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Assessment methodology for Energy Infrastructure Candidate Projects of Common Interest

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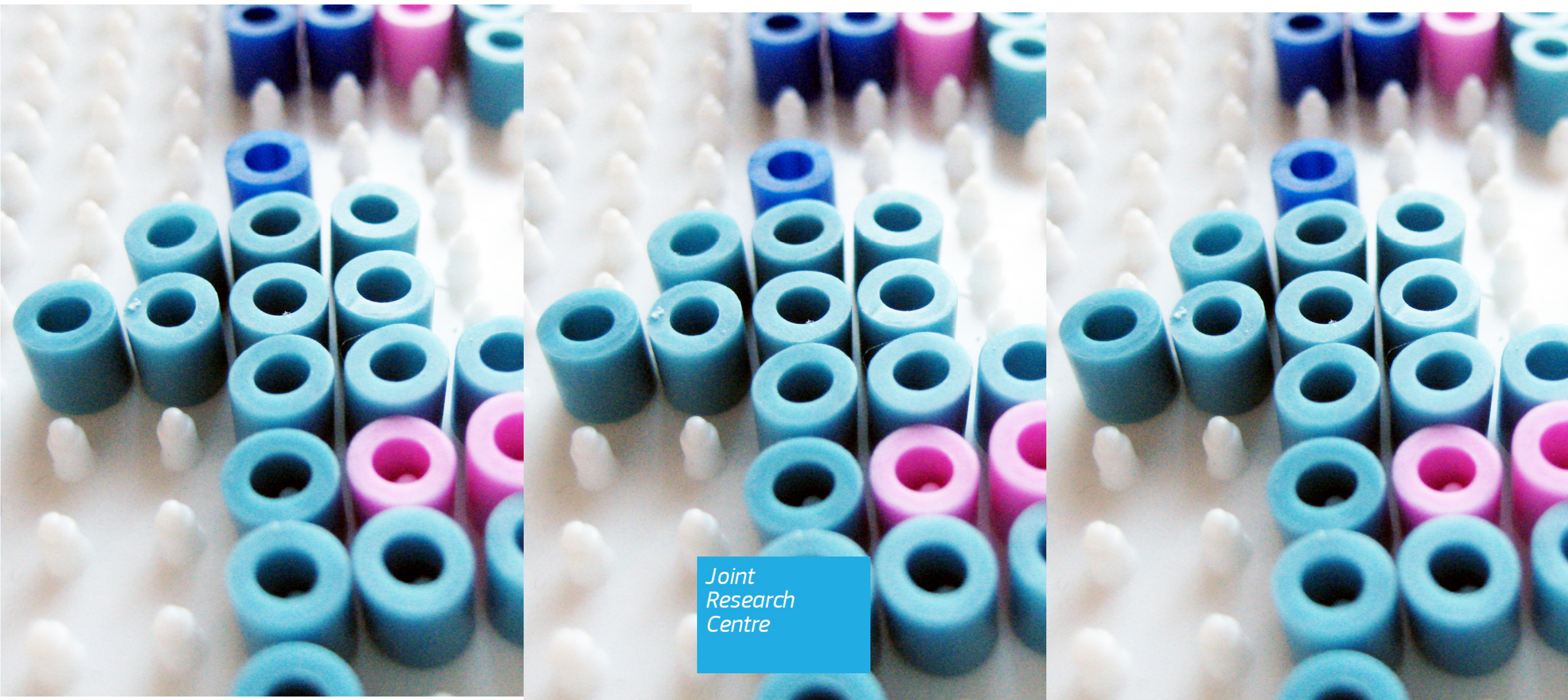

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ABBREVIATIONS AND ACRONYMS

ACER	Agency for the Cooperation of Energy Regulators.
CBA	Cost Benefit Analysis.
DG	Directorate-General.
ENTSO-E	European Network of Transmission System Operators for Electricity.
ENTSO-G	European Network of Transmission System Operators for Gas.
EU	European Union.
GTC	Grid Transfer Capability.
IET	Institute for Energy and Transport.
JRC	Joint Research Centre.
KPI	Key Performance Indicator.
LNG	Liquefied Natural Gas.
PCA	Principal Component Analysis.
PCI	Project of Common Interest.
TEN-E	Trans-European Networks for Energy.
TFEU	Treaty of the Functioning of the European Union.
TYNDP	Ten Year Network Development Plan.

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1 INTRODUCTION

Projects of Common Interest (PCIs) are key energy infrastructure projects, which will help Member States to integrate their energy markets and, in particular, end the isolation of some Member States from Europe-wide energy networks. The projects will also allow a greater diversity of sources to supply Europe's networks. Moreover, they will help power grids to cope with the increasing amounts of electricity generated from renewable energy sources and, thus contributing towards the reduction of CO2 emissions.[1]

Figure 1 illustrates the energy infrastructure categories and respective requirements for Projects of Common Interest under the Regulation (EU) No. 347/2013. The first list of PCIs was published in October 2013 and contains a total of 248 projects,[2] mostly electricity transmission lines and gas pipelines and interconnectors. The selection of these projects represents a step towards the implementation of the Guidelines for Trans-European Networks for Energy (TEN-E).

The list of PCI projects is to be updated every two years and as of January 2015 this process is on-going as the revised list of PCI projects is to be released in October 2015. Regulation (EU) No. 347/2013 specifies that all projects included in the 2015 PCI Union list shall be part of the Ten Year Network Development Plan (TYNDP) 2014 (Figure 1): "*After adoption of the first Union list, for all subsequent Union lists adopted, proposed electricity transmission and storage projects, falling under the categories set out in Annex II.1(a), (b) and (d) and gas projects, falling under the categories set out in Annex II.2, shall be part of the latest available 10-year network development plan for electricity and gas, developed by the ENTSO for Electricity and ENTSO for Gas, respectively.*"

Furthermore, Regulation (EU) No. 347/2013 calls upon the development of a methodology by the European Network of Transmission System Operators for Electricity (ENTSO-E) and the ENTSO for Gas (ENTSO-G) for harmonised energy system-wide Cost-Benefit Analysis (CBA) at Union level for Projects of Common Interest falling under the categories set out in Annex II.1 (a) to (d) and Annex II.2.

[1] European Commission (2013), COM(2013) 0711 final.
[2] European Commission (2013), COM(2013) 6766 final.

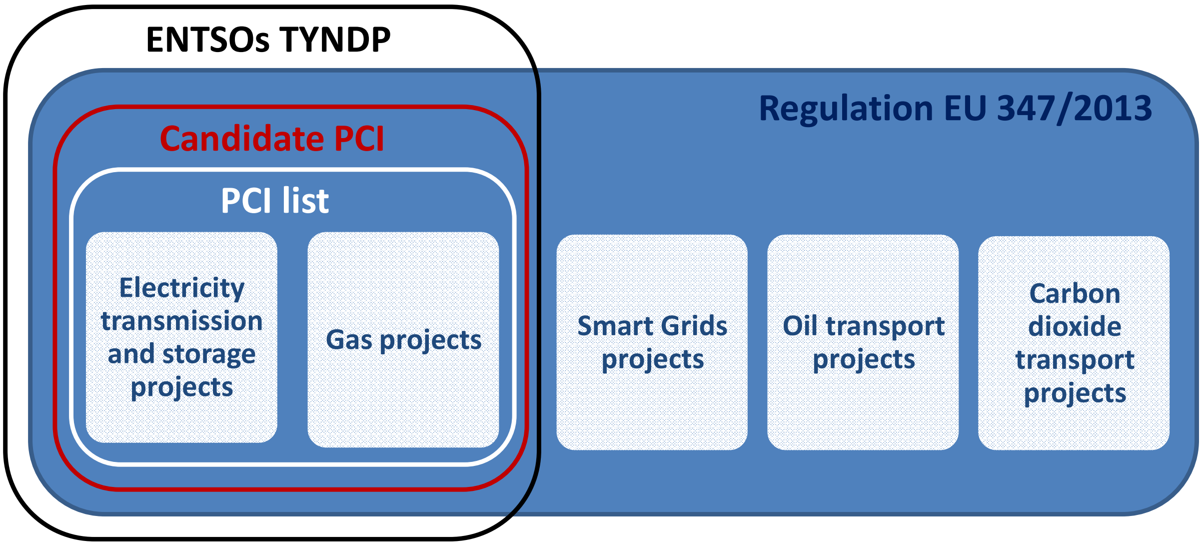

Figure 1 Projects of Common Interest under Regulation (EU) No. 347/2013

The projects are evaluated by Regional Groups, set-up by the European Commission and are comprised of representatives from competent Ministries, national regulatory authorities and the gas and electricity transmission system operators and project promoters, ENTSO-E, ENTSO-G, the Agency for the Cooperation of Energy Regulators (ACER) and European Commission and other participants.[3] Directorate-General (DG) Joint Research Centre (JRC) will support the Regional Groups in their task of assessing each project's compliance with the criteria set up in the Regulation (EU) No. 347/2013 and its added value on a European-level, notably in the priorities of electricity transmission and storage and gas transmission, liquefied or compressed natural gas infrastructure and storage. On a related note, DG JRC was involved in the development of assessment framework for PCI in the area of Smart Grids and evaluation of the first Union list of Smart Grid projects within the Smart Grid Task Force Expert Group 4.[4] Furthermore, DG JRC assists the Smart Grid thematic group in evaluation of the second year Smart Grid PCI.

In this report, DG JRC develops an assessment methodology for the evaluation of project proposals in the area of transmission and storage for electricity and gas. This assessment methodology builds on the outputs of the Cost-Benefit Analyses (CBA), developed by the ENTSO-E and the ENTSO-G, which are applied to project proposals included in their respective TYNDP[5] and in the case of gas projects, also including a project specific CBA submitted by the project promoters. Figure 2 depicts the workflow of the PCI assessment process and the actors involved.

[3] Source: Terms of Reference for electricity and gas Regional Groups (draft, November 2014).
[4] The report is available at:
http://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/documents/evaluation_of_smart_grid_projects_within_the_smart_grid_task_force_expert_group_4_eg4.pdf
[5] Only projects that are included in the TYNDP can be considered for a PCI status. The TYNDPs are prepared and published by ENTSO-E for electricity and ENTSO-G for gas on a bi-annual basis.

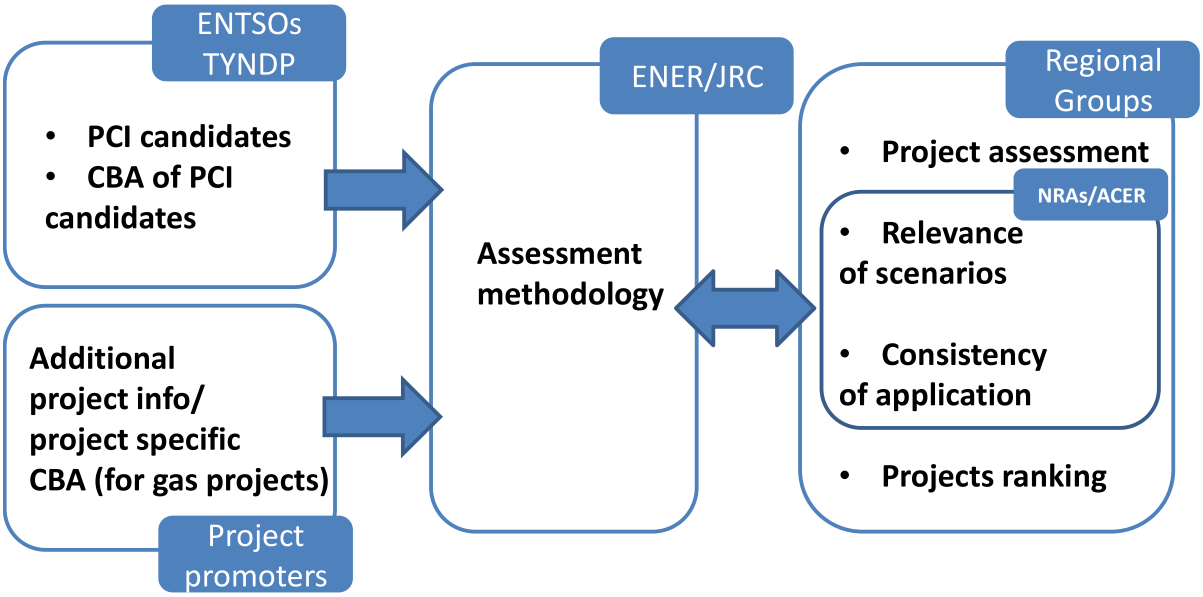

Figure 2 Overview of the PCI assessment process

Furthermore, the evaluation will be conducted on the basis of the criteria for the PCIs which are specified in Regulation (EU) No. 347/2013. In particular, for electricity transmission and storage projects the criteria are: market integration, sustainability and security of supply; and for gas projects: market integration, security of supply, competition and sustainability.

DG JRC will also participate in the Regional Group meetings, presenting the assessment method and (potentially) adapting it according to comments and views of the Regional Group members. Finally, DG JRC will assist the Regional Groups in ensuring consistency across regions and between the energy infrastructure categories, and provide any additional scientific and technical support required.

The final Union-wide list of projects will be adopted through a delegated act procedure by DG ENER in accordance with Article 290 of the Treaty on the Functioning of the European Union, while respecting the right of the Member States to approve PCIs on their respective territory.

The objective of this document is to present a (draft) methodology for updating the Union list of PCIs as stated in point 23 of the Regulation (EU) No. 347/2013. Furthermore, Article 4.2.4 of the Regulation states that *«Neither the regional list nor the Union list shall contain any ranking, nor shall the ranking be used* ***for any subsequent purpose..»*** (emphasis added). Therefore, the assessment methodology and any consequent rankings will be developed only for the internal use of the Regional Groups.

In particular, the assessment methodology will be CBA-based as its inputs will be the results from ENTSO-E and ENTSO-G's CBAs conducted for each project. Using results from a CBA analysis is a requirement of the Regulation. The methodology will be subject to approval by the Regional Groups. Furthermore, ACER and the National Regulatory Authorities (NRAs) are responsible for validating the consistency of the application across the Regional Groups and providing an opinion on the relevance of scenarios (Figure 2).

This document is structured as follows: Section 2 outlines the main challenges for developing the methodology Section 3 provides a description of the assessment methodology. Finally, Section 4 summarises.

2 CHALLENGES FOR DEVELOPING THE METHODOLOGY

The main challenges identified by DG JRC for the development of the assessment methodology are as follows:

1. DG JRC did not participate in the CBA assessment of the candidate projects. Therefore, a high interaction with the stakeholders is necessary to fully comprehend the output of the assessments and to better understand the assumptions driving these outputs.
2. DG JRC aims at proposing a methodology which will meet the following requirements:
    a. Robustness
    b. Minimum subjectivity
    c. Ease of interpretation of the results
    d. Minimum operational complexity
3. The assessment methodology must be (as much as possible) common across the Regional Groups and take into account the heterogeneity of projects (e.g. transmission and storage projects are to be included together in the single Union list).
4. The results yielding from applying the methodology are highly dependent on the characteristics and the quality of the data sets provided by ENTSO-E, ENTSO-G and the project promoters. The classification or ranking procedure involves an iterative process that alternatively considers both the results from the CBA and the technical features of each individual project.
5. Most of the indicators provided by ENTSO-E and ENTSO-G are not monetised and the indicators use different units of measure. Thus, normalisation is required prior to any other step. Furthermore, the Regional Groups must also take into account extra-CBA information. For example, the Regulation states that the Regional Groups shall furthermore take into consideration: the urgency of each proposed project in order to meet the Union energy policy targets of market integration; the number of Member States affected by each project, whilst ensuring equal opportunities for projects involving peripheral Member States; the contribution of each project to territorial cohesion; and the complementarity with regard to other proposed projects (Article 4.4). Thus, the assessment methodology must consider that not all of the aspects are quantifiable.
6. Many indicators are expected to be highly correlated as some of the definitions are conceptually connected.
7. Any data analysis effort relies on data availability. Therefore, as the final datasets were not available during the drafting of this report, it may be necessary in the future to modify the

details of the methodology based on the specificities of the available data at hand. For example, certain variables may be used as proxies for others that will be not made available. Furthermore, the instruments and methodologies employed may need to be adapted to the data correlation structures.

In the following sub-sections, some particular challenges for electricity and gas projects are presented.

2.1 ELECTRICITY PROJECTS (TRANSMISSION AND STORAGE)

The information is provided by ENTSO-E's TYNDP 2014 web page [1]. The essential data source on the CBA's outcome is the Key Performance Indicators (henceforth KPIs) assessment of all PCIs candidates (except storage projects), which are included in the TYNDP 2014 for electricity [2].

DG JRC also uses the following sources of relevant information for the analysis:

- The six Regional Investment Plans [1] and all auxiliary information on TYNDP from ENTSO-E (e.g. Frequently Asked Questions, reports on comments and stakeholder consultations).
- Additional information from the project promoters.

Within the electricity and storage priorities, each project proposal is characterised by twelve KPIs. In the analysis of the KPIs database made available by ENTSO-E, DG JRC identified the following issues to be addressed in the development phase of the ranking methodology:

- Some KPIs have different values across the four 2030 Visions - differentiated based on the amount of cross-country integration of Renewable Energy Sources (RES) and attainment of environmental goals - that ENTSO-E has considered following extensive stakeholder consultation.
- Several indicators are provided in ranges. Therefore, the methodology must take into account:
  - The value of each KPI (average value within the range will be considered).
  - The uncertainty characterising each KPI value.
- Some KPIs are cardinal, while others are ordinal. Some statistical tools are valid only for one type of data.
- TYNDP 2014 includes evaluation of clusters of PCI candidates, thus all KPIs are assessed at cluster level. The evaluation of projects by cluster or by individual investment item might not yield the same results in terms of ranking.

- The KPI dealing with the integration of Renewable Energy Sources (RES) is measured in two different ways: 1) generation capacity from RES (in MW), connected and transmitted in the network due to the project and 2) avoided spillage of RES (in MWh) as a result of the project deployment.
- There is limited or no information on the Security of Supply KPI for electricity transmission projects, as currently in the PCI candidate list within the TYNDP 2014, which leads to inability to perform assessment of the project contribution to the Security of Supply criterion (as required in the Regulation (EU) No. 347/2013).
- Analogously, complete item-by-item cost data information is a clear prerequisite for assessment. However, this information is missing entirely from the currently available data pertaining to of electricity transmission projects (as in the PCI candidate list within the TYNDP 2014).
- From that same list, one can gather that the Environmental impact and social impact KPIs are not assessed in a large number of cases (resp. 42 and 37). Such a large number of missing values is a serious hindering for consistent construction of composite indicators, and puts the employability of the whole KPIs at risk. Any effort to improve data availability on this regard would be clearly desirable.
- Information for candidate storage projects is provided in the TYNDP 2014 [2]. The same document does not provide any information on the Security of Supply, environmental impact and social impact KPIs for storage projects. Moreover, cost data are missing for these projects as well.
- The PCI candidate projects are unevenly distributed across the four regions (BEMIP, NSI East, NSI West, NSOG), while a consistent methodology is needed across regions. In particular, as of 23rd December 2014, there were about 30 candidate projects for BEMIP, 89 for NSI East, 49 for NSI West and 30 for the NSOG.[6]

2.2 GAS PROJECTS (LNG, TRANSMISSION AND STORAGE)

The data for the gas PCI candidate projects will be provided by ENTSO-G (benefits) and the project promoters (costs).

- The data will be available *after* the assessment methodology is presented during the Regional Groups' meetings. In particular, it is expected that ENTSO-G will publish the TYNDP in mid-February 2015. After this publication, the project promoters will be provided

[6] Source: DG ENER webpage regarding the public consultation on the list of proposed Projects of Common Interest: http://ec.europa.eu/energy/infrastructure/consultations/pci_list_new_en.htm

adequate time to prepare and submit their projects' indicators related to costs. Thus, the full data set will not be available before the beginning of March 2015. As the identification of proper assessment methodologies is dependent on the underlying data and the methodology will be delivered before any data is available, the potential for scientific contributions to the assessment methodology is very limited. In particular, the choice between (many of the available) statistical techniques should be based on the particular characteristics of the provided data. Therefore, many of the available statistical techniques cannot be beforehand considered to be used for the assessment methodology.

- ENTSO-G's CBA will be conducted using 52 configurations (different energy and CO_2 prices; demand profiles etc.), over 5 time steps, with and without the project under evaluation for a series of indicators. For each project ENTSO-G will calculate 154 different results which will be provided for each infrastructure level (2), global context (2) and time step (5). Therefore, about 2800 values (data points) will be calculated per project per country and some projects will have impacts on several countries. These data size calculations do not include costs and qualitative data. The handling of the configurations and visions is explored in a subsequent chapter (3.2).
- The above two points, availability and quantity of data, signify that there will be a very large quantity of data to be processed and assessed in very little time which further limits the potential assessment methodological approaches that can be considered.
- Costs for gas projects are confidential and some of the members of the Regional Groups will not have access to them. Thus, they will not be part of ENTSO-G's CBA outputs as they will be calculated by the project promoters following guidelines from ENTSO-G. Furthermore, they will have to be evaluated separately from the CBA and the sections of the analysis that will refer to costs must not reveal (or indicate) the underlying data.
- There are an uneven number of PCI candidate projects across the four regions (NSI West, NSI East, Southern Gas Corridor and Baltics), while a consistent methodology is needed across regions. Statistical methodologies are sometimes sensitive to the number of observations/data (i.e. number of project proposals). In particular, as of 23rd December 2014, there were about 59 candidate projects for NSI West, 65 for NSI East, 41 for Southern Gas Corridor and 26 for the Baltics.[7]

[7] Source: DG ENER webpage regarding the public consultation on the list of proposed Projects of Common Interest: http://ec.europa.eu/energy/infrastructure/consultations/pci_list_new_en.htm

3 CANDIDATE PCI ASSESSMENT METHODOLOGY

This section describes the main steps of the assessment methodology. These are presented in Figure 3.

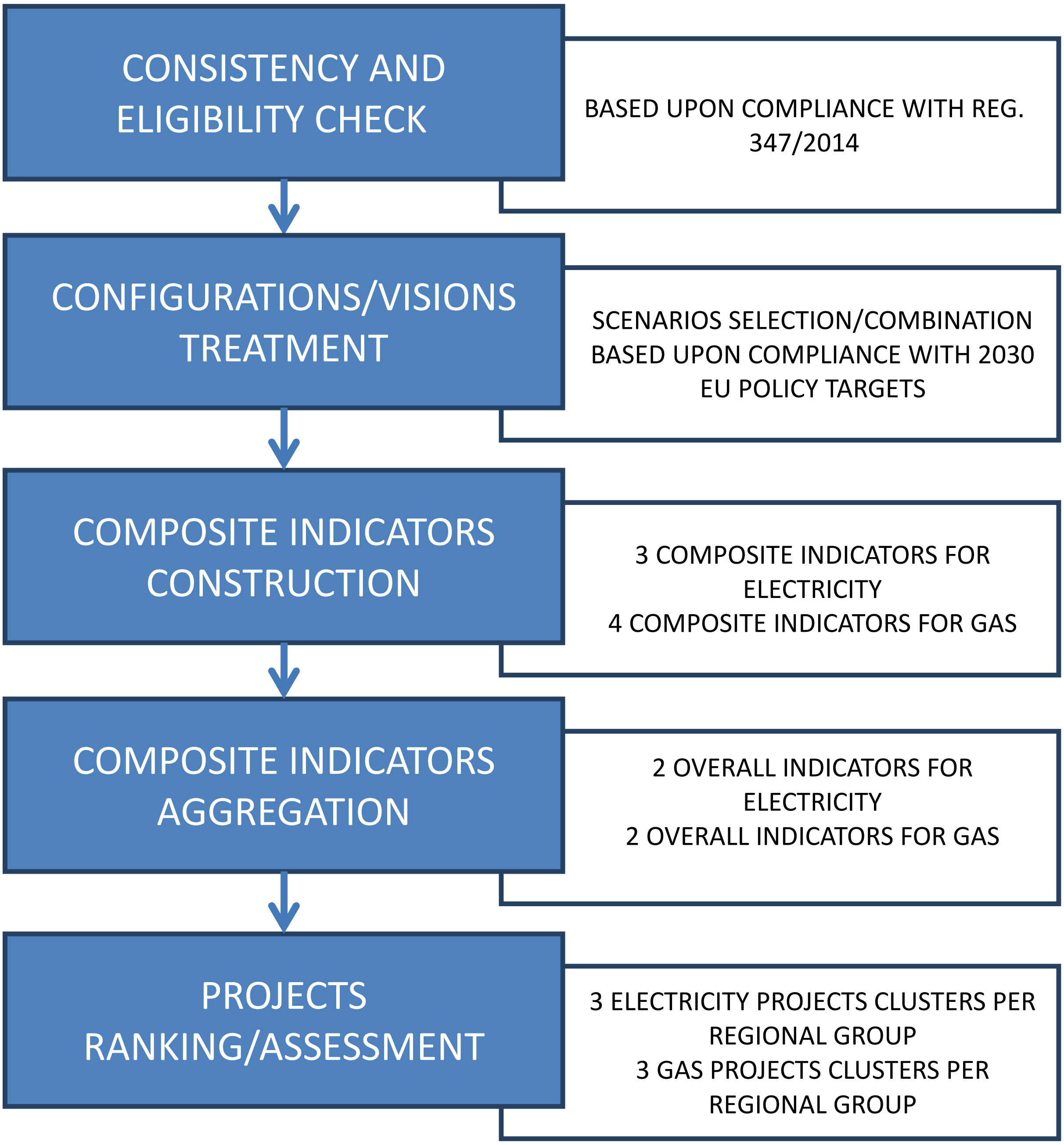

Figure 3 Flow-chart with the main methodological steps

3.1 CONSISTENCY AND ELIGIBILITY CHECK

The first step entails a data consistency check and a compliance check of the proposed projects. In particular, Article 4 of Regulation (EU) No. 347/2013 states:

1. *Projects of common interest shall meet the following general criteria:*
   a. *the project is necessary for at least one of the energy infrastructure priority corridors and areas;*
   b. *the potential overall benefits of the project, assessed according to the respective specific criteria in paragraph 2, outweigh its costs (including long-term ones);*
   c. *the project meets any of the following criteria:*
      i. *involves at least two Member States by directly crossing the border of two or more Member States;*
      ii. *is located on the territory of one Member State and has a significant cross-border impact as set out in Annex IV.1;*
         – *for electricity transmission, the project increases the grid transfer capacity, or the capacity available for commercial flows, at the border of that Member State with one or several other Member States, or at any other relevant cross-section of the same transmission corridor having the effect of increasing this cross-border grid transfer capacity, by at least 500 Megawatt compared to the situation without commissioning of the project;*
         – *for electricity storage, the project provides at least 225 MW installed capacity and has a storage capacity that allows a net annual electricity generation of 250 Gigawatt-hours/year;*
         – *for gas transmission, the project concerns investment in reverse flow capacities or changes the capability to transmit gas across the borders of the Member States concerned by at least 10 % compared to the situation prior to the commissioning of the project;*
         – *for gas storage or liquefied/compressed natural gas, the project aims at supplying directly or indirectly at least two Member States or at fulfilling the infrastructure standard (N-1 rule) at regional level in accordance with Article 6(3) of Regulation (EU) No 994/2010 of the European Parliament and of the Council;*

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

When a Group draws up its regional list:

i. *each individual proposal for a project of common interest shall require the approval of the Member States, to whose territory the project relates; if a Member State decides not to give its approval, it shall present its substantiated reasons for doing so to the Group concerned;*

ii. *it shall take into account advice from the Commission that is aimed at having a manageable total number of projects of common interest.*

3.2 CONFIGURATIONS/VISIONS TREATMENT

The ENTSOs CBAs contain a number of different cases to be calculated for each candidate project. In particular, ENTSO-E provides 4 "visions" for 2030 while ENTSO-G provides 52 "configurations". These configurations/visions cannot be considered as forecasting exercises. They are presented as potential "states of the world" and not as predictions and this may explain why the ENTSOs have not assigned probabilities or weights. Characteristically, ENTSO-G's CBA methodology [4] does not include any of the words "forecast", "foresight" or "prediction."

3.2.1 ELECTRICITY "VISIONS"

The four visions in ENTSO-E TYNDP 2014 differ mainly with respect to [1]:

- The trajectory toward the Energy roadmap 2050: Visions 3 and 4 maintain a regular pace from now until 2050, whereas Visions 1 and 2 assume a slower start then acceleration after 2030. Fuel and CO2 prices favour coal in Visions 1 and 2 and gas in Visions 3 and 4.
- The consistency of the generation mix development strategy: Visions 1 and 3 build from the bottom-up on each country's energy policy; Visions 2 and 4 assume a top-down approach, with a more harmonised European integration.

As for Visions 1 and 2, the TYNDP 2014 text indicates that very similar load profiles and generation mixes are assumed throughout the Union, esp. as regards coal and gas plants (and the connected relative prices) and planned nuclear phase-outs and installations in the various countries. The difference between the two Visions (parallel to the one between Visions 3 and 4) essentially lies in the higher degree of EU policy integration, determining a higher level of interconnection which is reflected in the better price alignment across Member States.

3.2.2 GAS "CONFIGURATIONS"

For gas projects, ENTSO-G's CBA contains 52 configurations which are total combinations of the following different scenarios and cases:

- Global context (2)
  - "Green" high CO_2 emissions prices combined with a continuous reduction in the oil-price linkage mitigating the increase of gas price with higher electricity demand and low carbon heating solutions vis-à-vis the alternative scenario ("grey"). This scenario is equivalent to ENTSOE's Vision 3 (green transition).
  - "Grey" low CO_2 emissions prices and high energy prices with lower electricity demand and higher carbon heating solutions than in the alternative scenario ("green"). This scenario is equivalent to ENTSOE's Vision 1 (slow progress).
- Price configurations (13). Two potential price supply scenarios (low and high) are examined individually for the following six supply sources and routes: Algeria (pipe), Azerbaijan (pipe), Libya (pipe), LNG, Norway (pipe) and Russia (pipe). Furthermore, a scenario where all prices are aligned is examined. ENTSO-G will propose a number of configurations that should not be considered for each individual Regional Group (e.g. the differences between the high versus low price for Algerian gas configurations may not be significant for Northern European countries) a significant number will remain.
- Infrastructure scenarios (2). Impact of a project assessed by comparing situation with and without the project for two different levels of infrastructure:
  - Low Infrastructure Scenario (LI): Existing Infrastructures + Infrastructure projects having a FID (Final Investment Decision) status (whatever their PCI status is).
  - High Infrastructure Scenario (HI): Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is) + Infrastructure projects not having a FID status (whatever their PCI status is).

To conduct the necessary computations, for FID projects, ENTSO-G removes the project from the TYNDP analysis in both the low and the high infrastructure scenarios. For non-FID projects the project is added in both cases.

All scenarios are calculated over a 21-year time horizon starting from the year of analysis (n) up to (n+20) at 5-year steps as required by Regulation (EU) No. 347/2013. Therefore, each state of the world is simulated for 2015, 2020, 2025, 2030, and 2035.

3.2.3 SELECTION OF CONFIGURATIONS/VISIONS

As the PCIs are selected on the basis of the benefit for the entire EU, the configurations/visions explored will be those that are more consistent with EU policies and targets (e.g. Europe 2030). On this basis many of the configurations/visions will have a lower significance and some will not be examined.

For electricity projects, Visions 1 and 2 are scenarios of non-compliance to the EU's 2030 environmental policy goals [2]. Therefore, in the current methodology these scenarios are disregarded and the focus is placed on a combination of Visions 3 and 4, i.e. the ones conforming to EU policy targets.

For gas projects, the reference case for assessing the PCI candidate projects will be the usage of the following scenarios as this combination is more in-line with both the EU's 2030 environmental policy goals:

- Global context: the "green" scenario will be considered as this is more in-line with the Europe 2030 targets.
- Price configurations: as this is not a forecasting exercise, the price alignment is the one to be used for the assessment.
- Infrastructure scenarios: given that all projects in the TYNDP will be expected to be implemented, the "high infrastructure" scenario will be used for the assessment. However, the results of both infrastructure configurations will be thoroughly examined and compared.

Although the assessment will be conducted based on the above combination of configurations, the remaining ones will not be ignored but analysed so as to provide insight in those cases where the results are of particular extremities.

3.3 PCI SELECTION CRITERIA

The Regulation defines specific selection criteria for the PCIs. For electricity projects these are:

"…for electricity transmission and storage projects falling under the energy infrastructure categories set out in Annex II.1(a) to (d), the project is to contribute significantly to at least one of the following specific criteria:

> *(i)* ***market integration****, inter alia through lifting the isolation of at least one Member State and reducing energy infrastructure bottlenecks; competition and system flexibility;*
>
> *(ii)* ***sustainability****, inter alia through the integration of renewable energy into the grid and the transmission of renewable generation to major consumption centres and storage sites;*
>
> *(iii)* ***security of supply****, inter alia through interoperability, appropriate connections and secure and reliable system operation;"*

For gas projects the specific criteria are:

".. for gas projects falling under the energy infrastructure categories set out in Annex II.2, the project is to contribute significantly to at least one of the following specific criteria:

> *(i)* ***market integration,*** *inter alia through lifting the isolation of at least one Member State and reducing energy infrastructure bottlenecks; interoperability and system flexibility;*
>
> ***(ii) security of supply,*** *inter alia through appropriate connections and diversification of supply sources, supplying counterparts and routes;*
>
> ***(iii) competition,*** *inter alia through diversification of supply sources, supplying counterparts and routes;*
>
> ***(iv) sustainability,*** *inter alia through reducing emissions, supporting intermittent renewable generation and enhancing deployment of renewable gas;"*

More details regarding the calculation of the criteria for both electricity and gas candidate projects are available in Annex IV of Regulation (EU) No. 347/2014.

3.4 COMPOSITE INDICATORS CONSTRUCTION

The next step is to use the indicators provided by ENTSO-E and ENTSO-G's CBAs and construct relevant composite indicators for the decision making process. These composite indicators can be calculated at different levels of aggregation. DG JRC considers three alternatives:

1. For each indicator, as specified in 3.4.1 and 3.4.2, grouping projects by performance.
2. Calculating composite indicators and then grouping projects by performance.
3. Directly calculating a single composite indicator for each project.

The first strategy is conceptually straightforward but does not effectively reduce the dimensionality of the candidate PCI task. Therefore, applying this strategy would provide only marginal benefits to the Regional Groups and the general PCI process.

The second methodology relies directly on Regulation (EU) No. 347/2013, which defines specific criteria for PCIs (3 for electricity and 4 for gas). Thus, combining the indicators from the ENTSOs CBAs under the criteria of the Regulation would be of particular use for the Regional Groups. Furthermore, this strategy would reduce the quantity of data that needs to be assessed while retaining the relevant information.

The third approach would involve directly calculating a single numerical value for each individual project, thus providing a single ranking.

Taking into consideration the above, DG JRC promotes a two-step approach by combining the 2^{nd} and 3^{rd} alternative above. The indicators resulting from the CBAs will be combined into composite indicators, namely one composite indicator for each benefit criterion of the Regulation (3 for electricity and 4 for gas projects). In particular, the economic performance indicators will have a significant role in this process.

A composite indicator will also be constructed for the costs of each project. The composite indicators for benefits will be used in conjunction with the composite indicator for costs when assessing and comparing the projects. In this manner, projects of different sizes (different levels of benefits and costs) can be compared. Otherwise, if one were to consider only the benefits, there would be an inherit bias for evaluating more positively projects of larger size, but not necessarily of larger benefit. Furthermore, as individual indicators are provided in different units (e.g. MW, euros) normalized composite indicators are necessary for conducting comparisons across projects.

3.4.1 INDICATORS FOR ELECTRICITY PROJECTS

For electricity candidate PCI projects, the outputs of the CBA are:

- A first group of indicators that are independent of the scenarios:
  1. GTC direction 1 (MW) (Grid Transfer Capability): it reflects the ability of the grid to transfer electricity between bidding areas.
  2. GTC direction 2 (MW): the same but in the opposite direction.
  3. Resilience: B6 (Ordinal values)
  4. Flexibility: B7 (Ordinal values)
  5. Environmental Impact: S1. Range in kms
  6. Social impact: S2. Range in kms
  7. C1: Cost
- A second group of indicators are Vision-dependent. Uncertainties are attached to these values, so that assessed KPIs are presented in ranges.
  1. Security of Supply (SoS): B1 (MWh/year)
  2. Socio Economic Welfare (SEW): B2 (MEuros/year)
  3. RES integration: B3 (MWh or MW)
  4. Losses: B4 (MWh).
  5. CO_2 emissions: B5 (kT/year).

For developing composite indicators, the following elements have been considered:

- Cost, environmental impact and social impact (C1, S1 and S2) are used to compare costs and benefits.
- In the first steps only, KPIs expressed in ranges are transformed into a single value using the average value of the range.

- RES integration (B3). This indicator is expressed in MWh when it measures the reduction of renewable generation curtailment, and alternatively, in MW when referring to the additional amount of RES generation injected in the network. Measurement heterogeneity for this KPI was first tackled by converting all values into a common measurement unit. A very preliminary estimation was performed based on figures 5-9 and 5-10 of the TYNDP 2014. In these figures, the projects are grouped based on the following equivalence:
  - Neutral effect (<100 MW or 50 GWh).
  - 100 – 500 MW or 50 – 300 GWh.
  - > 500 MW or >300 GWh

  This classification provides an equivalence of 0.6-0.5 GWh for each MW. A single equivalence of 0.55 is established. This assumption will be reviewed and possibly modified in future steps of the assessment process.

The first KPI grouping attempt for electricity projects based on the policy criteria of Regulation (EU) No. 347/2013 is showed in Table 1.

SPECIFIC CRITERIA		
Market integration	*Sustainability*	*Security of Supply*
B2: SEW	**B3**: RES integration	**B1:** Improved SoS
	B5: CO2 emissions	**B6**: Technical resilience
	B4: Variation in losses	**B7**: Flexibility

Table 1 KPIs included in each specific criterion for electricity projects.

The GTC indicator will be used for the eligibility check when evaluating the PCI cross-border impact, as indicated in 3.1, using the maximum single direction value of the GTC.

It is important to note that several KPIs for electricity are provided in ranges, and this poses the problem of the adequate treatment of this source of uncertainty. According to ENTSO-E's CBA [5], these ranges originate from planning scenarios within each vision, and also from different simulation algorithms employed in KPI assessment. DG JRC proposes to take the average of the ranges (i.e., sum of extremes divided by two). At a later stage, the robustness of the methodology with regard to the uncertainty associated with the ranges will be explored through appropriate statistical methods.

3.4.2 INDICATORS FOR GAS PROJECTS

The grouping of the benefit indicators from the ENTSO-G's CBA Energy-System Wide step will be based on ENTSO-G's guidelines to the Regional Groups ([5], p.64).These are as follows (criterion : indicators):

1. Security of supply: "N-1", bi-directional, import Rte diversification, Supply Source Price Diversification, Supply Source Dependence, Remaining Flexibility and Disrupted demand.
2. Sustainability: Coal for power generation, CO2 emission from power generation, Commenting and developing on project benefits, Infrastructure Environmental Impact.
3. Competition: import Rte diversification, Supply Source Price Diversification, Supply Source Dependence Price convergence and gas supply.
4. Market integration: bi-directional, import Rte diversification, Supply Source Price Diversification, Remaining Flexibility and Price convergence, gas supply.

3.4.3 ACCOUNTING FOR THE CORRELATION STRUCTURE: MULTIVARIATE ANALYSIS

At first the indicator values need to be normalized, as they are expressed in different units and orders of magnitude. Normalisation is a standard procedure in the construction of composite indicators. This method aims at expressing the data in deviations, so that the variation and correlation structure are preserved, but levels are averaged out. A classic example is z-score normalisation, routinely used to standardise normal distributions (it does not *a priori* privilege any individual indicator). For the purposes of this exercise the data will be first transformed with a logarithmic function (only if needed). This is necessary so as to bring all dimensions on an equal footing, while maintaining the order (rank) of the data. After the logarithmic transformation, a standardisation process will be used (e.g. removing the mean and then dividing by the standard deviation for each value).

The next step is to perform a correlation analysis. In the case where significant (and sensible) correlations among the CBA indicators are identified it will be necessary to take this correlation structure into account while integrating CBA indicators into composite indicators for the specific criteria of Regulation (EU) No. 347/2013. If one were to ignore the correlation structure, one would face the risk of factoring in the same variables multiple times. Preliminary statistical analysis on a subset of the available data for electricity projects from the relevant TYNDP has shown that many indicators have strong correlations.

Principal Component Analysis (henceforth PCA) will be used to factor-in the indicators correlation structure for the construction of the composite indicators.[8] PCA is a common statistical technique that allows identifying a smaller set of uncorrelated variables carrying most of the information (i.e. variation) which is present in the correlated observed variables. It essentially consists in constructing a set of summations of percentage fractions of the observed variables, under the constraints that a) these summations are uncorrelated with each other and b) their variances are maximised. The resulting "combined" variables can be interpreted as the underlying factors driving

[8] For an overview of PCA see chapter 4 in [6].

the movement in the observable data. The procedure provides guidance as to how many underlying factors exist, as well as to the amount of indicator variance that is explained by each one of them. These factors can be then considered as the fundamental factors determining a candidate PCI's score in each of the relevant policy dimensions, and be weighed up to construct the composite indicators. Constructing composite indicators significantly reduces the dimensionality of the data set and enables comparisons. This approach would be common for both electricity and gas PCI candidate projects.

In particular, PCA will be used in order to create the composite indicators for the candidate project benefits, by criterion of Regulation (EU) No. 347/2014 (3 for electricity and 4 for gas projects). Furthermore, a composite indicator for the costs of each project will also be constructed and re-scaled according to the units for the overall benefits composite indicator.

3.5 COMPOSITE INDICATORS AGGREGATION

After the composite indicators per Regulation criterion are calculated, it is possible to proceed to build an overall composite indicator for benefits. This can be done in various ways. Possibly the plainest approach is to take the arithmetic average between the indicators. However, by this method, it is implicitly assumed that high values in one indicator exactly compensate correspondingly low values in other indicators. Another possibility is to aggregate by taking the geometric mean, whereby instead an indicator's high values more than compensate for low values elsewhere.

However, both methods disregard the correlation pattern within composite benefit indicators themselves. In order to account for it, it is instead possible to apply PCA once again. If this approach evidences between-indicator correlation, it is possible to avoid the ensuing risk of double counting by employing the principal component(s) that it generates in the construction of the overall composite indicator. Then, the overall benefit and cost indicators will be considered in conjunction for the assessment of the project proposals, per Regional Group. In other words, the evaluation of the PCI candidate projects of this step in the overall process will rely on these two overall indicators. This statistical approach (PCA) is in-line with Regulation (EU) No. 347/2013 Article 4, where there is no explicit preference for one policy criterion over the other.

Finally, based on the results achieved above, for each Regional Group, the PCI candidate projects will be placed into three groups/clusters.

4 SUMMARY

Projects of Common Interest are of particular importance for Europe's energy system due to the multiple benefits that they (will) provide. In this context, DG JRC is developing an assessment methodology for PCI candidate project proposals.

The development of this methodology poses many challenges due to the uniqueness of the exercise, the heterogeneity of the projects proposed, the large quantity of data and cases calculated etc. Although the general approach will be common for both electricity and gas candidate projects, the particular steps will not be identical as there are differences in both Regulation (EU) No. 347/2 and in the ENTSO-E's and ENTSO-G's CBAs in terms of the criteria that need to be assessed, the indicators calculated, the information requested from project promoters etc.

For both electricity and gas projects, DG JRC proposes an assessment methodology which is based upon the following general steps: consistency and eligibility check, configurations/visions treatment, composite indicators construction, composite indicators aggregation and projects assessment/ranking. The proposed methodology will be presented and discussed with the Regional Groups.

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