementation of a cross-border aggregation platform will optimise the flexibility value brought by the aggregators in the region using a coordinated and non-discriminatory approach and contribute to a better management of the distribution networks while encouraging growing penetration level of RES. In this context, the project proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation).

2.1.12 System architecture and deployed assets

The main technologies addressed by the ALPGRID project are the following:

- Upgrade of primary and secondary substations in the network area operated by e-distribuzione: installation of automated and control devices, remote terminal units (RTUs), real-time network monitoring and fault detection devices and OLTC management, deployment of flywheel storage facilities mostly used for quality of service purposes, installation of tools for RES forecasting, etc.

- Upgrade of secondary substations in the network area operated by Wiener Netze: close to 600 MV/LV substations will be equipped with automation and control devices, RTUs and communication elements; stationary battery storage system will be installed at nearly 30 selected MV/LV substations; deployment of broadband communication infrastructure for the connection of the upgraded assets to the DSO’s control centre; installation of advanced control systems and sensors for increased network observability and controllability, etc.

- Upgrade of secondary substations in the project area under responsibility of Kärnten Netz: installation of remote load-break switches, short-circuit indicators with remote reading, voltage measurement at the secondary side of the transformer, replacement of some pole-mounted substation with cabinet-type; deployment of smart outage management system, etc.;

- Deployment of solutions to enhance the flexibility of assets being part of the aggregators portfolio (e.g. demand response and DG aggregation platform to support automated aggregation of flexible assets with different profiles);

- Deployment of storage solutions (Li-Ion technology) connected to the HV/MV grid for provision of services to the TSOs (e.g. synthetic system inertia, enhanced frequency response, etc.) and the DSOs (e.g. voltage control);

- Power forecasting and control technologies for the non-dispatchable distributed renewable plants;

- Development and deployment of virtual cross-border aggregation platform between the aggregators on both sides of the border: installation of distributed sets of processes on the servers of all participants, development of interfaces for both, market participants (e.g. other aggregators) and DSOs and TSOs.

2.1.13 Contribution to the smart grid specific criteria

The benefits of the ALPGRID project are assessed according to the specific criteria, outlined in Article 4(2)(c) of the Regulation and captured by a set of 21 Key Performance Indicators, as derived from the criteria in Annex IV to the Regulation. In this context, the ALPGRID project promoters argue the project impact on each of the six specific criteria, by selecting a set of KPIs to better capture the project's impact against a specific criterion.

Table 7 – Table 12 below set forth the KPIs selected for capturing the project's impact against each specific criterion, and the estimation approach used. Depending on the current degree of uncertainty in the information provided by the promoters and the assumptions made, the JRC has used an approach based on colour-coding (Vasiljevska and Gras, 2017) to evaluate the project's contribution to each specific criterion.

Policy criterion 1: Integration and involvement of network users with new technical requirements with regard to their electricity supply and demand

The ALPGRID project is expected to increase the network hosting capacity for new distributed non-dispatchable RES while avoiding necessary investments, in terms of deployment of new lines/substations, network reinforcement, etc. Moreover, this would lead to reduction of the negative environmental impact of such network upgrade.

Additional level of information, as a result of enhanced network observability and RES forecast capabilities, would allow for involvement of network users in provision of new services to the DSOs/TSOs.

In this context, the promoters address the project's impact on the first specific criterion using the KPIs indicated in Table 7.

Table 7 ALPGRID: evaluation of project's impact against the first specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_1: Reduction of GHG emissions	The project is expected to reduce the level of GHG emissions as a result of anticipated increase of MV network hosting capacity for non-dispatchable RES and avoided RES curtailment through better network monitoring and control. The promoters application positively assess this KPI for the whole project area (estimated 13600-27200 tonnes CO2/year in Italy and 66000-82000 tonnes CO2/year in Austria), based on the expected increase of additional hosting capacity, annual equivalent hours of RES production and CO2 emission rates for both Italy and Austria.	

KPI_2: Environmental impact of electricity grid infrastructure	The promoters anticipate positive environmental impact of the project as a result of avoided reinforcements and refurbishment of the electricity grid (e.g. new power lines and substation to allow for increased network hosting capacity for RES and improved network operational security and efficiency) due to the ALPGRID project deployment. The positive environmental impact is qualitatively assessed and reported with sufficient level of detail, in terms of reduced visual and electro-magnetic impact, noise, vegetation, fauna, cultural heritage, etc.	
KPI_3: Installed capacity of distributed energy resources in distribution networks	Deployment of innovative voltage control schemes within the ALPGRID project is expected to increase the network hosting capacity for DER. Nevertheless, this increase largely depends on the location of new DER, which is out of control of the DSOs. The promoters provide an estimation of the increase of DER hosting capacity due to the project deployment, based on other pilot projects in the area using similar technologies. In this context, assuming a baseline scenario for 2016, the ALPGRID project is expected to increase the installed capacity of DER by 10%-20% and 20%-25% for the Italian and Austrian part of the project area, respectively.	
KPI_4: Allowable maximum injection of power without congestion risk in transmission networks	The promoters argue positive impact of the project on this KPI as a result of enhanced forecasting tools for RES and improvement of RES control enabled by the project. Nevertheless, the application also argues that additional injection of power into the distribution network could increase the probability of reverse power flows in steady state conditions through the primary substations into the transmission network. In the Italian part of the project area, the majority of the HV/MV substations already encounter reverse power flows for at least 5 % of the time in the year (data for 2016), whereas for the Austrian part of the project operated by Kärnten Netz, reverse power flows are observed in up to 50 % of the time for selected substations located in more rural environment. An assessment of such risk requires detailed simulation studies which has not been performed at the current level of the project development.	
KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	The ALPGRID project is expected to reduce the RES curtailment during low demand periods (caused by reverse power flows into the transmission network), as a result of participation of RES in the dispatching service market. The promoters provide an estimation of 1.2 % reduction of energy not withdrawn for the Italian part of the project area as a result of participation of distributed RES in the dispatching service market. In the Austrian part of the project region (operated by Kärnten Netz), it is expected that additional RES generation cannot be	

	deployed in the BaU scenario as this region currently encounters RES generation curtailment (especially during construction works on the grid). Such RES curtailment is expected to be considerably reduced by the ALPGRID project deployment	
KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	The ALPGRID project is considered to have positive impact on this KPI due to additional data and information flows coming from improved network observability and RES and load forecast capability enabled by the project. The proposed project may lead to improved methodologies for allocation of costs for all grid users and catalyse the evolution of regulatory framework for new services provided by DG to the DSOs and TSOs.	

Policy criterion 2: Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation

The ALPGRID project is expected to increase the efficiency and interoperability of electricity transmission and distribution networks as a result of enhanced network observability and controllability and promotion of closer cooperation between the DSOs and TSOs in the management and control of distributed generation, as connection of new generation can occur at both TSO and DSO level.

In this context, the promoters address the project's impact on the second specific criterion using the KPIs indicated in Table 8.

Table 8 ALPGRID: evaluation of project's impact against the second specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_7: Operational flexibility for dynamic balancing of electricity in the network	The promoters assess this KPI as ratio between the DG that can be modified (in response to price signals or system requirements) vs. the total generation rated power connected to the distribution network in the project area. Currently, there is no communication link between the DG connected to the distribution network and the DSOs. The ALPGRID project proposes deployment of broadband communication for real-time information exchange between the DG and the DSOs and therefore, significant increase of nearly 87 % of RES capacity in the Italian part of the project area able to participate in power control. Similarly, positive impact is assessed in the Austrian part of the project region due to adoption of broadband communication infrastructure for real-time information exchange between the DSO and the generation and storage operators, which increases the participation of storage capacity in providing operational flexibility for dynamic balancing by nearly 8 %.	

KPI_8: Ratio of reliably available generation capacity and peak demand	The promoters anticipate increase of the Reliably Available Capacity (RAC) as a result of expected increase of Net Generating Capacity. Growing level of RES would be enabled by the project deployment as a result of coordinated operation of existing non-dispatchabe RES units with new storage assets (in the Italian part of the project area) and adoption of control devices and forecast tools for the non-dispatchaple hydro plants (the Austrian part of the project). Quantitative estimation of this KPI requires specific simulation studies and is not provided at this stage of project development.	
KPI_9: Share of electricity generated from renewable sources	The project is reported to have positive impact on this KPI due to increased hosting capacity of RES, enabled by the project deployment, which can be safely integrated into the distribution system. This KPI is positively assessed to a value between 3.7 % and 7.4 % for the Italian part and 1 % - 2 % for Austrian part of the project area.	
KPI_{13}: Level of losses in transmission and distribution networks	The project area experiences reverse power flows in some time periods, which may increase the level of network losses, particularly also with growing penetration levels of RES (which is one of the goals of ALPGRID project). On the other hand, the project deploys advanced voltage control concepts expected to lead to more efficient network operation and therefore reduce network losses. The promoters provide references of pilot projects using similar technology as in the ALPGRID project, where some level of losses reduction is achieved. Nevertheless, promoters argue that estimation of the network losses require detailed network simulations, which have not been performed at the current level of the project development. To this end, the impact of the ALPGRID project on this KPI cannot be assessed with sufficient level of confidence at this stage of the project development.	

Policy criterion 3: Network security, system control and quality of supply

The implementation of innovative protection and voltage control mechanisms within the ALPGRID project allows for improved MV network voltage profile (thus network security, control and quality of supply), while better exploiting the distribution network hosting capacity. The promoters address the project's impact on the third specific criterion using the KPIs indicated in Table 9.

Table 9 ALPGRID: evaluation of project's impact against the third specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{10}: Stability of the electricity system	The ALPGRID promoters envisage alleviation of possible system instabilities (typically in terms of voltage) at both distribution and transmission system level, as a result of coordinated voltage control and increased controllability of non-dispatchable RES connected to the MV grid. However, the positive impact cannot be assessed with sufficient level of confidence due to a low level of data maturity at this stage of the project.	
KPI_{11}: Duration and frequency of interruptions per customer, including climate-related disruptions	The project is expected to decrease the duration of interruptions per customer (SAIDI) in the range of 3 % - 6 % in the Italian part of the project, as a result of the following ALPGRID project investments: deployment of fault detectors with real-time measurements, use of more reliable and efficient circuit breakers combined with broadband communication network (connecting all relevant network nodes) which will allow for prompt and reliable isolation of the faulty network sections. Similarly, up to 50 % of SAIDI reduction is expected in the network area operated by Wiener Netze and between 10 % and 30 % of SAIDI reduction in the network operated by Kärnten Netz. The frequency interruption per customer (SAIFI index) is not provided at this stage of the project development.	
KPI_{12}: Voltage quality performance	The ALPGRID project solutions allow for growing RES penetration levels while improving voltage quality. The promoters propose monitoring voltage line profiles in respect to two variables: 1) maximum line voltage reached during defined monitoring period and 2) the 95% voltage value during the monitoring period. The promoters argue expected improvement in the voltage profile, based on the results of the Italian demonstrator of GRID4EU project, where similar technologies have been deployed.	
KPI_{17}: Availability of network components (related to planned and unplanned maintenance) and its impact on network performance	Higher network observability and control, enabled by the ALPGRID project, is expected to reduce failures of network components. In this respect, some positive impact has been assessed; however uncertainties still persist in the information provided at this stage of the project development.	

KPI_{18}: Actual availability of network capacity with respect to its standard value	The ALPGRID project is expected to provide better utilisation of the network capacity due to improved controllability of non-dispatchable DER generation and thus better management of RES. In this respect, some positive impact has been assessed; however uncertainties still persist in the information provided at this stage of the project development.	

Policy criterion 4: Optimised planning of future cost-efficient network investments

Distribution network monitoring and control functionalities, enabled by the project, would lead to better management of critical network operating conditions, which in turn would reduce the needs for additional network capacity and associated investments. Furthermore, the project also addresses enhancement of the RES forecasting capabilities, leading to lower reserve-margin and, ultimately, NTC-reduction needs on the Italy-Austria interconnector.

Finally, the cross-border aggregation platform proposed in the ALPGRID project will allow for integration of different flexibility resources on both sides of the border and potentially increase the exploitation capacity of the existing interconnections by offering such flexibility to the TSOs. This would consequently lead to more cost-efficient future network investments.

The promoters select the KPIs presented in Table 10 to address the project impact on the fourth specific criterion.

Table 10 ALPGRID: evaluation of project's impact against the fourth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{16}: Percentage utilisation (i.e. average loading) of electricity network components	Improved monitoring and control of the distribution network, enabled by the ALPGRID project, shall allow for DSOs to better manage the network operational conditions and accordingly the lifespan of the network equipment. In this respect some positive impact has been assessed with some confidence, nevertheless uncertainties still persist in the information provided to allow for positive assessment with sufficient level of confidence.	
KPI_{19}: Ratio between interconnection capacity of a Member State and its electricity demand	The cross-border aggregation platform, proposed by the ALPGRID project and thereby increased coordination of flexibility resources is expected to decrease the NTC reduction of the single cross-border link between Italy and Austria in periods of critical operating conditions. In this respect, promoters anticipate slight increase in the average NTC values; nevertheless, due to uncertainties in the information provided and the assumptions made, the KPI cannot be positively assessed with sufficient level of confidence at this stage of the project development.	
KPI_{20}: Exploitation of interconnection	The project is expected to have positive impact on this KPI as a result of improved RES forecast functionalities	

capacities	and enhanced control and management of the DER infeed into the network. This would lead to lower reserve margin and NTC reduction in periods of critical network operating conditions. Moreover, the ALPGRID project will integrate different flexibility resources on both sides of the border and increase the exploitation capacity of the existing interconnections by offering such flexibility to the TSOs. Nevertheless, positive impact cannot be assessed with sufficient level of confidence due to uncertainties in the information provided.	
KPI_{21}: Congestion rents across interconnections	The project is expected to increase the exploitation of the interconnection capacity; however, the impact on price differentials on both sides of the border (and therefore the congestion rents) cannot be assessed at this stage of the project's development as it depends on the uptake of the markets and it requires closer cooperation with both TSOs impacted by the project. In this regard, the impact on this KPI cannot be positively assessed with sufficient level of confidence due to significant lack of information at the current stage of the project development.	

Policy criterion 5: Market functioning and customer services

The cross-border aggregation platform, put forward by the ALPGRID project, is envisaged to largely increase the demand response potential in the project area and thus contribute to the development and functioning of a market for new customer services. In this regard, the promoters address the project's impact on the fifth specific criterion using the KPI indicated in Table 11.

Table 11 ALPGRID: evaluation of project's impact against the fifth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures	The project suggests development of cross-border platform for aggregating flexibilities from both sides of the border, facilitated by the upgraded monitoring and control capabilities of the distribution networks in the whole project area. Such aggregation platform will, therefore, involve MV customers in the voltage regulation and energy efficiency measures. In this context, the demand response potential in the Austrian part of the project area accounts for 3.7 % of the expected peak demand by 2020 (TYNDP 2016). Similarly, the demand response potential in Italy is expected to reach 3.5 % from the peak load in 2020 (TYNDP 2016). Considering a zero value for the BaU scenario (as there is no aggregation platform currently installed at the Italian side of the project), a value of 3.5 % is assumed for this KPI in the Italian part of the project area). In this regard, the promoters anticipate that the ALPGRID project will act as enabler for the exploitation of the DR potential, particularly in Italy.	

Policy criterion 6: Involvement of users in management of their energy usage

Development of cross-border flexibility aggregation platform is expected to facilitate the involvement of users in more effective management of their energy usage.

The promoters address the project's impact on this specific criterion using the KPIs indicated in Table 12.

Table 12 ALPGRID: evaluation of project's impact against the sixth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_9: Share of electricity generated from renewable sources	The promoters envisage positive impact of the ALPGRID project on this KPI as a result of expected increase of hosting capacity due to improved network monitoring and control and development of aggregation services. In this respect, the KPI is assessed to a value between 3.7 % and 7.4 % for the Italian part and 1 % - 2 % for Austrian part of the project area.	
KPI_{14}: Ratio between minimum and maximum electricity demand within a defined time period	The aggregation capability enabled by the project would allow for peak load smoothing and therefore level out the difference between the minimum (Pmin) and maximum (Pmax) demand (within a defined time period). However, positive impact of this KPI cannot be assessed with sufficient level of confidence due to uncertainties in the information provided.	
KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures	The project suggests development of cross-border platform for aggregating flexibilities from both sides of the border, facilitated by the upgraded monitoring and control capabilities of the distribution networks in the whole project area. Such aggregation platform will, therefore, involve MV customers in the voltage regulation and energy efficiency measures. In this context, the demand response potential in the Austrian part of the project area accounts for 3.7 % of the expected peak demand by 2020 (TYNDP 2016). Similarly, the demand response potential in Italy is expected to reach 3.5 % from the peak load in 2020 (TYNDP 2016). Considering a zero value for the BaU scenario (as there is no aggregation platform currently installed at the Italian side of the project), a value of 3.5 % is assumed for this KPI in the Italian part of the project area). In this regard, the promoters anticipate that the ALPGRID project will act as enabler for the exploitation of the DR potential, particularly in Italy.	

2.1.14 Economic appraisal

The following section presents the societal benefits of the ALPGRID project in monetary terms along with the total cost (capital and operational expenditure), subject to societal cost-benefit analysis performed and communicated by the promoters. Furthermore, the outcome of the societal cost-benefit analysis, in term of economic indicators such as NPV, IRR and B/C are used to verify whether, for this project, the overall benefits outweigh the costs and, therefore, if the project complies with the 2nd general criteria of the Regulation (Article 4 (b)).

The promoters assumed the following values for the variables used in the societal CBA:

- **Demand growth**: 327.286 GWh (year 2020) and 311.285 GWh (year 2030);
- **Discount rate**: A value of 4% has been used as social discount rate [9];
- **Time horizon**: 20 years has been chosen as time horizon (relative to both, ICT and energy infrastructure investments considered in the project);
- **Ancillary service market price (primary and secondary reserve)**: 130k€/MW/y;
- **Ancillary service market price (primary, secondary, tertiary reserve and balancing) with power plant auxiliaries enhanced by storage system**: 65-75k€/MW/y;
- **Thermal generation price (Natural Gas CCGT)**: 65 €/MWh;
- **Cost of energy not supplied** (Italian side of the project): 10 €/kWh (residential LV customers), 35 €/kWh (non-residential LV customers) and 60 €/kWh (MV customers);
- **Carbon prices**: 16.5-36€/ton (16.5€/t from 2020 – 2025, 20 €/t from 2025-2030 and 36 €/ton from 2030-2035) [10].

The project reports positive outcome of the economic cost-benefit analysis according to the following indicators: NPV equal to 25.2 million € and B/C of 2.6 (for the Italian part of the project area) and NPV equal to 42.2 million € and B/C of 1.8 (for the Austrian part of the project area). The main monetised benefits and costs of the project are listed below.

2.1.14.1 Main monetised benefits

The ALPGRID project is expected to deliver a set of positive impacts and in that respect, the following monetised benefits are communicated by the project promoters:

- Improved efficiency of dispatching service market;
- Reduction of RES curtailment following TSO order;
- Deferred distribution investments;
- Reduced outage times;
- Increased RES hosting capacity;
- Reduced CO_2 and air pollutant emissions and reduced fossil fuel usage;
- Avoided cost of capacity purchase for primary and secondary reserve;
- More competitive bids at the ancillary service market and therefore improvement in the social welfare costs (lower TSOs costs).

([9]) (Vasiljevska and Gras, 2017), available at http://ses.jrc.ec.europa.eu/publications/reports/assessment-framework-projects-common-interest-field-smart-grids

([10]) (Commission Staff Working Document, 2011)

2.1.14.2 Main costs

The main costs associated with the project deployment are:

- Power flow and power quality control devices in digitalized primary and secondary substations;
- Real-time power monitoring and fault detection devices in digitalized primary and secondary substations;
- Storage solutions for flexibility provision available to the TSOs and DSOs;
- Solutions to enhance the flexibility of assets belonging to the aggregators portfolio (e.g. local control systems, IT connection equipment, energy storage coupling to RES);
- Power forecasting and control technologies for the non-dispatchable distributed renewable plants;
- Aggregation platform and virtual cross-border coordination between the Italian and Austrian aggregators;
- Maintenance/ Insurance and Personnel costs.

2.1.14.3 Sensitivity analysis

The Net Present Value (NPV) of the project varies along with variation of the following critical variables:

- **Discount rate:** Increasing the discount rate value from 4% to 5.5% lowers the calculated project NPV by 31% (for the Italian part of the project) and 24% (for the Austrian part of the project).
- **CO_2 price:** In the Austrian part of the project area, lower CO_2 price (6.2 €/tCO2 over the whole operating period) decreases the NPV by 3.5 %, whereas higher CO_2 price (36 €/tCO2 over the whole operating period) increases the NPV by nearly 7 %.
- **Time horizon:** Decreasing the time horizon to 15 years lowers the NPV by nearly 57 % (for the Italian part of the project area) and by ca. 45 % for the Austrian counterpart.

2.1.15 Additional non-monetised benefits

In addition to the quantified benefits, the project proposal addresses further impacts that could not be (entirely) quantified and consequently included in the KPI analysis, such as:

- **Solidarity with other Member States** – neighbouring countries in the region (Slovenia, Croatia and Switzerland) are expected to benefit from the improved operational security in the project area, which can be particularly relevant with growing RES penetration levels. Moreover, the project would also facilitate the cross-border flows from South-Eastern to Western Europe, thus allowing for increased deployment of RES in the Balkans.
- **Macro-regional security of supply** – increased RES-based connections and provision of additional services enabled by the cross-border aggregation platform is expected to have an impact at a wider regional level, in terms of increased regional security of supply. This would lead to growing potential for transit flows

from Eastern to Western Europe without or with reduced need for new interconnectors.

- **Improved quality of supply to serve regionally high-tech manufacturing industries** – the proposed network upgrades would reduce the probability of severe voltage dips, whose presence may impair manufacturing conditions of high-tech manufacturing industries present in the project area.

- **Technological innovation with replication potential** – the project demonstrates large replication potential, in what concerns deployment of similar systemic approach technologies in other European regions with cross-border challenges, while granting opportunities to different market players to benefit from such investments and set off energy service markets.

2.1.16 Summary of the ALPGRID project's evaluation

The ALPGRID project includes deployment of both, mature smart grid technology elements and innovative, cross-border flexibility platform operated jointly by aggregators in both Member States. As such it uses smart grid technologies and solutions to increase distribution network observability and control, while providing leverage for market players (aggregators, generation units, storage operators, etc.) in the project area to offer flexibility to the DSOs and TSOs. Additionally, development of a cross-border flexibility platform enables increased and more efficient use of the flexibility sources in the region while effectively dealing with network operational challenges in the presence of growing penetration of RES.

The project relies on anticipated upcoming regulations in both Member States to create a joint entity (cross-border virtual flexibility platform) opened to all market participants leveraging on technologies developed in previous pilot projects. In this respect, the project area would benefit from increased observability and control of the electricity network, optimisation of power flow and enhanced voltage control, increased network security and quality of supply, increased integration of non-dispatchable RES into the electricity network, etc. Additionally, the project is expected to increase the utilisation of the existing cross-border interconnection and cross-border participation in the electricity market. As such, the ALPGRID project proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation) and it complies with the general criterion 1(c)(i) of Article 4 of the Regulation.

The ALPGRID project demonstrates overall positive contribution to the six smart grid specific criteria, outlined in Article 4 (2) of the Regulation and positive outcome of the project's societal cost-benefit analysis.

2.2 Smart Border Initiative (Germany and France)

2.2.1 General overview

The Smart Border Initiative (SBI) project is a cross-border energy optimisation project, which originates from the need for more balanced and resilient energy systems at local level. Driven by practical needs and highlighting the added value of a regional project, the SBI offers an integrated approach of cross-border distribution network optimisation, smart mobility solutions and multi-energy sub-systems, with the aim to improve energy efficiency, security of supply and network resilience in the project region. In this context, the German Energy Agency (DENA) with the support of Tilia [11] have decided to launch a common initiative to develop the SBI project. The project involves DSOs and TSOs from Germany (Energis Netzgesellschaft and Amprion) and France (Enedis and RTE) among

[11] http://www.tilia.info/

other market players (technology manufacturers, consultancies, etc.). The SBI is composed of three closely interconnected modules, namely:

1. **Joint optimisation of the cross-border electricity distribution system -** This project module focuses on optimising the development and operation of the electricity distribution systems in the project area through improved balancing of local generation and consumption at the DSO level and integration and use of flexible resources.

2. **Smart mobility and integration into the smart grid (implementation of a vehicle to grid interface) –** This module aims at development and operation of EV charging infrastructure in the project area, considering electricity network constraints and development and adoption of smart and low-carbon strategy for cross-border mobility (including cross-border mobility platform for various mobility services, e.g. location and availability of parking and charging infrastructure).

3. **Energy efficiency and sector coupling (developing an interface to add energy efficiency and sector coupling measures to the smart grid) –** This module aims at development of integrated local energy systems, leveraging the coupling of different energy sectors (heating, cooling and electricity) and more particularly it focuses on development of an interface to the DSO for e.g. provision of flexibility services, RES management, etc.

Increased shares of distributed non-dispatchable RES along with growing demand for electric vehicle charging in the project area pose significant challenges on the electricity system operation in the region. To this end, the project envisages a development of a cross-border smart grid mechanism for joint monitoring and steering of network components to enhance the operation of the distribution grids in the project area, while increasing transmission and distribution network capacity. Such mechanism also includes definition of coordination procedures between the involved parties (DSO, TSO, aggregators, flexibility owners, etc.), technical procedures for monitoring and control of the flexibility options and algorithms to ensure optimal use of these options, while making use of a common data management system (including relevant information on the grid status on each side of the border).

Additionally, a cross-border interconnector at DSO level is envisaged, based on identification of existing and future grid challenges in the project region and subject to internal cost-benefit analysis of the project.

Finally, flexibilities provided by modules 2 and 3 will respond to the identified network challenges and further contribute to the network optimisation, while allowing for higher penetration levels of RES.

Main project goals:

- Optimisation of the energy system in the project region by utilising cross-border synergies and integrating the electricity grid planning and operation with the planning and operation of smart e-mobility, energy efficiency and sector coupling concepts;

- Enhancement of network security, reliability and quality of supply;

- Enabling growing penetration level of RES in the region;

- Increased system operational efficiency, as a result of joint cross-border systemic approach;

- Development of a market for provision of flexibility services.

2.2.2 Compliance with the general criteria of Article 4 (1) (c) of the Regulation

The main idea of the SBI project revolves around development of optimised cross-border electricity distribution systems, considering a regional approach, to be integrated in the market and grid operation of both Member States involved and optimised with regard to the integration of electro mobility, energy efficiency and energy sector coupling. As such, the project addresses the cross-border region of two Member States and complies with the general criterion 1(c)(i) of Article 4 of the Regulation.

In this context, the project intends to develop a cross-border data management system for efficient operation of the regional smart grid and a cross-border interconnection at distribution network level. Additionally, it aims to foster joint standards for the development of optimisation mechanisms of the cross-border electricity distribution systems to ensure interoperability, connectivity and ultimately functionality of the systems and technologies within the smart grid environment.

2.2.3 Project's necessity for the '*s*mart grid deployment' thematic area

The SBI project includes various smart grid elements with a strong cross-border regional focus, covering the region of Saarland and Lorraine (south-west Germany and north-east France).

The first module of the project, which aims at optimisation of the development and operation of the distribution networks in the cross-border area, addresses the use of flexibility resources (electric vehicles (EVs), district heating and cooling, buildings, etc.). Modules 2 and 3 focus on development of interfaces for smart mobility and multi-energy sector coupling employed, respectively, for efficient electricity network operation and management of growing levels of non-dispatchable RES.

For this purpose, cross-border data management system will be put in place (as part of module 1) based on a set of communication and coordination measures between: 1) the DSOs for operation and maintenance of the distribution network cross-border line; 2) the aggregators and DSOs for utilisation of flexibility options with respect to market signals and network requirements and 3) the DSOs and TSOs with regard to market coupling and network operation in the cross-border region.

Furthermore, development and implementation of EV and hydrogen charging infrastructure is envisaged (as part of module 2) for deployment of cross—border mobility services (e.g. roaming solutions for vehicle charging, low-carbon transport services, etc.) and use of the EV charging as a flexibility source integrated into the electricity management system operated by the DSOs.

Finally, coupling the electricity and heating sectors through district heating and cooling (DHC) systems is planned as part of module 3 to efficiently manage the increased penetration levels of non-dispatchable RES using for instance, heat pumps, thermal storage and building and industries in the region as potential sources of flexibility.

To this end, the three modules centre on a strong cross-border dimension and enable the DSOs to jointly address the challenges in the region and beyond, notably the increased share of renewable energy and security of supply. As such, the project proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation).

2.2.4 System architecture and deployed assets

The main system assets addressed by the SBI project are the following:

- **Development of a cross-border data management system able to monitor and optimise in real time the operation of the cross-border smart grid** – selection of necessary data and interfaces to allow for the efficient operation the distribution networks in the region; implementation of a common online data management platform and information flows; definition and set up of communication and coordination measures for coordination activities between different parties (e.g. DSOs-DSOs, DSOs-aggregators, DSOs-TSOs), etc.
- **Deployment of a cross-border interconnection at the MV distribution network level** – subject to planning and implementation study and internal CBA.
- **Development of a compatible smart grid mechanism –** this mechanism will allow for efficient exploitation of flexibility options with regard to different possible operational circumstances (critical network conditions, electricity market, integration of centralised vs. decentralised energy storage, etc.). Moreover, it defines the coordination procedures between the involved parties (DSOs, TSOs, aggregators, flexibility owners, etc.), technical procedures for monitoring and control of flexibility options, possibilities for efficient integration of DSO interconnectors in the existing market coupling, etc.
- **Development of EV and hydrogen charging infrastructure on both sides of the border and their integration into a back-end system –** such infrastructure addresses preparation of a detailed charging development plan, including location, number of charging stations, placement and grid connection, based on observed cross-border vehicle traffic in the region and distribution network constraints. The back-end system will be accessible from both sides of the border and it will provide user-friendly solutions to resolve roaming issues for charging, billing and paying. To this end, the project aims at upgrading the existing charging infrastructure in the project area, namely in what concerns the following:
    - Update and digitalisation of existing charging stations up to future related standards to allow for integration of the existing infrastructure into the back-end system;
    - Implementation of new charging infrastructure with an initial estimate of: ca. 25 fast charging stations (50 kW, triple charger); ca. 25 normal charging stations (22 kW); ca. 50 private charging stations (<11 kW), etc.
- **Development of smart mobility solutions and services –** the project includes development of solutions for cross-border roaming services, EV incentive possibilities, provision of flexibility services to the DSO, app-based solutions for further provision of e-mobility services to the customers (e.g. location of vacant charging stations).
- **Development of central cross-border mobility platform –** this platform will integrate different mobility services in the project area and thereby providing the EV users with the following information: navigation, locations for parking and charging, e-ticket for public transport, traffic, weather, etc. Furthermore, this information will encourage public authorities to take further action for smart and sustainable mobility (e.g. e-buses, hydrogen mobility, etc.).
- **Deployment of energy data management system in industrial companies, local municipalities, social housing, etc. for provision of demand response/flexibility –** the efficiency potential of each residential, industrial or commercial site will be used for optimisation of the distribution network operation and energy consumption in the region. The deployment of this asset will be aligned with the joint optimisation of the cross-border distribution systems (module 1).

2.2.5 Contribution to the smart grid specific criteria

The benefits of the SBI project are assessed according to specific criteria, outlined in Article 4(2)(c) of the Regulation, captured by a set of 21 Key Performance Indicators, set out in Annex IV to the Regulation. In this context, the SBI project promoters argue the project's impact against the six specific criteria, by selecting a fitting set of KPIs for each of them in turn.

Table 13 – Table 18 set forth the KPIs selected for capturing such project impact against each specific criterion, and the estimation approach used. Depending on the current degree of uncertainty in the information provided by the promoters and on the assumptions made, the JRC has used an approach based on colour-coding (Vasiljevska and Gras, 2017) to evaluate the project's contribution to each specific criterion.

Policy criterion 1: Integration and involvement of network users with new technical requirements with regard to their electricity supply and demand

The SBI project aims to create favourable conditions for integration and involvement of different network users with new technical requirements, such as flexible loads coming from EV, heat pumps users, buildings and industries, etc. through provision of user-friendly solutions and services, (e.g. roaming, smart charging, etc.), adoption of energy data management system for industries, local municipalities, social housing, etc.

In this context, the promoters address the project impact on the first specific criterion using the KPIs indicated in Table 13.

Table 13 SBI: evaluation of project's impact against the first specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_4: Allowable maximum injection of power without congestion risk in transmission networks	The promoters assume that no increase of reverse flows from DSOs to TSOs will take place if additional production units are connected to the distribution network. As the project aims at cross-border optimisation at DSO level, some positive impact has been assessed with some confidence; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	The promoters anticipate no increase in the curtailed RES compared to the BaU scenario due to currently low level of RES and distribution network limitations. Nevertheless, growing RES penetration level and large-scale adoption of e-mobility in the future may pose significant challenges to the electricity network operation. In this context, some positive impact has been assessed with some confidence as a result of cross-border optimisation of the distribution networks in the project area and creation of favourable conditions for provision of flexibility services; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_9: Share of electricity generated from renewable sources	The promoters anticipate an increase in the share of electricity generated from RES due to optimisation of the distribution networks in the project area and integration and involvement of end-users in the provision of flexibility services. As a result, promoters expect a 20 % increase of RES capacity that can be safely integrated into the system, based on a previous smart grid projects (GRID4EU and Smart Country).	

	In this respect, the project is expected to have positive impact on this KPI.	
KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures	The project is expected to increase the demand side participation of flexible loads and as such the promoters anticipate positive project impact on this KPI by referring to the flexibility associated with industrial load and EV users. Assuming no flexibility coming from EVs and limited industrial load flexibility in the BaU scenario and available flexibility from EVs as long as they are connected to the charging infrastructure, the promoters provide positive estimation of this KPI. Nevertheless, uncertainties still persist in the information provided or in the assumptions made as more accurate assessment of this KPI cannot be performed due to the maturity of the project.	

Policy criterion 2: Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation

The SBI project is expected to increase the distribution and transmission network operational efficiency and interoperability as a result of the following activities enabled by the project: development of a cross-border smart grid mechanism to enhance the operation of the distribution networks of both sides of the border; application of common technical standards to allow interoperability, connectivity and functionality of the technologies and systems in the project area; optimisation of the development and operation of EV charging infrastructure considering electricity grid constraints and roaming services to customers across the border; coordination of planning and operation procedures of the electricity distribution networks and the electro mobility, energy management and power-to-heat solutions, etc.

In this context, the promoters address the project's impact on the second specific criterion using the KPIs indicated in Table 14.

Table 14 SBI: evaluation of project's impact against the second specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{13}: Level of losses in transmission and distribution networks	The promoters expect an increase in the absolute value of losses due to higher utilisation of the DSO assets (enabled by the project). This increase would, however, be offset by a relative increase in the RES connected to the distribution network.	
KPI_{16}: Percentage utilisation (i.e. average loading) of electricity network components	The average loading of electricity network components is expected to increase (e.g. average loading at transformer level due to higher RES infeed). At the same time, joint optimisation of the distribution network, enabled by the project, will contribute to more efficient loading of the electricity network elements. Quantitative estimation of this KPI requires specific simulation studies and is not provided at this stage of project development.	

Policy criterion 3: Network security, system control and quality of supply

The project addresses this criterion by making a reference to the following tasks proposed by the project: cross-border matching of supply and demand and provision of more efficient compensation of regional imbalances (e.g. efficient multi-energy sub-system); active management of feed-in and flexible load to maintain grid stability and allow for efficient integration of RES, etc. To this end, the RES penetration level can be significantly increased without compromising the network's security of supply. Additionally, the promoters stress the need to analyse the extent of these benefits at the expense of higher network utilisation rates, which may result in higher network losses.

The promoters address the project's impact on the third specific criterion using the KPIs indicated in Table 15.

Table 15 SBI: evaluation of project's impact against the third specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_4: Allowable maximum injection of power without congestion risk in transmission networks	The promoters assume that no increase of back-feed flows from DSOs to TSOs will take place if additional production units are connected to the distribution network. As the project aims at cross-border optimisation at DSO level, some positive impact has been assessed with some confidence; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	The promoters anticipate no increase in the curtailed RES compared to the BaU scenario due to currently low level of RES and distribution network limitations. Nevertheless, growing RES penetration level and large-scale adoption of e-mobility in the future may pose significant challenges to the electricity network operation. In this context, some positive impact has been assessed with some confidence as a result of cross-border optimisation of the distribution networks in the project area and creation of favourable conditions for provision of flexibility services; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_9: Share of electricity generated from renewable sources	The promoters anticipate an increase in the share of electricity generated from RES due to optimisation of the distribution networks in the project area and integration and involvement of end-users in provision of flexibility services. As a result, promoters expect a 20 % increase of RES capacity that can be safely integrated into the system, based on a previous smart grid projects (GRID4EU and Smart Country). In this respect, the project is expected to have positive impact on this KPI.	
KPI_7: operational flexibility provided for dynamic balancing of electricity in the network	The project is expected to provide significant increase in the network's operational flexibility for dynamic balancing as a result of increase in the controllable capacity coming from EVs and loads subject to demand side management, etc. However, the exploitation of such flexibility will also depend on the market rules in place, which is beyond the	

	control of the project promoters. As the project aims at optimisation of the development and operation of the distribution networks in the cross-border area using different flexibility resources (EVs, district heating and cooling, buildings, etc.), a positive impact can be assessed with sufficient level of confidence.	
KPI_8: ratio of reliably available generation capacity and peak demand	The promoters anticipate positive impact on this KPI due to increase of generation capacity on the one hand, and lower peak demand (as a result of DSM, e-mobility, etc.) on the other. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{10}: stability of the electricity system	The promoters expect a positive impact of the project on this KPI as a result of a more robust network structure and integration and optimisation of the local energy system, enabled by the project. Additionally, the promoters make reference to the part of SAIDI related to the system average interruption duration due to load/generation balancing issues and do not take into account grid-related causes. Finally, as the project impact on this KPI would also depend on the ultimate decision for deployment of a MV interconnection and its capacity, it cannot be reliably assessed at this stage of the project development.	
KPI_{11}: duration and frequency of interruptions per customer, including climate-related disruptions	The promoters expect decrease of SAIDI and SAIFI due to more robust distribution network structure enabled by the project and based on similar studies in the project region. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{12}: voltage quality performance	The promoters expect decrease in voltage violations as a result of a more robust distribution network structure even in the presence of growing RES penetration levels. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{14}: Ratio between minimum and maximum electricity demand within a defined time period	The project is envisaged to have a positive impact on this KPI due to increased controllable load, subject to demand side participation, which would ultimately result in lower difference between the minimum and maximum electricity demand. In this context, the promoters report a value of 10% for the peak load reduction by making reference to similar projects.	
KPI_{17}: Availability of network components (related to planned and unplanned	The project is expected to minimise the effects of component failures and non-availability due to enhanced observability and control of the distribution networks in the project area. The promoters relate this KPI with expected increased network reliability (decrease of SAIDI	

maintenance) and its impact on network performance	and SAIFI).In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{18}: Actual availability of network capacity with respect to its standard value	The promoters expect positive project impact on this KPI due to increased network monitoring and steering capabilities and possible deployment of MV network interconnection. Nevertheless, stronger impact of the SBI project on this KPI cannot be assessed with a sufficient level of confidence at this stage of the project deployment as the impact would also depend on the ultimate decision on the installation of a MV interconnection.	

Policy criterion 4: Optimised planning of future cost-efficient network investments

The promoters address the project impact on this criterion by making a reference to the following activities of the project: coordination of the planning and operation procedures of the distribution networks with the planning and operation of electro mobility, energy management and power-to-heat solutions; integrating cogeneration facilities, heat pumps and thermal storage to efficiently manage variable non-dispatchable RES, efficient planning of the design and location of future EV and hydrogen charging infrastructure, etc.

The following KPIs (Table 16) have been selected to address the project's impact on the fourth specific criterion.

Table 16 SBI: evaluation of project's impact against the fourth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_3: Installed capacity of distributed energy resources in distribution networks	Enhanced distribution network operation and management enabled by the SBI project is expected to significantly increase the DG installed capacity and enable DG connection at an earlier stage compared to the BaU scenario. In turn, this will incentivise DG deployment in areas where it has not been viable before. In this respect, promoters estimate a 20 % increase of DG installed capacity compared to the BaU scenario, based on previous pilot projects projects (GRID4EU and Smart Country).	
KPI_4: Allowable maximum injection of power without congestion risk in transmission networks	The project is expected to have a positive impact on this KPI as a result of cross-border optimisation of the distribution networks in the project area. It is assumed that no increase of reverse flows from DSOs to TSOs will take place if additional production units are connected to the distribution network. Although convincingly argued due to lack of more detailed information at this stage of the project development, the expected positive impact cannot be assessed with a sufficient degree of certainty.	

KPI$_5$: Energy not withdrawn from renewable sources due to congestion or security risks	The promoters anticipate no increase in the curtailed RES compared to the BaU scenario due to currently low level of RES and distribution network limitations. Nevertheless, growing RES penetration level and large-scale adoption of e-mobility in the future may pose significant challenges to the electricity network operation. In this context, some positive impact has been assessed as a result of distribution network cross-border optimisation and creation of favourable conditions for provision of flexibility services; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI$_{12}$: voltage quality performance	The promoters expect decrease in voltage violations as a result of more robust distribution network structure even in presence of growing RES penetration levels. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	

Policy criterion 5: Market functioning and customer services

The SBI project largely addresses the development of markets for innovative customer services, such as smart charging options for EV users, provision of information on energy consumption for demand response, development of cross-border roaming services for EV charging, provision of flexibility services to the DSOs, etc.

In this regard, the promoters address the project's impact on the fifth specific criterion using the KPIs indicated in Table 17.

Table 17 SBI: evaluation of project's impact against the fifth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI$_1$: reduction of greenhouse emissions	The promoters report expected reduction of the GHG emissions due to increased number of EV and share of RES and energy savings (through energy efficiency and energy sector coupling). The KPI is positively quantified to 3384 tonnes of reduced CO2/year (in module 2) and 13745 tonnes of reduced CO2/year (in module 3).	
KPI$_2$: Environmental impact of electricity grid infrastructure	The project is expected to have positive impact on this KPI as it will reduce the need to build additional distribution network assets. As a result, it is anticipated noise reduction and reduced visual impact as well as lower impact on vegetation and fauna.	
KPI$_5$: Energy not withdrawn from renewable sources due to congestion or security risks	The promoters anticipate no increase in the curtailed RES compared to the BaU scenario due to currently low level of RES and distribution network limitations. Nevertheless, growing RES penetration level and large-scale adoption of e-mobility in the future may pose significant challenges to the electricity network operation. In this context, some positive impact has been assessed as a result of distribution networks cross-border optimisation and creation of favourable conditions for provision of flexibility services; however uncertainties still persist in the	

	information provided due to the maturity of the project.	
KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	Valuable information on the demand response potential from EV users and residential/industrial customers enabled by the project would facilitate provision of adequate incentives for network users providing flexibility. Such incentives could also be provided through network tariffs. Additionally, the cross-border nature of the SBI project would require coordination of the two network tariff systems so that contradictory incentives are avoided. The project is, therefore, expected to have positive impact on this KPI. Further details on the type of new information that can be measured and collected with the project deployment and the way this information would be used in defining more accurate methods of allocating costs, will be provided at a later stage of the project.	
KPI_{11}: duration and frequency of interruptions per customer, including climate-related disruptions	The promoters report expected decrease of SAIDI and SAIFI due to more robust distribution network structure enabled by the project and based on similar studies in the project region. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{12}: voltage quality performance	The promoters expect decrease in voltage violations as a result of more robust distribution network structure even in presence of growing RES penetration levels. In this regard, some positive impact has been assessed; however uncertainties still persist in the information provided due to the maturity of the project.	
KPI_{16}: Percentage utilisation (i.e. average loading) of electricity network components	The average loading of electricity network components is expected to increase (e.g. average loading at transformer level due to higher RES infeed). At the same time, joint optimisation of the distribution network, enabled by the project, will contribute to more efficient loading of the electricity network elements. Quantitative estimation of this KPI requires specific simulation studies and is not provided at this stage of project development.	
KPI_{19}: Ratio between interconnection capacity of a Member State and its electricity demand	The promoters expect increase of the interconnection capacity at MV level due to potential deployment of physical cross-border distribution network interconnection. Nevertheless, the project impact on this KPI would also depend on the final decision for installation of such interconnection and its capacity, and therefore, stronger impact cannot be reliably assessed at this stage of the project development.	
KPI_{20}: exploitation of interconnection capacities	Deployment of cross-border data management system enabled by the project is expected to optimise the operation of the distribution networks in the project area and contribute to better exploitation of the existing	

	interconnection capacities. Moreover, potential installation of additional MV cross-border interconnector (subject to internal CBA) could additionally increase the value of this KPI. However, more accurate estimate of the project impact on this KPI cannot be provided at this stage of the project development.	
KPI_{21}: congestion rents across interconnections	Currently, congestion rents take place at high voltage level. Possible deployment of the MV cross-border interconnector would increase the cross-border energy trade and potentially have impact on the congestion rents. The project's impact on this KPI cannot be reliably assessed at this stage of the project development, as it would also depend on the final decision for installation of such interconnection and its capacity.	

Policy criterion 6: Involvement of users in management of their energy usage

The SBI project is envisaged to positively contribute to the fulfilment of this criterion by empowering various customers (EV users, residential/industrial load subject to DSM, etc.) with the ability to monitor, manage and control their electricity consumption; integration and involvement of different network users in more efficient and sustainable operation of the distribution networks in the project area, etc.

The promoters address the project's impact on this specific criterion using the KPIs indicated in Table 18.

Table 18 SBI: evaluation of project's impact against the sixth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{15}: Demand side participation in electricity markets and in energy efficiency measures	The project is expected to increase the demand side participation of flexible loads and as such the promoters anticipate positive project impact on this KPI by referring to the flexibility associated with industrial load and EV users. Assuming no flexibility coming from EVs and limited industrial load flexibility in the BaU scenario and flexibility provision from EVs as long as they are connected to the charging infrastructure, the promoters provide positive estimation of this KPI. Nevertheless, uncertainties still persist in the information provided due to the maturity of the project.	
KPI_3: Installed capacity of distributed energy resources in distribution networks	Enhanced distribution network operation and management enabled by the SBI project is expected to significantly increase the DG installed capacity and enable DG connection at earlier stage compared to the BaU scenario. This, in turn will incentivise DG deployment in areas where it has not been viable before. In this respect, promoters estimate a 20 % increase of DG installed capacity compared to the BaU scenario, based on previous pilot projects (GRID4EU and Smart Country).	

KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	Valuable information on the demand response potential from EV users and residential/industrial customers enabled by the project would facilitate provision of adequate incentives for network users providing flexibility. Such incentives could also be provided through network tariffs. Additionally, the cross-border nature of the SBI project would require coordination of the two network tariff systems so that contradictory incentives are avoided. The project is, therefore, expected to have positive impact on this KPI. Further details on the type of new information that can be measured and collected with the project deployment and the way this information would be used in defining more accurate methods of allocating costs will be provided at the later stage of the project development.	

2.2.6 Economic appraisal

The SBI project is in its early planning stage and in this regard some project parameters (e.g. exact project location, deployment of a cross-border MV interconnector, etc.) are still expected to be defined by the end of this phase. The choice of these parameters is subject to studies, including internal CBA to estimate the costs and benefits of different project realisation options and ensure that the project’s total benefits outweigh its costs. As the SBI project has not yet reached a sufficient level of maturity, a quantitative CBA could not be reliably performed at this stage of its development and the promoters indicate project’s costs and expected benefits in qualitative terms.

2.2.6.1 Main monetised benefits

The SBI project is expected to deliver a set of positive impacts and in that respect the following benefits (expressed qualitatively) have been communicated by the project promoters:

- Deferred or optimised distribution capacity investments at HV/MV substations and MV network levels as a result of better integration of DER/RES and cross-border optimisation of the EV charging infrastructure;
- Optimised DER/RES integration to support the implementation of 2020/2030 RES targets at both sides of the border;
- Increased energy savings through energy efficiency and energy sector coupling, which could also results in reduction of network technical losses;
- Optimised planning of the number of charging stations, as a result of roaming management solutions and services, interoperability of technology, etc.;
- Reduction of LV network reinforcement costs as a result of optimisation of the EV charging infrastructure and processes;
- Increased penetration level of EV;
- Additional environmental benefits (reduction of SO_x, NO_x emissions, air quality, etc.).

2.2.6.2 Main costs

The main costs associated with the SBI project deployment are:

- Development and operation of distribution grid optimisation – smart grid taking into account the specificities of the cross-border region (module 1 of the project);
- Deployment of MV cross-border interconnector (final decision is subject to internal CBA);
- Development, implementation and testing of a cross-border mobility platform, addressed in module 2 of the project;
- Development of a cross-border smart charging infrastructure (module 2);
- Conception and definition of data, stakeholders and requirements of the energy management system addressed in module 3 of the project;
- Identification and analysis of the flexibility potential in module 3 of the project and its link with the smart grid of module 1;
- Development of a cross-border data management system;
- Project design and management, etc.

2.2.7 Additional non-monetised benefits

The project proposal also includes a set of additional non-monetary impacts, such as:

- **Enhanced consumer awareness and market participation** – the SBI project is expected to play significant role in empowering customers to take an active role in more efficient network operation and ultimately impact the electricity price; creation of innovative market mechanisms for new energy services, such as energy efficiency, demand response, etc.;
- **Increase of social awareness and acceptance** – the project aims to create a public awareness about the project, maintain the public interest on the project and motivate people to take part in it (online and offline communication on the process to connect new installation to the smart grid, building up an open data platform, user experience reports, etc.);
- **Exchange of best practices** – the project results would enable sharing good practices among local energy shareholders across the Franco-German border;
- **Provision of attractive service to daily commuters in the project area** – the mobility platform developed in the project is expected to facilitate the use of individual and public modes of transportation in the project area;
- **Project replicability potential** – most adequate and cost-effective smart grid technologies and tools with respect to the regional/cross-border characteristics will be identified, which may serve as basis for public/private decision making and assist the development of other cross-border projects.

2.2.8 Summary of the SBI project's evaluation

The Smart Border Initiative project capitalises on cross-border cooperation in one of the Franco-German regions, exploiting strong regional complementarities based on integrated approach of several energy modules and with the aim to achieve the energy transition objectives set in both Member States, while effectively addressing the Energy Union's goals.

In this context, the project presents an innovative approach of addressing common cross-border energy challenges in the project area by integrating the electricity grid with electric mobility and district heating and cooling systems and exploiting the flexibilities of both the electric mobility and the heating systems for optimising the development and operation of the distribution electricity networks in the project area. To this end, it includes a variety of actors among which French and German DSOs, TSOs, regional and local authorities, technology providers, research centres and other relevant local actors working in the field of energy and electric mobility.

The project addresses a cross-border region of two Member States by developing a cross-border data management system for efficient operation of the regional smart grid and potentially a cross-border interconnection at distribution network level (final decision subject to internal CBA). Additionally, it aims to develop common standards for development of mechanism for optimisation of the cross-border electricity distribution systems to ensure interoperability, connectivity and ultimately functionality of the systems and technologies within the smart grid environment. Therefore, the SBI project complies with the general criterion 1(c)(i) of Article 4 of the Regulation and it proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation).

The project is currently in its early design phase. As a result some project parameters (e.g. exact project location, installation of a cross-border MV network interconnector, etc.) are still to be defined. Moreover, as the project has not yet reached a high level of maturity, a quantitative societal cost-benefit analysis could not be conducted at the current stage of the project's development. Consequently, the economic appraisal of the project's expected benefits is demonstrated in qualitative terms. Notwithstanding the uncertainties in the information provided, at the current stage of development, the project is expected to positively contribute to the six smart grid specific criteria, outlined in Article 4(2)(c) of the Regulation.

2.3 SINCRO.GRID (SLOVENIA AND CROATIA)

2.3.1 General overview

The project area involves the distribution and transmission network of Slovenia and Croatia, which covers the whole territory of both countries.

Recently, the lack of flexibility on voltage and frequency regulation has reached its limit; a further worsening could potentially endanger future developments towards the integration of renewable and distributed generation. To address this issue, the current proposal focuses on new voltage profile management patterns that will allow for increased integration of renewables into the grid, while enabling secure and reliable delivery of electric power to the end-users. For this purpose, a dedicated control centre will be established to support various voltage and frequency control processes.

The project mainly addresses the needs of the transmission system to deal with increased penetration of RES, connected both at the transmission and distribution grids, and in particular:

- The need to deal with voltage fluctuations outside the operational limits;
- Increased needs for ancillary services, especially secondary and tertiary reserve, both capacity- and energy-wise;
- Increased need for primary infrastructure due to the fluctuating nature of renewable generation.

Main project goals:

- Enhanced voltage control, primarily in terms of removing overvoltages caused in periods of increased generation and low consumption, and additionally, low voltage problems that may evolve in the future will also be addressed;
- Efficient deployment of RES in ancillary service provision in Slovenia and Croatia;
- Relieving local power flows at 110 kV grid (operated by the TSOs in both Member States), providing alternative ancillary services (secondary reserves) in Slovenia, and consequently removing current operational deficiency caused by market price drop and closure of conventional generators;
- Increasing network capacities at the transmission network by use of real-time control of the network elements operational limits and thus allowing for capacity investment deferral;
- Improving observability of the distribution network, which would facilitate transmission network operation and potentially lead to reduction of future demands for ancillary services;
- Improving observability of RES operation and its impact on the transmission and 110 kV network operation;
- Enhanced communication platform for Demand Side Management (DSM) for provision of tertiary reserve, thus allowing for more transparent co-operation between reserve providers and TSOs;
- Increased cross-border capacity with real-time control of network operational limits.

Two TSOs (ELES in Slovenia and HOPS in Croatia) and two DSOs (SODO in Slovenia and HEP in Croatia) are involved in the project. The project is led by the TSOs since it primarily addresses problems on the transmission grid. DSOs will enhance the observability of the distribution grid by providing forecasting tools for DG generation, thus helping the TSOs in predicting any necessities for ancillary services and network operation, mainly in terms of voltage control.

Expected project impacts:

- Increased penetration of RES into the distribution and transmission grids of both Slovenia and Croatia (the project deployment allows for an additional 330 MW of wind power to be installed in Croatia);
- Enhanced voltage profiles at both transmission systems of Slovenia and Croatia;
- Relieved local power flows on 110 kV grid and reduced shortage of ancillary services (secondary reserve) in the range of 12 MW from battery storage and controllable DG units in Slovenia;
- Enhanced utilisation of existing transmission and 110 kV grid using Dynamic Thermal Rating (DTR);
- Better observability of distribution and transmission grids using advanced forecasting tools, DTR and information coupling of distribution and transmission systems;

- Additional 5 MW of tertiary reserves provided through Demand Side Management by establishing a common communication platform that will allow for provision of more accurate data to the TSO.

2.3.2 Compliance with the general criteria of Article 4 (1) (c) of the Regulation

SINCRO.GRID complies with both, the general criterion 1 (c) (i) and 1 (c) (ii) of Article 4 of the Regulation as it includes significant investments for each involved party (TSOs and DSOs from two Member States) and tangible impact on the network operation of each project promoter.

In addition to the compliance with the general criterion 1 (c) (i) and pursuant to the general criterion 1 (c) (ii) of Article 4 of the Regulation, the significant cross-border impact is addressed with reference to the following requirement (Annex IV.1 to the Regulation):

- The project includes investments at MV network levels of 10 kV and higher (10 kV, 20 kV and 35 kV) and HV grid (110 kV and higher);

- The project area involves 3 294 910 network users;

- The consumption in the project area in 2013 amounted to 12 816 GWh in Slovenia and 16 407 GWh in Croatia, which together sums up to 29 333 GWh;

- The peak demand in the project area in 2013 was 4 769 MW. The installed power of non-dispatchable renewable sources variable in nature (solar and wind) was 532 MW in Slovenia in 2013 and 555.8 MW in Croatia, which together amounts to 23 % of the peak demand. The project area also includes significant penetration level of run-of-river hydro plants, which together with the solar and wind production accounts for 29.8% of the total energy consumption in the project area.

- The project involves TSOs and DSOs from Slovenia and Croatia.

2.3.3 Project's necessity for the 'smart grid deployment' thematic area

The project area exhibits high degree of transit power flows, which in certain periods can reach more than 100% of the peak consumption in some parts of the electricity networks addressed by the project. In addition to the strong transit fluctuations, increased penetration levels of intermittent RES cause both TSOs of Slovenia and Croatia to face similar problems related to voltage control. As a result, each of the neighbouring TSOs conducted a separate analysis on this issue and the results revealed that at least 1350 MVar of compensation devices are needed in both countries together to solve the overvoltage problem, if addressing it separately. On the other hand, by establishing a common virtual cross-border control centre, the need for compensation devices would reduce to 1050 MVar due to coordinated actions of the neighbouring TSOs.

The geographical position of Slovenia and Croatia lies in between regions with a surplus of energy (Central Europe and the Balkans) and regions with a high deficit (Italy), which makes their transmission grid subject to very high transits of electric energy. This calls for building additional interconnections in order to serve market needs; however, it results in borders being congested most of the time. The construction of new power lines is challenging due to problems related to spatial planning and therefore, it is essential to utilise the existing infrastructure to a maximum extent by implementing smart grids solutions. This requires a high level of co-operation between TSOs and DSOs, and enables increased utilisation of the existing grid while still maintaining an adequate level of reliability and security of supply. As such, the project proves necessary for the smart grid deployment thematic area (Annex I, 4 (10) to the Regulation).

The main smart grid elements deployed in SINCRO.GRID project are the following:

- **Deployment of dynamic line rating on highly interconnected lines with cross-border impact** – Dynamic thermal rating systems increase the complexity of tasks within the control centre as more dynamic operation is introduced. Therefore, the rules for system operation have to be adjusted and maintenance procedures enhanced to better manage the increased responsibilities of the field staff. New operational and market agreements have to be justified also to third parties not directly involved in this project in order to achieve an increase in transfer capacities according to ENTSO-E standards.

- **Centralised voltage and reactive power control –** The centralised voltage/reactive power control integrates reactive sources from both power systems with optimisation function tailored to RES and DER operation, as well as conventional production units.

- **A virtual cross-border control centre with improved information flows, common data representation, dynamic system optimisation, and common forecasting algorithms** – The forecasting algorithms will integrate the knowledge and local experience with RES and improve their predictability as regards to wind, solar and small hydro production. With increased utilisation of the network, each of the operators will need to rely on the coordinated actions of the other TSOs and DSOs in order to provide reliable and safe operation of the grid.

- **Storage systems at the TSO-DSO interface and DG storage units replacing conventional units for active power system control and relieving local power flows –** DG and storage units will be upgraded with advanced systems for secondary reserve operation in order to keep a reliable provision of ancillary services.

2.3.4 System architecture and deployed assets

The project proposal assumes deployment of the following assets:

- **Virtual cross-border control centre** – a joint ELES – HOPS Virtual Cross-border Control Centre (VCBCC) and corresponding infrastructure will be set up to allow for coordinated and controlled network operation and RES production at the Slovenian and Croatian HV and MV networks, as well as to allow for power system optimization in the whole control area. The VCBCC will be integrated within the existing SCADA/EMS systems on both sides (operated by ELES and HOPS) and with additional advanced tools, such as: simulation tools based on measurements and state estimator's output, advanced visualisation tools and SUMO – a system for real-time and short-term forecast assessment of the network operational limits.

- **Compensation devices** – Static Var Compensators (SVC) with a total capacity of 1050 Mvar will be installed in the project area through coordinated approach between the two TSOs, both of which face the issues of overvoltages. The results show that separate solutions (compensation in Slovenia or Croatia separately) lower the voltage, but still do not solve the issue in all substations. Installing full configuration in both countries solves the issue at considerably lower cost and also leaves some operational reserve.

- **Storage** – The Slovenian TSO will implement 10 MW of secondary reserve from battery storage (Li-Ion technology) with energy capacity of 30 MWh.

- **DG units providing secondary reserve** – The Slovenian TSO assumes the following units to be included in the provision of secondary reserve: two bio gas power plant with total installed capacity of 1.4 MW and one small hydro power plant with installed capacity of 2 MW.

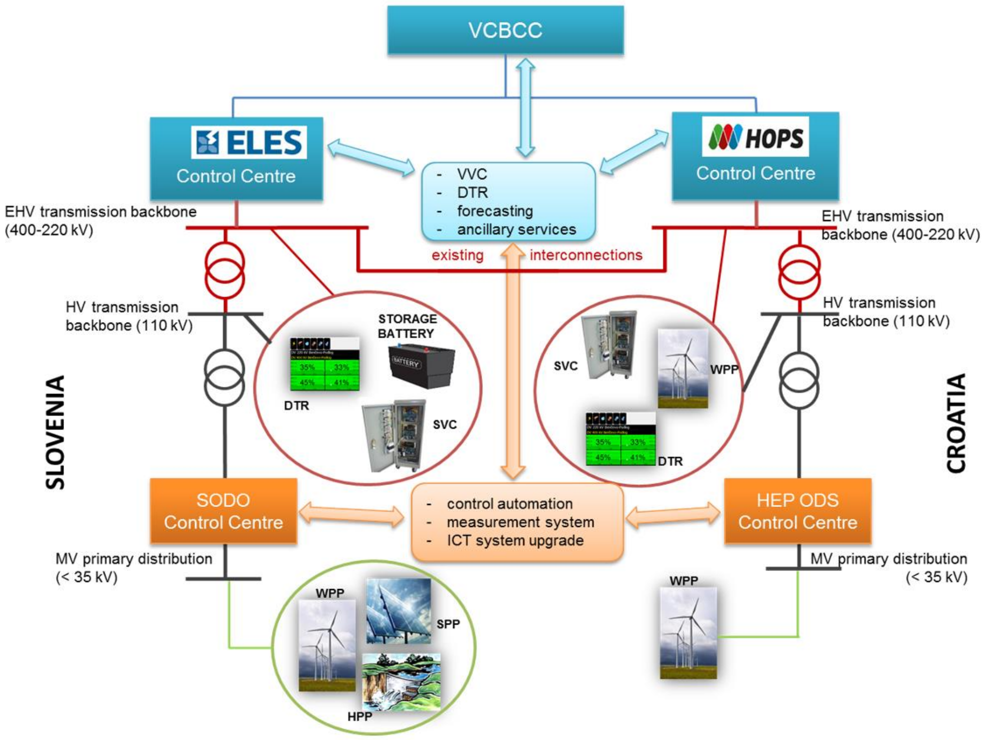
- **Dynamic thermal rating (DTR)** – DTR will be implemented at all transmission power lines in the Slovenian transmission grid, as part of the SUMO architecture (DTR advanced system developed by ELES in partnership with research institutions and industry). The central part of the system is the SUMO BUS, which collects data from all subsystems and provides information to the operators in control centres by means of advanced visualisation tools. The Croatian TSO will adopt the DTR system on the most critically loaded lines, connecting wind power plants and consumers in the coastal areas of Croatia with the mainland.

- **Load and DG generation forecast** – Growing penetration of renewables causes increased uncertainties for transmission system operation and consequently increased needs for ancillary services (secondary and tertiary reserve, both in terms of capacity and energy). As a result, the Slovenian DSO is developing a forecasting tool that will provide a day-ahead forecast for the whole area of Slovenia. The forecast needs to be upgraded so as to be able to provide short-term forecasts and a geographical breakdown of forecasts for specific nodes.

- **ICT infrastructure** – The existing ICT infrastructure needs to be upgraded in order to provide reliable data needed for the operation of the virtual cross-border control centre, the DTR system, control and support of DG and demand side participation and storage units in ancillary services, and data exchange between SODO and ELES.

Figure 1 illustrates the system architecture of the SICNRO.GRID project.

Figure 1. SINCRO.GRID system architecture



Source: SINCRO.GRID promoters

2.3.5 Role of DSOs and TSOs

TSOs will be leading the activities, as the project primarily focuses on issues on the transmission network. DSOs will increase the observability of their grid by implementing short-term forecasting tools based on metering data, which will be used by the TSO to optimise operation and ancillary services. Some DG generation at MV distribution grid will be included in the ancillary services market in Slovenia. Wind farms in the Croatian distribution grid will be included in the voltage control mechanisms.

The project will require co-operation between DSOs and TSOs in the following domains:

- Establishment of a virtual cross-border control centre, which will require a high level of co-operation between both TSOs;

- ICT connection of DSO and TSO control centres in both Member States and standardised data exchange;

- Development of common voltage control mechanism, including existing and new active devices at the transmission level, as well as existing active components at the distribution level with the inclusion of wind farms for coordinated voltage control at the TSOs level and between TSOs and DSOs. The project will also require co-operation between DSOs and TSOs to establish standardised data exchange and data flow from the distribution to the transmission level.

- Installation of storage units at the 110 kV substations on the MV side – the choice of optimal installation points will be jointly determined by TSO and DSO in Slovenia;

- Development of standardised communication protocols for data exchange in demand response services, which will increase DR potential for ELES' ancillary services.

2.3.6 Contribution to the smart grid specific criteria

The benefits of the SINCRO.GRID project are assessed according to specific criteria, outlined in Article 4(2)(c) of the Regulation and captured by a set of 21 Key Performance Indicators, as derived from the criteria in Annex IV to the Regulation. In this context, the SINCRO.GRID project promoters argue the project impact on each of the six specific criteria, selecting a set of KPIs to better capture the project's impact against a specific criterion.

Table 19 – Table 24 below set forth the KPIs selected for capturing the project's impact against each specific criterion, and the estimation approach used. Depending on the current degree of uncertainty in the information provided by the promoters and on the assumptions made, the JRC has used an approach based on colour-coding (Vasiljevska and Gras, 2017) to evaluate the project's contribution to each specific criterion.

Policy criterion 1: Integration and involvement of network users with new technical requirements with regard to their electricity supply and demand

The project will allow for additional DG and RES to be connected into the transmission and distribution networks of the project area, while ensuring higher level of security of supply and contributing to lower environmental impact (in terms of GHG emissions).

The promoters select the following KPIs (Table 19) to capture the project's impact on this criterion.

Table 19 SINCRO.GRID: evaluation of project's impact against the first specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_1: Reduction of greenhouse gas emissions	The project is expected to reduce the CO_2 emissions due to the following activities enabled by the project: increased network observability and voltage regulation, which on the other hand would result in additional 330 MW of wind power connection in the Croatian transmission and distribution system; deployment of storage units (which will replace the 30 MW gas-fired power plant) for provision of secondary reserve in Slovenia; provision of DSM for tertiary reserve in Slovenia; reduced technical losses, etc. In this regard, the KPI is positively quantified to 10.9 tonnes/GWh per year using the formula proposed in the assessment framework.	
KPI_9: share of electricity generated from renewable sources	The promoters report positive assessment of this KPI in terms of percentage variation in the share of electricity generated from RES that can be safely integrated into the system in both SG and BaU scenario. The KPI is positively quantified to 2.4 %, based on additional renewable energy (676 GWh per year) that can be safely integrated into the grid, as a result of the project deployment.	
KPI_{10}: stability of the electricity system	One of the central ideas behind the SINCRO.GRID project is dealing with overvoltage problems in the project area. In this context, the promoters assess this KPI in terms of improvement of transmission network voltage profiles as a result of deployment of compensation devices and inclusion of RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area. This would lead to resolution of nearly 100% of the overvoltage issues in the selected network nodes and in this respect, the KPI is positively quantified.	

Policy criterion 2: Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation

The project is envisaged to increase the level of RES that can be safely integrated into both, distribution and transmission network. This would require stronger cooperation between DSOs and TSOs on each side of the project border. Additionally, more efficient operation of both distribution and transmission network is expected due to inclusion of DG and storage in provision of ancillary services and increased exploitation of the interconnection capacities in the project area.

The KPIs presented in Table 20 address the project's impact on the second specific criterion.

Table 20 SINCRO.GRID: evaluation of project's impact against the second specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_3: Installed capacity of distributed energy resources in distribution networks	The promoters anticipate positive impact of the project on this KPI as the project will allow for installation of additional 310 MW and 20 MW of wind power in the Croatian transmission and distribution system, respectively. In the Slovenian part of the project, the KPI is estimated on the basis of the national plan for RES integration (additional 600 GWh of RES, predominantly connected to the distribution network), as project promoters have no control on the location and additional capacity of DG installed into the grid. Current overvoltage issues would prevent integration of this additional RES to the network in the BaU scenario, and in this regard, the project plays a key role in enabling connection of additional DG into both distribution and transmission network. The KPI is, therefore, positively quantified to 2.24% using the formula proposed in the assessment framework.	
KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	There is no historical data on energy curtailment in the project area as according to the national legislation in Slovenia and Croatia, all the RES connected to the grid can operate at maximum capacity. Nevertheless, future deployment of increased RES may trigger overvoltage protection relays to disconnect DGs from the network for a short period of time. In this regard, the project is expected to reduce possible curtailed renewable energy in the future as a result of enabling 719 MW of wind units in Croatia included in the voltage control mechanism and additional 12 MW of battery storage and DG in Slovenia providing secondary reserves.	
KPI_{14}: ratio between minimum and maximum electricity demand within a defined time period	This KPI is positively assessed to around 0.85% due to additional capacity of storage and demand response (ca. 12 MW) enabled by the project, which would result in lowering the difference between the P_{max} and P_{min}.	
KPI_{20}: exploitation of interconnection capacities	The project is expected to increase the average NTC in the project area thanks to the deployment of dynamic thermal rating. Assuming that the average load flow would not be affected by the project deployment, the KPI is positively assessed to 9 % for both, the interconnections Slovenia → Italy (direction from Slovenia to Italy) and Austria → Slovenia (direction from Austria to Slovenia). Additionally, the expected increase of 15 % of NTC at the Slovenia – Croatia interconnector (due to the deployment of DTR), would result in a positive assessment of the KPI also for this interconnection (nearly 13 %).	

Policy criterion 3: Network security, system control and quality of supply

The promoters anticipate positive project's impact on this specific criterion (mainly in terms of improved voltage profiles) as a result of inclusion of storage and DG units in provision of secondary reserve, deployment of dynamic thermal rating, etc. Therefore, the project facilitates growing penetration levels of RES that can be safely integrated into the grid.

The following KPIs (Table 21) have been selected to address the project's impact on this specific criterion.

Table 21 SINCRO.GRID: evaluation of project's impact against the third specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_4: Allowable maximum injection of power into transmission networks without congestion risks	The promoters report positive impact of the project on this KPI (nearly 17 %), as a result of additional capacity from RES that could be safely integrated into the distribution and transmission network. In this context, the KPI is positively assessed based on the worst case power flow conditions and the size of the largest production unit that can be connected to the grid without risking generation curtailment, in both the BaU and SG scenarios.	
KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	The project could provide additional information to the regulator on how RES can contribute to ancillary services (secondary reserves) and the incentives that would stimulate them to provide such services. Additionally, RES units will be included in the operation of transmission and distribution systems with the goal of optimising losses and regulating voltage. Regulatory mechanisms can be established in order to adequately reward participating DG, by eliminating old regulatory mechanisms of Var energy penalties and introducing new ones.	
KPI_7: operational flexibility provided for dynamic balancing of electricity in the network	The project is expected to increase the operational flexibility for dynamic network balancing; in this respect, the KPI is assessed as a ratio of DG and storage that can be modified vs. total storage and DG in the project area. Positive assessment of this KPI is calculated (around 29.5 %) due to inclusion of storage and DG in the supply of secondary reserve in Slovenia and connection of wind generation to the central voltage control in Croatia.	

KPI_{10}: stability of the electricity system	One of the central ideas behind the SINCRO.GRID project is dealing with overvoltage problems in the project area. In this context, the promoters assess this KPI in terms of improvement of transmission network voltage profiles as a result of deployment of compensation devices and inclusion of controllable RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area. This would lead to resolution of nearly 100% of the overvoltage issues in the selected network nodes. In this respect, the KPI is positively quantified.	
KPI_{11}: duration and frequency of interruptions per customer, including climate-related disruptions	Presence of overvoltages in the project area may lead to equipment failure and, consequently, outage risks. Due to the project's nature (overvoltages mainly occurring at the transmission network level), the SAIDI and SAIFI are not the most adequate indicators to represent the issue at stake. To this end, promoters have only taken into account network outages (using SAIDI and SAIFI) caused by failures of transmission network equipment (linked to overvoltages). Network reconfigurations would be required to deal with overvoltages in the project area, which on the other hand would have effect on network security (using the N-1 criterion). An estimate of 50% decrease in system security due to overvoltages (calculated as the periods when the N-1 criterion is not fulfilled) is reported in the BaU compared to the SG scenario.	
KPI_{12}: voltage quality performance	The promoters assess the project impact on this KPI in terms of reduced number of hours with voltage violations due to the project deployment. The project is expected to have positive impact (estimated value of 99.99%), as a result of deployment of compensation devices and inclusion of RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area.	
KPI_{14}: ratio between minimum and maximum electricity demand within a defined time period	This KPI is positively assessed (around 0.85 %) due to the additional capacity of storage and demand response (ca. 12 MW) enabled by the project, which would result in lowering the difference between the P_{max} and P_{min}.	
KPI_{16}: percentage utilisation (i.e. average loading) of electricity network components	Dynamic thermal rating in Slovenia deals with better utilisation of the grid and will increase the capacity of the existing transmission infrastructure and NTC values. However, promoters expect that the physical cross-border flows will remain the same using the phase-shift transformers, as the current ones already exceed the NTC values. Similar results are also expected for the Croatian part of the project.	

	Additionally, the project is expected to increase the utilisation of the internal electricity network components, however no quantification for this KPI has been provided at the current stage of the project development.	
KPI_{17}: availability of network components (related to planned and unplanned maintenance) and its impact on network performances	This KPI is positively estimated on the basis of reduced average lifespan of HV equipment by 2 years in BaU scenario due to overvoltage problems, whereas an average lifespan of HV equipment is reported to be 40 years. In this context, the SINCRO.GRID solutions tackling overvoltage issues are expected to increase the availability of transmission network components by 2 years.	

Policy criterion 4: Optimised planning of future cost-efficient network investments

The project is expected to optimise the planning of future cost-efficient network investments as a result of increased security of supply (solving overvoltage issues), increased network efficiency (e.g. reduced peak load) and increased network utilisation and NTC (and potential decrease of the energy market prices of the neighbouring countries), which would in turn postpone some transmission network investment.

Also, the implementation of the project would possibly affect the level of losses in the grid and consequently have an impact on the future grid development. As one of the main goals of the project is solving the overvoltage issue in the project area, deployment of compensation devices and advanced VVC mechanism may potentially increase the total energy losses.

The promoters choose the following KPIs (Table 22) to address the project's impact on this criterion.

Table 22 SINCRO.GRID: evaluation of project's impact against the fourth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_2: Environmental impact of electricity grid infrastructure	The project is expected to have positive environmental impact as a result of deferred/avoided transmission grid investments, mainly resulting from dynamic thermal rating (estimated deferral of the planned Skofja Loka-Cerkno and Divaca-Koper 110 kV lines by 10 years) and installation of storage (which will replace the 30 MW gas-fired power plant). In this context, deferred/avoided transmission grid investments would bring positive environmental impact, in terms of land use and landscape changes, reduced/avoided visual, acoustic impact and environmental impact.	

KPI_5: Energy not withdrawn from renewable sources due to congestion or security risks	There is no historical data on energy curtailment in the project area as according to the national legislation in Slovenia and Croatia; all the RES connected to the grid can operate at maximum capacity. Nevertheless, future deployment of increased RES may trigger overvoltage protection relays to disconnect DGs from the network for a short period of time. In this regard, the project is expected to reduce possible curtailed renewable energy in the future as a result of enabling 719 MW of wind units in Croatia included in the voltage control mechanism and additional 12 MW of battery storage and DG in Slovenia providing secondary reserves.	
KPI_8: ratio of reliably available generation capacity and peak demand	SINCRO.GRID project is expected to increase the reliably available capacity by 12 MW due to inclusion of DG and storage capacity in the secondary reserve in Slovenia. The KPI is positively quantified to around 0.21 % using the formula proposed in the assessment framework.	
KPI_{10}: stability of the electricity system	One of the central ideas behind the SINCRO.GRID project is dealing with overvoltage problems in the project area. In this context, the promoters assess this KPI in terms of improvement of transmission network voltage profiles as a result of deployment of compensation devices and inclusion of RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area. This would lead to resolution of nearly 100% of the overvoltage issues in the selected network nodes and in this respect, the KPI is positively quantified.	
KPI_{11}: duration and frequency of interruptions per customer, including climate-related disruptions	Presence of overvoltages in the project area may lead to equipment failure and, consequently, outage risks. Due to the project's nature (overvoltages mainly occurring at the transmission network level), the SAIDI and SAIFI are not the most adequate indicators to represent the issue at stake. To this end, promoters have only taken into account network outages (using SAIDI and SAIFI) caused by failures of transmission network equipment (linked to overvoltages). Network reconfigurations would be required to deal with overvoltages in the project area, which on the other hand would have effect on network security (using N-1 criterion). An estimate of 50% decrease in system security due to overvoltages (calculated as period when N-1 criterion is not fulfilled) is reported in the BaU compared to the SG scenario.	

KPI_{12}: voltage quality performance	The promoters assess the project impact on this KPI in terms of reduced number of hours with voltage violations due to the project deployment. The project is expected to have positive impact (estimated value of 99.99%), as a result of deployment of compensation devices and inclusion of controllable RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area.	
KPI_{13}: level of losses in transmission and distribution networks	The project is expected to increase network losses by 0.07 %, using the quantification formula proposed in the JRC assessment framework (Vasiljevska and Gras, 2017) due to the following: • Installed compensation devices would solve the voltage problem, however, on the other hand, increase peak losses in the amount of 2.4 MW due to their operation; • Around 10 % of energy is expected to be lost in the charging/discharging cycle of the battery; • The advanced VVC mechanism is also expected to increase the losses by on average 1 MW in each system, thus increasing energy losses by 17.520 MWh (calculated using a load flow analysis for typical grid situations).	
KPI_{14}: ratio between minimum and maximum electricity demand within a defined time period	This KPI is positively assessed (around 0.85 %) due to additional capacity of storage and demand response (ca. 12 MW) enabled by the project, which would result in lowering the difference between the P_{max} and P_{min}.	
KPI_{16}: percentage utilisation (i.e. average loading) of electricity network components	Dynamic thermal rating in Slovenia aims at better utilisation of the grid and will increase the capacity of the existing transmission infrastructure and NTC values. However, promoters expect that the physical cross-border flow will remain the same using the phase-shift transformers, as the current physical cross-border flows already exceeds the NTC value. Similar results are also expected for the Croatian part of the project. Additionally, the project is expected to increase the utilisation of the internal electricity network components, however no quantification for this KPI has been provided at the current stage of the project development.	
KPI_{21}: congestion rents across interconnections	The expected increase in NTC enabled by the project would likely have an impact on the congestion rents and, consequently, on the revenue from cross-border capacity auctions of the neighbouring TSOs. Based on the promoters' previous experience, the increase in NTC will be followed by a decrease in auction prices with net effect on income accruing from such auction in the whole project area close to zero. The promoters are, however, not able to accurately estimate the effect on the overall income.	

Policy criterion 5: Market functioning and customer services

The project is expected to increase the number of new participants in the ancillary services market, thus potentially reducing the costs of secondary reserve, while ensuring higher level of security of supply. Also, the project would enable increased demand response participation in the provision of tertiary reserve. Additionally, increased network capacity along with higher NTC values will further facilitate market integration and enable new market services.

The promoters use the following KPIs (Table 23) to capture the project's impact on this specific criterion.

Table 23 SINCRO.GRID: evaluation of project's impact against the fifth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_6: Methods adopted to calculate charges and tariffs, as well as their structure, for generators, consumers and those that do both	The project could provide additional information to the regulator on how RES can contribute to ancillary services (secondary reserves) and the incentives that would stimulate them to provide such services. Additionally, RES units will be included in the operation of transmission and distribution systems with the goal of optimising losses and regulating voltage. Regulatory mechanisms can be established to adequately reward participating DG by eliminating old regulatory mechanisms of var energy penalties and introducing new ones.	
KPI_{10}: stability of the electricity system	One of the central ideas behind the SINCOR.GRID project is dealing with overvoltage problems in the project area. In this context, the promoters assess this KPI in terms of improvement of transmission network voltage profiles as a result of deployment of compensation devices and inclusion of RES (e.g. wind farms) in the cross-border voltage/var control algorithms in the whole project area. This would lead to resolution of nearly 100% of the overvoltage issues in the selected network nodes and in this respect, the KPI is positively quantified.	
KPI_{15}: demand side participation in electricity markets and in energy efficiency measures	The project is expected to increase the demand side participation, particularly in the provision of tertiary reserve to the Slovenian TSO (to which 15 MW of demand response capacity are currently contributing). The implementation of a communication platform at DSO level would facilitate data exchange between demand response providers and the DSO/TSO, and thus account for additional capacity of demand response available to the DSO/TSO. In this regard, the KPI is positively assessed for the whole project area (around 0.1 %). Additionally, the amount of demand response capacity participating in the tertiary reserve in Slovenia, in particular, is expected to increase by 33 %.	
KPI_{18}: actual availability of network capacity with respect to its standard value	The dynamic thermal rating proposed in the project would contribute to better network utilisation and lead to increased availability of network capacities. As a result, the KPI is positively assessed to 15 %.	

KPI_{19}: ratio between interconnection capacity of a Member State and its electricity demand	The promoters anticipate increase in the average NTC (considering the average NTC at each interconnector in the project area) as a result of the dynamic thermal rating addressed in the project. Consequently, the KPI is positively quantified to around 4 % for the whole project area.	
KPI_{20}: exploitation of interconnection capacities	The project is expected to increase the average NTC in the project area due to deployment of dynamic thermal rating. Assuming that the average load flow would not be affected by the project deployment, the KPI is positively assessed to nearly 9 % for both, the interconnections Slovenia → Italy (direction from Slovenia to Italy) and Austria → Slovenia (direction from Austria to Slovenia). Additionally, the expected increase of 15 % of NTC at the Slovenia – Croatia interconnector (due to the deployment of DTR), would result in a positive assessment of the KPI also for this interconnection (around 13 %).	

Policy criterion 6: Involvement of users in management of their energy usage

The project is expected to contribute to this specific criterion by involving additional network users in provision of tertiary reserve through demand response. In this respect, the promoters select the following KPIs (Table 24) to address the project's impact on this criterion.

Table 24 SINCRO.GRID: evaluation of project's impact against the sixth specific criterion

Selected KPIs	Calculation approach and impact evaluation	
KPI_{15}: demand side participation in electricity markets and in energy efficiency measures	The project is expected to increase the demand side participation, particularly in the provision of tertiary reserve to the Slovenian TSO (to which 15 MW of demand response capacity are currently contributing). The implementation of a communication platform at DSO level would facilitate data exchange between demand response providers and the DSO/TSO, and thus account for additional capacity of demand response available to the DSO/TSO. In this regard, the KPI is positively assessed to around 0.1 % for the whole project area. Additionally, the amount of demand response capacity participating in the tertiary reserve in Slovenia, in particular, is expected to increase by 33 %.	

2.3.7 Economic appraisal

The following section presents the societal benefits of the SINCRO.GRID project in monetary terms along with the total cost (capital and operational expenditure), subject to societal cost-benefit analysis performed and communicated by the promoters. Furthermore, the outcome of the societal cost-benefit analysis, in term of economic indicators such as NPV, IRR and B/C are used to verify whether the overall project' benefits outweigh the project's costs and therefore the project complies with the 2nd general criteria of the Regulation (Article 4 (b)).

The promoters assumed the following values for the variables used in the societal CBA:

- **Demand growth**: an average annual demand growth of 2.1% has been reported, according to the last demand forecast analysis performed by ELES. A similar situation applies in Croatia.
- **Discount rate**: a value of 4% has been used as social discount rate, according to the recommendation given in the JRC assessment framework for project of common interest in the field of smart grids [12];
- **Time horizon**: 15 years has been chosen as time horizon due to the lifespan of most of the investments, such as ICT equipment, DTR, etc.
- **Peak load growth**: 2 % as peak load forecast has been considered according to ELES peak load forecast analysis. A similar situation applies in Croatia.
- **Energy price for losses**: a value of 45 €/MWh has been assumed, as current price ELES pays for energy losses. A similar situation is assumed for Croatia.
- **Carbon prices**: 16.5 €/t from 2020-2025, 20 €/t from 2025-2030 and 36 €/t from 2030-2035, according to the EC reference scenario up to 2050 [13];
- **Cost of energy not supplied**: 4.13 €/kWh, calculated by the regulatory energy agency of Slovenia.

The project's economic assessment presents strongly positive outcome (NPV equal to 229.5 million € and B/C of 25.4), with the main benefits and costs listed below.

2.3.7.1 Main monetised benefits

- Reduction of GHG (as calculated in KPI_1 and using the carbon price provided in the Commission reference scenario up to 2050);
- Avoided cost of purchasing capacity for secondary reserve (due to additional 2 MW of DG and 10 MW of storage deployed within the project);
- Avoided generation capacity investment for spinning reserve (due to avoided cost of building a CCGT for provision of secondary reserve);
- Deferred transmission investment (due to deployment of dynamic thermal rating which would increase the transmission network capacity by 15 %);
- Financial benefits due to increased cross-border capacity (as a result of dynamic thermal rating deployment and consequently increase of NTC);
- Societal benefits due to increased cross-border capacity (between Slovenia and Italy and Slovenia and Austria);
- Reduced cost of equipment breakdown (due to resolution of the overvoltage issue in the project area);
- Increased value of service (total reduced energy not served as a result of lower HV equipment failure, reduced outages and energy not served from generation units);

([12]) (Vasiljevska and Gras, 2017), available at http://ses.jrc.ec.europa.eu/publications/reports/assessment-framework-projects-common-interest-field-smart-grids
([13]) (Commission Staff Working Document, 2011)

- Decreased amortisation value due to longer lifespan of equipment;
- Decreased cost of purchasing reactive power from generation units (due to adoption of reactive power compensation devices as part of the project).

2.3.7.2 Main costs

- Installation of compensation devices;
- Deployment of storage units for secondary regulation;
- Deployment of virtual cross-border control centre;
- Adoption of advanced dynamic thermal rating;
- Project coordination;
- Personnel cost, insurance and DTR licensing cost.

2.3.7.3 Sensitivity analysis

The following parameters are reported as critical and as such being subject to sensitivity analysis:

- **NTC values**: no increase of the NTC value would drop the NPV by 62 %; a higher increase of the NTC value (by 250 MW at the border with Italy and 150 MW at the border with Austria) would lead to an NPV increase of 87 %.
- **Carbon price**: use 6.2 €/tCO_2 over the whole operating period would lead to the NPV to drop by 28 %; use of 36 €/tCO_2 over the whole operating period would lead to an NPV increase of 19 %.
- **Discount rate**: an increase in the discount rate to 5.5 % would drop the NPV value by 13.4 %.

2.3.8 Additional non-monetised benefits

In addition to the quantified benefits, the project proposal addresses further impacts that could not be (entirely) quantified and consequently included in the KPI analysis, such as:

- **Increase in the macro-regional security of supply** – The increased security of supply addressed in the project is expected to have a positive impact on a wider regional level, since the project area hosts major transit flows from Eastern to Western Europe. Also, the project significantly contributes to an adequately functioning EU internal electricity market, by increasing the potential for transit flows without need for new interconnections: thus, it improves the energy system efficiency and resilience, as well as the region's renewable energy potential.
- **Solidarity with other countries** – all neighbouring countries in the region are expected to benefit from improved quality of supply enabled by the project, which is becoming more relevant along with growing RES penetration levels. Additionally, adequately addressing overvoltage and congestion issues in the project area would allow for increasing cross-border flows from South-Eastern to Western Europe, therefore facilitating growing renewable energy development in the Balkans.
- **Technological innovation with replication potential** – the project demonstrates a high replication potential: other South-East European and

Central-East European TSOs may learn from the systemic approach adopted in the project, in view of implementation of similar technology building blocks.

2.3.9 Summary of the SINCRO.GRID project's evaluation

The SINCRO.GRID is a mature project with clear objectives and a well-defined set of necessary actions to achieve these objectives. It is driven by existing challenges, mainly related to voltage and frequency regulation at the transmission network level, which have been recently strained to the limit in the project area, and may therefore compromise network reliability and security of supply and potentially endanger future development of renewable and dispersed generation integration. Therefore, the project's main idea revolves around development of a Virtual Cross-Border Control Centre (VCBCC) to effectively support various voltage and frequency control processes and enhance voltage profiles in the project area, while enabling increased integration of RES and secure and reliable supply of electric power to the end-users. Various measures proposed by the project, including advanced algorithms for VVC optimisation, integration of secondary reserves, and advanced real time operation of the grid using DTR, would require a high level of coordination at TSO-TSO and TSO-DSO level and, consequently, deployment of a communication platform for standardised data exchange.

To this end, the SINCRO.GRID project proves necessary for the 'smart grid deployment' thematic area (Annex I, 4 (10) to the Regulation) and it complies with the general criterion 1(c)(i), as well as with 1 (c) (ii) of Article 4 of the Regulation. The project proposal is very well articulated and documented and it demonstrates a significant positive contribution to the six smart grid specific criteria outlined in Article 4 (2) of the Regulation and a positive outcome of the project's societal cost-benefit analysis.

3 Summary of the projects' evaluation

The outcome of the overall projects' evaluation, emerged from the analyses presented in the previous sections, is summarised in the tables below. Table 25 illustrates an overview of each project's compliance with the eligibility requirements of Article 4 of the Regulation, namely: 1) its necessity for the 'smart grid deployment thematic area'; 2) its compliance with the general criteria under Article 4(1)(c); 3) that the overall project's benefits outweigh its costs by significantly contributing to the six specific criteria.

Table 25 Overview of projects' compliance with the general criteria of the Regulation (Article 4)

Assessment step	Project			
	ACON	ALPGRID	SBI	SINCRO.GRID
Necessity for the smart grid priority thematic area	√	√	√	√
Compliance with the general criteria (Article 4(1)(c))	√	√	√	√
Positive outcome of the societal cost–benefit analysis	√	√	**Not quantified due to early stage of project development**	√

In addition, Table 26 illustrates the overall assessment related to the contribution of each project proposal to the six smart grid specific criteria, outlined in Article 4(2)(c) of the Regulation, evaluated using the Key Performance Indicators derived from Annex IV (4) to the Regulation and based on the information provided by the promoters.

Table 26 Overall projects contribution to the smart grid specific criteria

SPECIFIC CRITERIA	ACON	ALPGRID	SBI	SINCRO.GRID
Integration and involvement of network users with new technical requirements with regard to their electricity supply demand				
Efficiency and interoperability of electricity transmission and distribution in day-to-day network operation				
Network security, system control and quality of supply				
Optimised planning of future cost-efficient network investments				
Market functioning and customer services				
Involvement of users in management of their energy usage				

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List of abbreviations and definitions

ACER	Agency for Cooperation of Energy Regulators
AMM	advanced meter management
BAU	business as usual
B/C	benefit-to-cost ratio
CBA	cost–benefit analysis
DER	distributed energy sources
DG	distributed generation
DHC	district heating and cooling
DSM	demand-side management
DSO	distribution system operator
DTR	dynamic thermal rating
EMS	energy management system
ENTSO-E	European Network of Transmission System Operators
EV	electric vehicle
GHG	greenhouse gas
HV	high voltage
ICT	information and communication technology
IRR	internal rate of return
KPI	key performance indicator
LTE	long term evolution
LV	low voltage
MV	medium voltage
NTC	net transfer capacity
NPV	net present value
OLTC	on load tap changer
PLC	power line carrier
PCI	project of common interest
RES	renewable energy sources

RTU	remote terminal unit
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index
SCADA	supervisory control and data acquisition
SG	smart grid
SVC	static var compensator
TEN-E	Trans-European Networks for Energy
TSO	transmission system operator
TYNDP	ten year network development plan
VCBCC	virtual cross-border control centre
VOLL	value of lost load
VVC	voltage-var control

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