ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects

FINAL- Approved by the European Commission

5 February 2015

Notice
This document reflects the work done by ENTSO-E in compliance with Regulation (EC) 347/2013. This document takes into account the comments received by ENTSO-E during the public consultation of the “Guideline for Cost Benefit Analysis of Grid Development Projects – Update 12 June 2013,”, organised between 03 July and 15 September 2013 in an open and transparent manner, in compliance with Article 11 of Regulation (EC) 347/2013. It includes the outcome of an extensive consultation process through bilateral meetings with stakeholder organization, continuous interactions with a Long Term Network Development Stakeholder Group, several public workshops and direct interactions with ACER, the European Commission and Member States held between January 2012 and September 2013. Furthermore; the document contains amendments and changes contained in the relevant Opinion of ACER, submitted on 30 January 2014, and of the Commission, submitted on 25 July 2014, pursuant to Article 11 of Regulation (EU) 347/2013. This document is now called “ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects” and is submitted to the European Commission for approval pursuant to Article 11 of Regulation (EU) 347/2013.

Contents

1 Introduction and scope ... 4

1.1 Transmission system planning ... 4

1.2 Scope of the document ... 5

1.3 Content of the document ... 6

2 Scenarios and planning cases ... 9

2.1 Scope of scenarios ... 9

2.2 Content of scenarios ... 9

2.2.1 Time horizons. ... 10

2.2.2 Bottom-up and Top-down approach ... 11

2.2.3 Reference and sensitivity scenarios ... 12

2.3 Technical and economic key parameters ... 13

2.3.1 Economic key parameters ... 13

2.3.2 Technical key parameters ... 13

2.3.3 Scenarios for generation ... 14

2.3.4 Scenarios for demand ... 15

2.3.5 Exchange patterns ... 15

2.4 From scenarios to planning cases ... 16

2.4.1 Market and Network studies ... 16

2.4.2 Selection of planning cases ... 17

2.4.3 Scope of planning cases ... 18

2.4.4 Content of a planning case ... 18

2.5 Multi-case analysis ... 19

3 Project assessment: combined cost benefit and multi-criteria analysis ... 21

3.1 Project identification ... 21

3.2 Clustering of Projects ... 22

3.3 Assessment framework ... 24

3.4 Grid Transfer Capability calculation ... 29

3.5 Cost and environmental liability assessment ... 29

3.6 Boundary conditions and main parameters of benefit assessment ... 30

3.6.1 Geographical scope ... 30

3.6.2 Time frame ... 31

3.6.3 Discount rate ... 31

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

3.6.4 Benefit analysis 32
3.7 Methodology for each benefit indicator 33
3.7.1 B1. Security of supply 33
3.7.2 B2. Socio-economic welfare 36
3.7.3 B3. RES integration 40
3.7.4 B4. Variation in losses (Energy efficiency) 41
3.7.5 B5. Variation in CO2 emissions 42
3.7.6 B6. Technical resilience/system safety margin 43
3.7.7 B7. Robustness/flexibility 45
3.8 Overall assessment and sensitivity analysis 47
3.8.1 Overall assessment 47
3.8.2 Sensitivity analysis 47
4 Technical criteria for planning 49
4.1 Definitions 49
4.2 Common criteria 50
4.2.1 Studies to be performed 50
4.2.2 Criteria for assessing consequences 51
4.2.3 Best practice 52
5 Annex 1: Impact on market power 54
6 Annex 2: Multi-criteria analysis vs cost benefit analysis 56
7 Annex 3: Total surplus analysis 57
8 Annex 4: Value of lost load 60
9 Annex 5: Assessment of ancillary services 62
10 Annex 6: Assessment of storage 64
11 Annex 7: Environmental and social impact 67

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

1 INTRODUCTION AND SCOPE

1.1 TRANSMISSION SYSTEM PLANNING

The move to a more diverse power generation portfolio due to the rapid development of renewable energy sources (RES) and the liberalisation of the European electricity market has resulted in more and more interdependent power flows across Europe, with large and correlated variations. Therefore, transmission system design must look beyond traditional (often national) TSO boundaries, and move towards regional and European solutions. Close co-operation of ENTSO-E member companies responsible for the future development of the European transmission system is required to achieve coherent and coordinated planning that is necessary for such solutions to materialize.

The main objective of transmission system planning is to ensure the development of an adequate European wide transmission system which, with respect to mid and long term time horizons:

- Enables safe grid operation;
- Enables a high level of security of supply;
- Contributes to a sustainable energy supply;
- Facilitates grid access to all market participants;
- Contributes to internal market integration, facilitates competition, and harmonisation;
- Contributes to energy efficiency of the system.
- Enables cross-country transmissions

In this process certain key rules have to be kept in mind, in particular:

- Requirements and general regulations of the liberalised European power and electricity market set by relevant EU legislation;
- EU policies and targets;
- National legislation and regulatory framework;
- Security of people and infrastructure;
- Environmental policies and constraints;
- Transparency in procedures applied;
- Economic efficiency.

The planning criteria to which transmission systems are designed are generally specified in transmission planning documents. Such criteria have been developed for application by individual TSOs taking into account the above mentioned factors, as well as specific conditions of the network to which they relate. Within the framework of the pan-European Ten Year Network Development Plan (TYNDP), ENTSO-E has developed common Guidelines for Grid Development (Annex 3 of TYNDP 2012). Thus, suitable methodologies have been adopted for future development projects and common assessments have been developed.

Furthermore, the EU Regulation 347/2013 requests ENTSO-E to establish a “methodology, including on network and market modelling, for a harmonised energy system-wide cost-benefit analysis at Union-wide level for projects of common interest” (Art. 11).

This document constitutes an update of ENTSO-E's Guidelines for Grid Development, aiming at compliance with the requirements of the EU Regulation, and ensuring a common framework for multi-criteria cost benefit analysis for candidate projects of common interest (PCI) and other projects falling within the scope below (TYNDP projects). In this regard all projects (whatever their promoter, TSO or third party, and storage projects as well as transmission ones) are treated and assessed in the same way.

Scope of the document

This document describes the common principles and procedures, including network and market modelling methodologies (see section 2.4.1), to be used when performing combined multi-criteria and cost benefit analysis in view of elaborating Regional Investment Plans and the Community-wide Ten Year Network Development Plan (TYNDP), as ratified by EU Regulation 714/2009 of the 3rd Legislative Package. Following the EU Regulation on guidelines for trans-European energy infrastructure (347/2013), it will also serve as a basis for a harmonised assessment at Union Level for Projects of Common Interest (PCI).

Typically, three categories of development transmission projects can be distinguished:

Those that only affect transfer capabilities between individual TSOs or price zones. These projects will be evaluated according to the criteria in this document.

Those that affect both transfer capabilities between TSOs or price zones and the internal capability of one or more TSOs' network. These projects will meet the criteria of this document and of the affected TSOs' internal standards.

Those that only affect an internal national network and do not influence interconnection capability. These do not fall within the scope of this guideline and are developed according to the TSO's internal standard.

When planning the future power system, new transmission assets are one of a possible number of system solutions. Other possible solutions include storage, generation, and demand side management. The scope of this methodology is planning future transmission system. However, the regulation also requires ENTSO-E to consider storage in its cost benefit methodology. The principles of assessing storage projects using this methodology are therefore described in Annex 6: Assessment of storage. Basically, this appendix explains the reason why the propose to assess storage projects exactly in the same way as transmission ones.

This CBA guideline sets out ENTSO-E criteria for the assessment of costs and benefits of a transmission (or storage) project, all of which stem from European policies on market integration, security of supply and sustainability. It describes the approaches for identifying candidate transmission projects and for calculating the cost and benefit indicators. In order to ensure a full assessment of all transmission benefits, some of the indicators are monetized (inner ring of Figure 1), while others are quantified in their original physical units, such as tons or kWh (outer ring of Figure 1).

This set of common European-wide indicators will form a complete and solid basis, both for project assessment within the TYNDP, and coherent project portfolio development for the PCI selection process[1].

Figure 1: Scope of cost benefit analysis (source: THINK project)

Content of the document

The CBA methodology is developed to evaluate all TYNDP projects against their value for the European society, providing important input for the selection process of Projects of Common Interest (PCI). However, since the CBA methodology is not developed with the objective of detailed allocation of costs and benefits between countries in mind, this CBA methodology can't be used as a straight-out-of-the-box solution for applying CBCA. Complementary guidelines are needed in this perspective to complete the information that is required for decision-making on the allocation of costs under a CBCA mechanism.

[1] It should be noted that he TYNDP will not contain any ranking of projects. Indeed, as stated by the EU Regulation 347/2013 (art4.2.4), « each Group shall determine its assessment method on the basis of the aggregated contribution to the criteria […] this assessment shall lead to a ranking of projects for internal use of the Group. Neither the regional list nor the Union list shall contain any ranking, nor shall the ranking be used for any subsequent purpose »

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Transmission system development focuses on the long-term preparation and scheduling of reinforcements and extensions to the existing transmission grid. This document describes each phase of the development planning process as well as the planning criteria and methodology adopted by ENTSO-E.

The first phase of the planning process consists of the definition of scenarios, which represent a coherent, comprehensive and internally consistent description of a plausible future. The aim of scenario analysis is to depict uncertainties on future system developments on both the production and demand sides. In order to incorporate these uncertainties in the planning process, a number of planning cases are built, taking into account forecasted future demand level and location, dispatch and location of generating units, power exchange patterns, as well as planned transmission assets. This phase is detailed in Chapter 2 - Scenarios and planning cases.

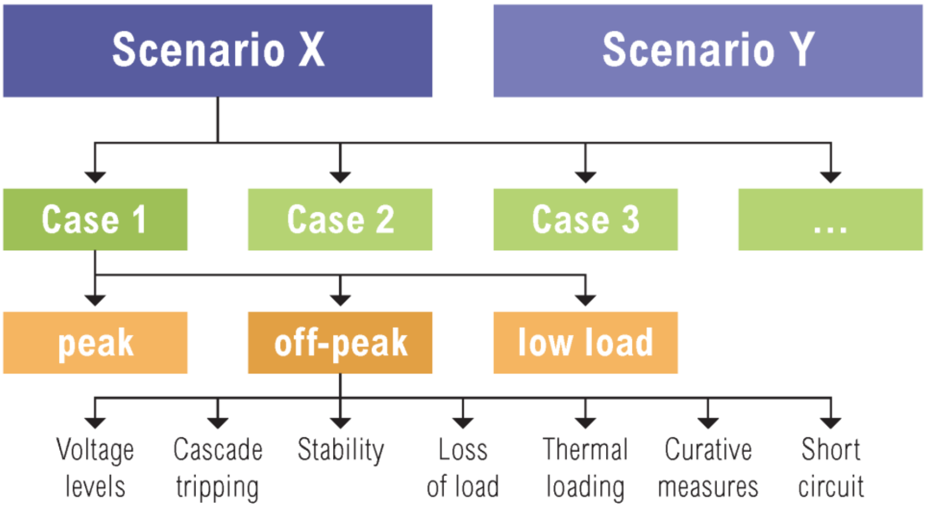


Figure 2: Scenarios and planning cases

Chapter 3 describes the multi-criteria cost-benefit analysis framework adopted for project assessment, complying with the Regulation (EU) n.347/2013.

The cost benefit impact assessment criteria adopted in this document reflect each transmission (or storage) project's added value for society. Hence, economic and social viability are displayed in terms of increased capacity for trading of energy and balancing services between bidding areas (market integration), sustainability (RES integration, CO2 variation) and security of supply (secure system operation). The indicators also reflect the effects of the project in terms of costs and environmental viability. They are calculated through an iteration of market and network studies. It should be noted that some benefits are partly or fully internalised within other benefits, such as avoided CO2 and RES

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

integration via socio-economic welfare, while others remain completely non-monetised, such as security of supply[2].

"*Network stress tests*" are performed on each planning case and follow specific technical planning criteria developed by ENTSO-E on the basis of long term engineering practice (see Figures 2 and 3). The criteria cover both the kind of contingencies[3]chosen as "proxies" for hundreds of other events that could happen to the grid, as well as the adequacy criteria that are relevant for assessing the overall behaviour of the transmission system. The behaviour of the system when simulating the contingencies provides an indication of its "health" and robustness. A power system that fails one of these tests is considered "unhealthy" and steps must be taken so that the system will respond successfully under the tested conditions. Several planning cases are thus assessed in order to identify how robust the various reinforcements are. This process is developed in Chapter 4.

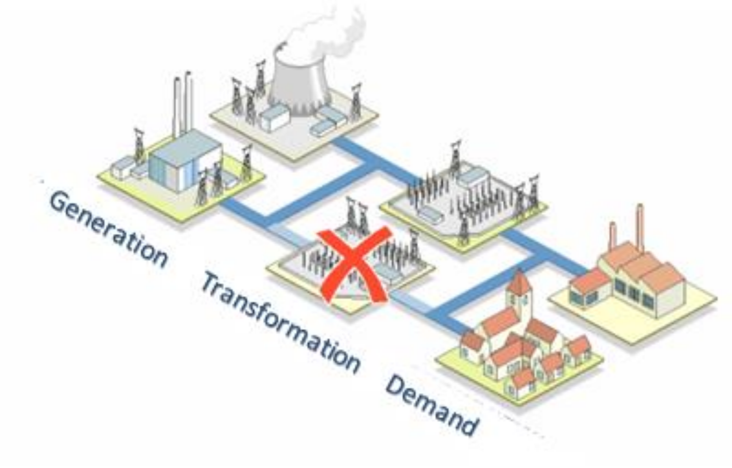


Figure 3: N-1 principle

This is a continuously evolving process, so this document will be reviewed periodically, in line with prudent planning practice and further editions of the TYNDP or upon request (as foreseen by Article 11 of the EU Regulation 347/2013).

[2] Annex 4 provides an overview of issues around monetisation of security of supply and Values of Lost Load (VOLL) available in Europe
[3] A contingency is defined like the loss of one or several elements of transmission grid

2 SCENARIOS AND PLANNING CASES

Planning scenarios are defined to represent future developments of the energy system. The essence of scenario analysis is to come up with plausible pictures of the future. Scenarios are means to approach the uncertainties and the interaction between these uncertainties. Planning scenarios are representation of how the generation-Transmission system could be manged one year along. Planning cases are point in time (snapshots) along these scenarios allowing to represent in full detail the grid situations at these moments..

Multi-criteria cost benefit analysis of candidate projects of European interest is based on ENTSO-E's System Outlook and Adequacy Forecast (SO&AF), which aim to provide stakeholders in the European electricity market with an overview of generation, demand and their adequacy in different scenarios for the future ENTSO-E power system, with a focus on the power balance, margins, energy indicators and the generation mix. The scenarios are elaborated after formally consulting Member States and the organisations representing all relevant stakeholders.

2.1 SCOPE OF SCENARIOS

Scenarios shall at least represent the Union's electricity system level and be adapted in more detail at a regional level. They shall reflect European Union and national legislations in force at the date of analysis.

2.2 CONTENT OF SCENARIOS

Planning scenarios are a coherent, comprehensive and internally consistent description of a plausible future (in general composed of several **time horizons**) built on the imagined interaction of **economic key parameters** (including economic growth, fuel prices, CO2 prices, etc.). A planning scenario is characterized by a **generation portfolio** (power installation forecast, type of generation, etc.), a **demand forecast** (impact of efficiency measures, rate of growth, shape of demand curve, etc.), and **exchange patterns** with the systems outside the studied region. A scenario may be based on trends and/or local specificities (bottom-up scenarios) or energy policy targets and/or global optimisation (top-down scenarios).

As it can take more than 10 years to build new transmission infrastructure, the objective is to construct scenarios that look beyond the coming 10 years. However, when looking so far ahead, it becomes increasingly difficult to define what a 'plausible' scenario entails. Therefore, as illustrated in Figure 5 coming from TYNDP 2014, the objective of the scenarios is to construct contrasting future developments that differ enough from each other to capture a realistic range of possible future pathways that result in different challenges for the grid.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

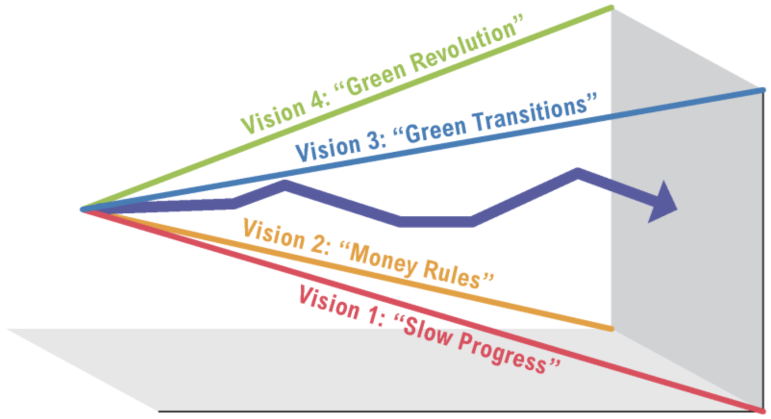


Figure 5: ENTSO-E visions

2.2.1 TIME HORIZONS.

The scenarios will be representative of at least two time horizons based on the following:

- Long-term horizon (typically 10 to 20 years). Long-term analyses will be systematically assessed and should be based on common ENTSO-E scenarios.
- Mid-term horizon (typically 5 to 10 years). Mid-term analyses should be based on a forecast for this time horizon. ENTSO-E's Regional groups and project promoters will have to consider whether a new analysis has to be made or analysis from last TYNDP (i.e former long term analysis) can be re-used.
- Very long-term horizon (typically 30 to 40 years). Analysis or qualitative considerations could be based on the ENTSO-E 2050-reports.
- Horizons which are not covered by separate data sets will be described through interpolation techniques.

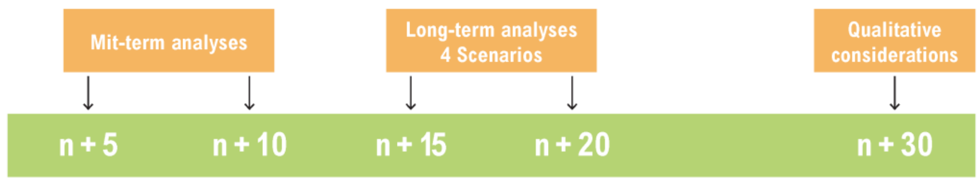


Figure 6: Time Horizons

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

As shown in Figure 6, the scenarios developed in a long-term perspective may be used as a bridge between mid-term horizon and very long term horizons (+30 or 40). The aim of the n+20 perspective should be that the pathway realized in the future falls within the range described by the scenarios with a high level of certainty.

2.2.2 BOTTOM-UP AND TOP-DOWN APPROACH

Until the preparation of the TYNDP 2010, the classic way of constructing generation and load scenarios within ENTSO-E (for the identification of grid development needs) was mainly based on a bottom-up approach. Load and generation prognoses were collected from each TSO and mathematically summarized. Hence, the basis of the analysis was more or less national.

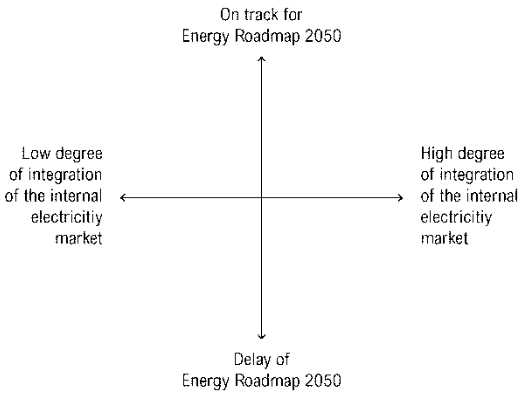
A new methodology was introduced by ENTSO-E in the TYNDP 2012. An EU 2020 scenario was constructed using a top-down approach, in which the load and generation evolution was constructed for all countries in a way that was compliant and coherent with the same macro-economic and political view of the future. For the EU 2020 scenario this meant that the forecasted load and generation assumptions had to be coherent with the EU 3x20 targets. Therefore, the load and RES generation in the EU 2020 scenario was derived from the NREAPs for EU countries. The top-down approach thus uses a common European basis.

Summarized, the scenarios used in cost-benefit analyses could be both top-down and bottom-up. One top-down scenario should be defined as the reference scenario. This scenario should be the one that best reflects the official European energy politics and goals. Thus, except when explicitly indicated, all key parameters listed below will be coherent at a European level with the economic background provided by the reference scenario.

'Zoom ENTSO-E: 2030 Visions for TYNDP 2014

For the TYNDP 2014, the scenarios are developed around 4 Visions described along two axes: integration of renewables and market integration.

The first axis (Y-axis) is related to the EU commitment to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050, according to the **European Energy roadmap 2050**. The objective is not to question this commitment but to check the impact of a delay in the realization of this commitment on grid development needs by 2030. The two selected outcomes are viewed to be extreme enough to result in very different flow patterns on the grid. The first selected outcome is a state where Europe is **on track** to realize the set objective of energy decarbonisation by 2050. The second selected outcome is a state where Europe faces a **serious delay** in the realization of the energy 2020 goals and likely delays on the route to decarbonisation by 2050.



The second axis (X-axis) relates to the degree of **European market integration**. This can be done in a **strong European framework or a context of a high degree of European integration** in which national policies will be more effective, but not preventing Member States developing the options which are most appropriate to their circumstances, or in a **loose European framework or a context of a low degree of European integration** that lack a common European scenario for the future energy system that results in parallel national schemes. The strong European framework should also include a well-functioning and integrated electricity market, where competition ensures efficient dispatch at the lowest possible costs on a European level. On the other hand, a loose European framework results in less market integration and poor cross-border competition.

2.2.3 Reference and sensitivity scenarios

European wide reference scenarios analysis will serve as basis for the project assessment at regional level. There will always be a compromise between robustness (driver for analysing a large number of scenarios) and workload (driver for reducing the number of scenarios analysed). The number of scenarios that is used should be large enough for transmission planners to get a complete picture of the effects that a project may have under different possible future conditions. However, it is also important that the calculations under each scenario are performed in a sufficiently detailed and accurate manner. This is a trade-off that must be made in each iteration of the TYNDP, but nonetheless we expect that, over time, experience and increasing computing power will allow the Regional Groups to continuously improve the robustness of the analysis without sacrificing quality.

The contents of the scenarios – and consequently the values used for the calculations - are updated in every iteration of the TYNDP process. The methodology does not specify or recommend how these values should be chosen.

Reference scenarios

Primary analyses should be based on common ENTSO-E scenarios, which are developed during the TYNDP process. ENTSO-E shall state the order in which the scenarios have to be analysed.
At least two scenarios should be analysed, for instance in order to take into account regional differences or to ensure robustness to different evolutions of the system.

Sensitivity scenarios

Secondary and optional analyses could be done on the other long-term scenarios. If these scenarios are not fully analysed, their effect on the different projects should be qualitatively considered. The other scenarios used for sensitivity analysis can be top-down scenarios or bottom-up.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

2.3 TECHNICAL AND ECONOMIC KEY PARAMETERS

2.3.1 ECONOMIC KEY PARAMETERS

Fuel costs will be based on reference values established by international institutes such as the IEA, if possible at the study horizon taken into account. The economic key parameters include, but are not limited to, the following list:

Economic parameter	**Level of coherence**
Economic growth	European
Coal cost	
Oil cost	
Gas cost	
Lignite cost	
Nuclear cost	
CO2 cost	
Biomass cost	

2.3.2 TECHNICAL KEY PARAMETERS

Technical key parameters include, but are not limited to, the following list:

Technical parameter	**Level of coherence**
Efficiency rate	New plants : European Old plants : National
Availability	European
CO_2 emission rate	European
SO_2 emission rate	European
NO_x emission rate	European

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Reserve power	European
Must-run units	European
Share of non dispatchable generation	European
Inter-temporal parameters of machines (such as minimum up- and down-time, ramping and start-up costs)	European

2.3.3 Scenarios for generation

Scenarios for generation will include generation capacities (assumptions on existing and new capacities as well as decommissioning), efficiency rate, flexiblity, must-run obligations and location (bidding area) of at least the following generation types:

Generation capacity	**Level of coherence**
Biomass	European
Coal	
Gas	
Oil	
Lignite	
Nuclear	
Wind	
Photovoltaic	
Geothermal	
Concentrated solar	
Marine energies	
CHP	
Hydro	

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Storage	
Capacity equipped for capturing carbon dioxide	

2.3.4 Scenarios for demand

Scenarios for demand will take into account at least the following items (for each bidding area):

Demand factors	**Level of coherence**
Economic growth	European
Evolution of demand per sector	
Load management	
Sensitivity to temperature	
Fuel shift	
Evolution of climate-related extreme weather events	
Evolution of population	National

2.3.5 Exchange patterns[4]

Exchange patterns outside the modelled area will be taken into account in the following way:

Exhange pattern	**Level of coherence**
Fixed flows between the region and the outside countries	European

[4] All off shore wind farm generation is allocated to a Member state, and hence, flows between countries are not variable depending on allocations of off shore wind farms.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

2.4 FROM SCENARIOS TO PLANNING CASES

The identification of the grid development needs related to a particular scenario is a complex resource and time-consuming process. The output of market studies(generation dispatch, power and energy balances, periods of constraint on interconnections) is used as an input for network studies to choose the most representative planning cases (points in time) to be studied. The results are compared and the transmission adequacy is further measured allowing the iterative process of identifying the required reinforcement projects for supporting the bulk flow patterns identified in the market study.

Thus, this is not a unidirectional process, but an iterative process with several feedback loops that could change assumptions (such as reserve, flexibility and sustainability of generation). Hence, it is important to keep the number of scenarios and cases that are fully calculated, and therefore need to be quantified, limited, and to assess the impact of possible different pathways through sensitivity analysis.

The use of these scenarios for long-term grid development will lead to the identification of new flexible infrastructure development needs that are able to cope with a range of possible future energy challenges outlined in the scenarios.

2.4.1 MARKET AND NETWORK STUDIES

ENTSO-E distinguishes between market studies and network studies. Market studies are used to calculate the dispatch of generation units and load all along the year on an hourly basis, using a very simplified model of the physical grid. They represent bidding areas through a network of interconnected nodes using a single branch to represent the physical interconnections that exist between each pair of bidding areas. The nodes do not have any internal grid constraints (each is assumed to be a copper plate). All branches possess a GTC value which represents the aggregated capacity of the physical infrastructure connecting these nodes in reality[5]. Network studies, on the other hand, contain the full detail of the physical grid and are used to calculate the actual load flows that take place in the network under given generation/load conditions. Network studies are in particular necessary to compute the GTCs used in market studies.

Market studies have the advantage of clearly highlighting the structural, rather than incidental, bottlenecks. They take into account several constraints such as flexibility and availability of thermal units, hydro conditions, wind and solar profiles, load profile and uncertainties. They also allow to measure the economy in generation costs allowed by investments in the grid (or in storage).

Network models have the advantage of representing the precise network flows that would be created by the dispatch and load patterns obtained through the market models. Calculations using network models

[5] GTC is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called "critical" domestic components (see 3.3). The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

are required to adequately represent GTC values in market models. Both types of models thus provide different information and –as they complement one another– are often used in an iterative manner.

2.4.2 SELECTION OF PLANNING CASES

Planning cases used in network studies[6] are selected inter alia based on the following considerations:

- outputs from market studies, such as system dispatch, frequency and magnitude of constraints;
- regional considerations, such as wind and solar profiles or cold/heat spell;
- (whether available) results of pan-European power transfer distribution factor (PTDF[7]) analysis.

Network studies have the advantage of representing the actual network flows, thus showing effects such as internal grid congestion and loop flows. They contribute to grid transfer capability (GTC) assessments and can show what increase is enabled by transmission projects. This output of the network studies can be retrofitted in market studies to assess the improvements brought by the expanded grid.

Market studies and network studies thus complement each other. They are articulated in a two-step, iterative process in order to ensure consistency and efficiency (every concern being properly addressed with the appropriate modelling).

[6] Ideally, all 8760 hours of the year should be assessed in a load flow. However, no tool is able to perform this in an efficient way on a wide perimeter today.
[7] The PTDF analysis show the linear impact of a power transfer. It represents the relative change in the power flow on a particular line due to an injection and withdrawal of power.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

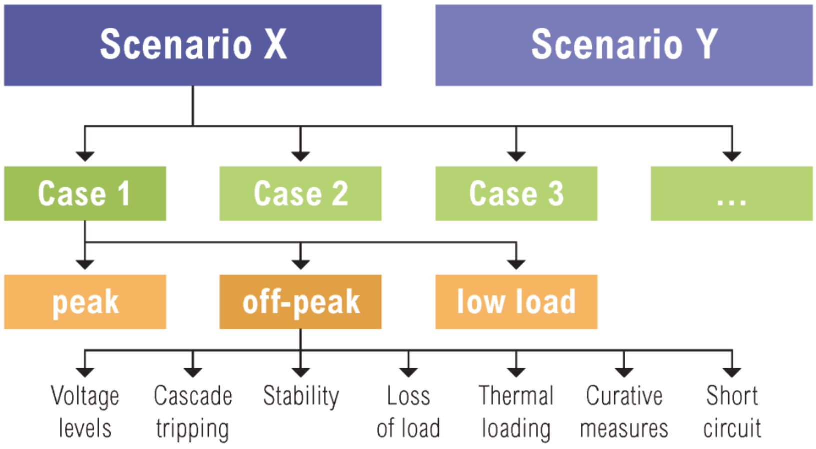


Figure 7: Scenarios and planning cases

2.4.3 Scope of planning cases

Each selected scenario is assessed by analysing the cases that represent it (see Fig. 7). These cases are defined by the TSOs involved in each study, taking into account regional and national particularities.

The following are the more important issues that have to be taken into account when building detailed cases for planning studies:

- Demand, generation and power exchange forecasts in different time horizons, and specific sets of network facilities are to be considered.
- Demand and generation fluctuate during the day and throughout the year.
- Weather is a factor that not only influences demand and (increasingly) generation, but also the technical capabilities of the transmission grid.

2.4.4 Content of a planning case

A planning case represents a particular situation that may occur within the framework specified by a scenario, featuring:

- One specific point-in-time (e.g. winter / summer, peak hours / low demand conditions, year), with its corresponding demand and environmental conditions;
- A particular realisation of random phenomena, generally linked to climatic conditions (such as wind conditions, hydro inflows, temperature, etc.) or availability of plants (forced and planned);

- The corresponding dispatch (coming from a market simulator or a merit order) of all generating units (and international flows);
- Detailed location of generation and demand;
- Power exchange forecasts with regions neighbouring the studied region;
- Assumption on grid development.

When building representative planning cases, the following issues should be considered taking into account the results from market analysis:

- Estimated main power exchanges with external systems.
- Seasonal variation (e.g. winter/summer).
- Demand variation (e.g. peak/valley).
- Weather variation (e.g. wind, temperature, precipitations, sun, tides).

All transmission assets that are included in existing mid-term plans[8] will be dealt with in the corresponding case taking into account the forecasted commissioning and decommissioning dates.
The uncertainty in the commissioning date of some future assets could nevertheless require a conservative approach when building the planning cases, taking into account:

- State of permitting procedure (permits already obtained and permits that are pending).
- Existence of local objection to the construction of the infrastructure.
- Manufacturing and construction deadlines.

A case without one or some reinforcements foreseen, as well as cases including less conservative approaches, could be analysed.

To check the actual role of a grid element, and thus compare different strategies (e.g. refurbishment of the asset vs. dismantling and building a new asset), it may be considered as absent in the planning case.

2.5 MULTI-CASE ANALYSIS

System planning studies are often based on deterministic analysis, in which several representative planning cases are taken into account. Additionally, studies based on a probabilistic approach may be carried out. This approach aims to assess the likelihood of risks of grid operation throughout the year and to determine the uncertainties that characterise it. The objective is to cover many transmission system states throughout the year taking into account many cases. Thus it is possible to:

- Detect '*critical system states*' that are not detected by other means.
- Estimate the probability of occurrence of each case that is assessed, facilitating the priority evaluation of the needed new assets.

[8] All new projects for which a final investment decision has been taken and that are due to be commissioned by the end of year n+5 (see Annex V, point 1a of EU Regulation 347/2013.)

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

The basic idea of probabilistic methods is based on creating multiple cases depending on the variation of certain variables (that are uncertain). Many uncertainties can lead to building multiple cases: demand, generation availability, renewable production, exchange patterns, availability of network components, etc. The general method consists of the following steps:

1. Definition of variables to be considered (for example: demand).

2. Definition of values to be considered for each of the variables and estimation of the probability of occurrence. In case a variable with many possible values is considered (for example: network unavailability), the amount of different possible combinations could justify the use of a random approach method.

3. Building the required planning cases. The number of cases depends on the number of variables and the number of different values for each of these.

4. Each case is analysed separately.

5. Assessment of the results. Depending on the amount of cases, a probabilistic approach could be needed to assess the results. A priority list of actions could result from this assessment.

If the variables used to build multiple cases are estimated in a pure probabilistic way, a statistical tool is needed for the assessment. In this case, besides helping to make a priority list of the actions needed in a development plan and identifying critical cases not known to be critical in advance, the probabilistic approach allows forecasting the Expected Energy Not Supplied (EENS) and Loss of Load Expectation (LOLE) and congestion costs. The probabilistic assessment of other variables, like short-circuit current, could also be very useful for planning decisions.

3 PROJECT ASSESSMENT: COMBINED COST BENEFIT AND MULTI-CRITERIA ANALYSIS

The goal of project assessment is to characterise the impact of transmission projects, both in terms of added value for society (increase of capacity for trading of energy and balancing services between bidding areas, RES integration, increased security of supply, …) as well as in terms of costs.

ENTSO-E has the role to define a robust and consistent methodology. Thus ENTSO-E has defined this multi-criteria CBA, which compares the contribution of a project to the different indicators on a consistent basis. A robust assessment of transmission projects, especially in a meshed system, is a very complex matter. Additional lines give more transmission capacity to the market and hence allow an optimization of the generation portfolio, which leads to an increase of Social-Economic Welfare[9] over Europe. Further benefits such as Security of Supply or improvements of the flexibility also have to be taken into due account. These technical aspects are hardly monetisable.
The multi-criteria approach shows the characteristics of a project and gives sufficient information to the decision makers. A fully monetized approach would entail one single monetary value, but because all results of the CBA are very dependent on the scenarios and horizons, this would lead to a perceived exactness that does not exist.
Furthermore this is the reason, why the costs are not compared with the monetised benefits, but are instead given as information.

The present chapter establishes an operative methodology for the identification of projects and (if applicable) project clusters, and consequent project or cluster assessment.
A project is defined as the smallest set of assets that effectively add capacity to the transmission infrastructure that can be used to transmit electric power, such as a transformer + overhead line + transformer.

A cluster is defined as a set of (a) a main project that is built to increase GTC across a certain boundary by a certain amount, and (b) one or more supporting projects that must be realized together with the main project in order to make it possible for the main project to realize its intended GTC increase.

3.1 PROJECT IDENTIFICATION

If transmission weaknesses are identified and the standards described in chapter 4 are not met, then reinforcement of the grid is planned. These measures can include, but are not limited to, the following:

[9] Socio-economic welfare (SEW) is characterised by the ability of a power system to reduce congestion and thus provide an adequate GTC so that electricity markets can trade power in an economically efficient manner (see also p. 22)

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

- Reinforcement of overhead circuits to increase their capacity (e.g. increased distance to ground, replacement of circuits).
- Duplication of cables to increase rating.
- Replacement of network equipment or reinforcement of substations (e.g. based on short-circuit rating).
- Extension and construction of substations.
- Installation of reactive-power compensation equipment (e.g. capacitor banks).
- Addition of network equipment to control the active power flow (e.g. phase shifter, series compensation devices).
- Additional transformer capacities.
- Construction of new circuits (overhead lines and cables), DC or AC.

For the avoidance of doubt, the following varieties of solution to transmission weaknesses are not expected to be appraised by these Guidelines – i.e. they are out-of-scope:

- Relocation of Generation: the location of generation, as set out in planning cases, is a given[10]
- Assumption of new demand-side services and electricity storage devices: demand-side services and storage are not considered as solutions to transmission weaknesses, since existing and future volume of these means of flexibility are modelled within background scenarios consulted upon with stakeholders.
- Generator Inter-trips: in this context, the treatment of system-to-generator inter-trips is ambivalent. On the one hand, system-to-generator inter-trips are recommended to mitigate emergency situations like out-of-range contingencies[11]. On the other hand, system-to-generator inter-trips are not normally proposed by most TSOs as primary solutions to transmission weaknesses, and should not be regarded as a structural measure to cope with transmission weaknesses and cannot substitute any grid reinforcement.

3.2 CLUSTERING OF PROJECTS

In situations where multiple projects depend on each other to perform a single function (i.e. a single project performs its function without a certain other project) they can be clustered in order to be assessed as a group. Clustering projects (illustrated by Fig. 9) is recommended by the EC[12] when:

- They achieve a common measurable goal;
- They are located in the same area or along the same transport corridor;
- They belong to a general plan for that area or corridor;

[10] TSOs, while having a role in informing the market and public authorities about system weaknesses, cannot choose to relocate, decommission or build generation.

[11] ENTSO-E : Technical background and recommendations for defence plans in the Continental Europe synchronous area (https://www.entsoe.eu/resources/publications/system-operations/)

[12] European Commission Guide to Cost-Benefit analysis of investment projects, July 2008., p. 20

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Clustering should only be applied in cases where projects truly depend on each other; i.e., where a common measurable goal that the project promoter(s) intend(s) to achieve with one project cannot be (fully) accomplished without realizing (one or more) supporting projects. Note that this implies that competitive projects cannot be clustered together.

In the process of clustering projects for the beginning one project is defined as a 'main' project, which is built with the intention to provide a dominant influence to the certain GTC increase. Full potential of the main project (ΔGTC_{FP}) is a maximum capacity in normal operation conditions of the main project.

If no other projects are necessary to use the full potential of the main project, there is no reason to cluster projects; hence it should be assessed on its own. However, if the main project requires one or more 'supporting projects' to be realized in order for GTC across this border to be increased, these supporting projects may be clustered with the main project according to the rules described in this section.

- They are partly or completely dependent on each other (one is a precondition of the other). For instance, a reactive shunt device that is needed to avoid voltage upper limit violations due to the addition of a new line, or a converter station and an HVDC cable.
- They are in series and/or almost completely dependent project on other projects.
    - In the process of clustering start from one as 'main project', which is intended to bring a highest value of GTC increase across a certain boundary, and then cluster other projects together with this project if they are needed to allow this main project to realize full potential. A project may be clustered with this main project ifit facilitates at least 20% of the full potential ,

The calculation is done as follows using the TOOT or PINT method as specified in section 3.6.4

Example:

- ΔGTC_{FP} =1000 MW
- ΔGTC_{A}(main project): 600 MW
- ΔGTC_{A+B}(main project <u>with</u> an internal reinforcement, project B: 1000 MW)
- the $\Delta GTC_{B,support}$ = 400 MW (because without the project B only 600 MW could be obtained, out of the 1000 MW)

- <u>If $\Delta GTC_{FP} >= \Delta GTC_{2,support} >= 0.20\ \Delta GTC_{FP}$</u>, project B can be clustered together with the main project A.
- This process is repeated for all other clustering candidates and ends when all candidate projects have been analysed. Note that the contribution of any subsequent project should be regarded in view of the full potential.
    - Example: Consider the above mentioned example. If a third project (Project C) were to be assessed after Project B had already been clustered with the main project (Project A), the contribution of Project C would be zero in all cases because the full potential of the main project (1000 MW) has already been unlocked after Project B was clustered with it.

The $\Delta GTC_{x,support}$ must be reported for each project embedded in the cluster.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

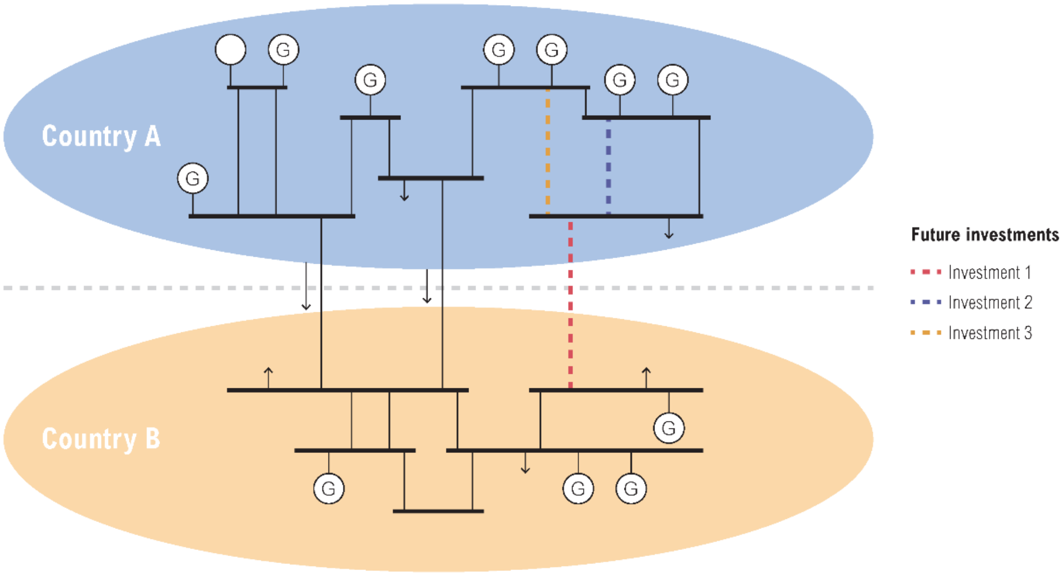


Figure 9: Clustering of projects

It is possible for a cluster to be limited to a single project item only. A project can also contribute to two clusters whose drivers are different, in which case its cost and benefits should only be counted in the one cluster.

Projects with commissioning dates being more than 5 years apart of each other cannot be clustered[13]. This "time limit criterion" is introduced in order to avoid excessive clustering.

3.3 ASSESSMENT FRAMEWORK

The assessment framework is a combined cost-benefit and multi-criteria assessment[14], complying with Article 11 and Annexes IV and V of the EU Regulation 347/2013. The criteria set out in this document have thus been selected on the following basis:

- They enable an appreciation of project benefits in terms of EU network objectives:
  - ensure the development of a single European grid to permit the EU climate policy and sustainability objectives (RES, energy efficiency, CO2);
  - guarantee security of supply;

[13] In the case of integrated offshore grids of complicated timescales, this '5 year rule' may need to be relaxed, according to the circumstances of that cluster.
[14] More details on multi-criteria assessment versus cost-benefit analysis are provided in Annex 2.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

- complete the internal energy market, especially through a contribution to increased socio-economic welfare ;
- ensure technical resilience of the system,

- They provide a measurement of project costs and feasibility (especially environmental and social viability).
- The indicators used are as simple and robust as possible. This leads to simplified methodologies for some indicators.

  The scheme below shows the main categories that group the indicators used to assess the impact of projects.

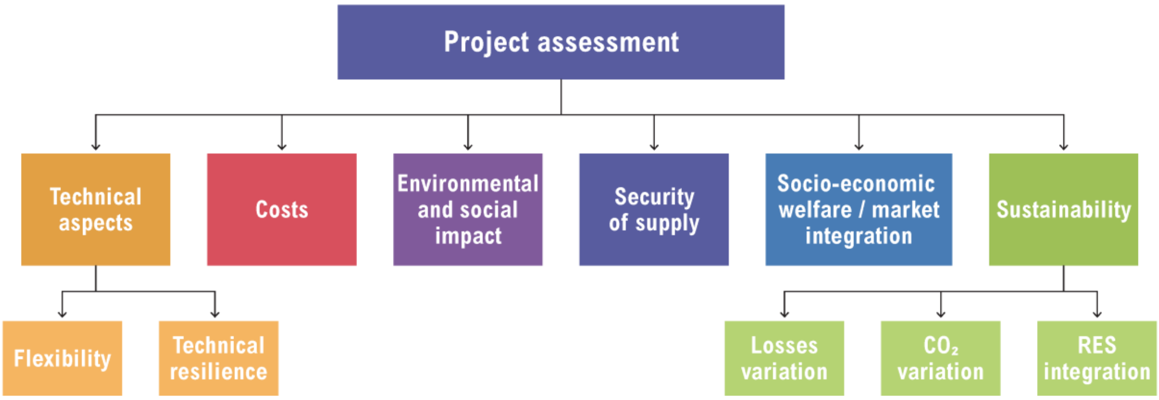


Figure 10. Main categories of the project assessment methodology

Some projects will provide all the benefit categories, whereas other projects will only contribute significantly to one or two of them. Other benefits, such as benefits for competition[15], also exist. These are more difficult to model, and will not be explicitly taken into account.

The **Benefit Categories** are defined as follows:

[15] Some definitions of a market benefit include an aspect of facilitating competition in the generation of electricity. These Guidelines are unable to well-define any metric solely relating to facilitation of competition. If transmission reinforcement has minimised congestion, that has facilitated competition in generation to the greatest extent possible. For further developments, see Annex 1.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

B1. Improved security of supply[16] (SoS) is the ability of a power system to provide an adequate and secure supply of electricity under ordinary conditions[17].

B2. Socio-economic welfare (SEW)[18] or market integration is characterised by the ability of a power system to reduce congestion and thus provide an adequate GTC so that electricity markets can trade power in an economically efficient manner[19].

B3. RES integration: Support to RES integration is defined as the ability of the system to allow the connection of new RES plants and unlock existing and future "green" generation, while minimising curtailments[20].

B4. Variation in losses in the transmission grid is the characterisation of the evolution of thermal losses in the power system. It is an indicator of energy efficiency[21] and is correlated with SEW.

B5. Variation in CO_2 emissions is the characterisation of the evolution of CO_2 emissions in the power system. It is a consequence of B3 (unlock of generation with lower carbon content)[22].

B6. Technical resilience/system safety is the ability of the system to withstand increasingly extreme system conditions (exceptional contingencies)[23].

B7. Flexibility is the ability of the proposed reinforcement to be adequate in different possible future development paths or scenarios, including trade of balancing services[24].

The **project costs**[25] are defined as follows:

C1.Total project expenditures are based on prices used within each TSO and rough estimates

[16] Adequacy measures the ability of a power system to supply demand in full, at the current state of network availability; the power system can be said to be in an N-0 state. Security measures the ability of a power system to meet demand in full and to continue to do so under all credible contingencies of single transmission faults; such a system is said to be N-1 secure.
[17] This category covers criteria 2b of Annex IV of the EU Regulation 347/2013, namely "secure system operation and interoperability".
[18] The reduction of congestions is an indicator of social and economic welfare assuming equitable distribution of benefits under the goal of the European Union to develop an integrated market (perfect market assumption).
[19] This category contributes to the criteria 'market integration" set out in Article 4, 2a and to criteria 6b of Annex V, namely "evolution of future generation costs".
[20] This category corresponds to the criterion 2a of Article 4, namely "sustainability", and covers criteria 2b of Annex IV.
[21] This category contributes to the criterion 6b of Annex V, namely "transmission losses over the technical lifecycle of the project".
[22] This category contributes to the criterion « sustainability » set out in Article 4, 2b and to criteria 6b of Annex V, namely " greenhouse gas emissions"
[23] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b and to criteria 2d of Annex IV, as well as to criteria 6b of Annex V, namely "system resilience" (EU Regulation 347/2013).
[24] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b , and to and to criteria 2d of Annex IV, as well as to criteria 6e of Annex V, namely "operational flexibility" (idem note 26).
[25] Project costs, as all other monetised values, are pre-tax.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

on project consistency (e.g. km of lines). Environmental costs can vary significantly between TSOs.

The **Project impact on society** is defined as follows:

S.1. Environmental impact characterises the project impact as assessed through preliminary studies, and aims at giving a measure of the environmental sensitivity associated with the project.

S.2.Social impact characterises the project impact on the (local) population that is affected by the project as assessed through preliminary studies, and aims at giving a measure of the social sensitivity associated with the project.

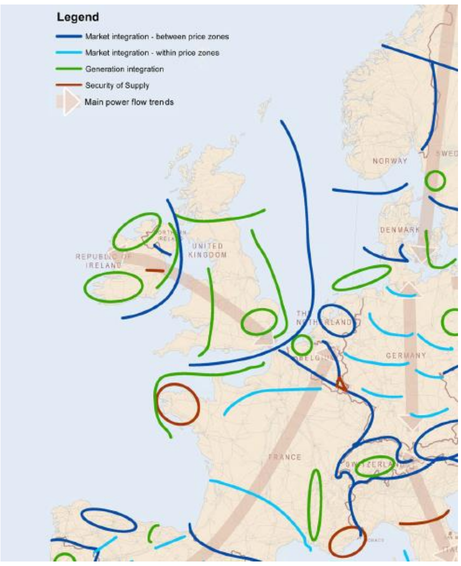
These two indicators refer to the remaining impacts, after potential mitigation measures defined when the projects definition becomes more precise.

The **Grid Transfer Capability (GTC)**is defined as follows:

The GTC reflects the ability of the grid to transport electricity across a boundary.

A boundary represents a bottleneck in the power system where the transfer capability is insufficient to accommodate the likely power flows (resulting from the scenarios) that will need to cross them. A boundary may be fixed (e.g. a border between states or bidding areas), or vary from one horizon or scenario to another.

The boundaries – and as such also the GTC variation across them – can be described along three types of concerns as illustrated in Fig 10 below



Generation accommodation: accommodation of both new and existing conventional and renewable generation.

Security of supply: avoiding load shedding in a specific area when ordinary contingencies are simulated.

Market integration: allow the market driven physicals flows to be accommodated within and across bidding areas

Figure 11: Illustration of GTC boundaries (source: TYNDP 2012)

The GTC depends on the considered state of consumption, generation and exchange, as well as the topology and availability of the grid, and accounts for safety rules described in chapter 4. When it concerns market integration, the GTC is oriented, which means that values might be different per direction.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

The GTC value that is displayed and used as a basis for benefit calculation must be valid at least 30 % of the time. The variation of GTC over the year may be given as a range in MW (max, min).

A project with a GTC increase of at least 500 MW compared to the situation without commissioning of the project is deemed to have a significant cross-border impact.

ASSESSMENT SUMMARY TABLE

The collated assessment findings are shown diagrammatically in the form of an assessment table, including the seven categories of benefits mentioned above, as well as two “impact” indicators (environmental and social impacts) and cost of a cluster (according to the guidelines in chapter 3.2.). In addition, a “neutral” characterisation of a cluster, is provided through an assessment of the GTC directional increase and the impact on the level of electricity interconnection relative to the installed production capacity in the Member State[26](see chapter 3.4 below). For those countries that have not reached the minimum interconnection ratio of 10%, each cluster, must report the contribution to reach this minimum threshold.

	CBA results non specific scenario		CBA results for each scenario							CBA results non specific scenario				
	GTC increase - direction 1 [MW]	GTC increase - direction 2 [MW]	TYNDP scenarios	Contribution to Interconnection rate [%]	B1 - SoS [MWh/y]	B2 - SEW [M€/y]	B3 - RES integration [MWh/y or MW/y]	B4 - Losses [MWh]	B5 - CO2 Emiss [kT/y]	B6 - Technical Resilience	B7 - Flexibility	S1 - protected areas [km]	S2 - urban areas [km]	C1 - Estimated cost [M€]
Assessment results CLUSTER														

Figure 12. Example of assessment summary table

[26] The COM (2001) 775 establishes that “all Member States should achieve a level of electricity interconnection equivalent to at least 10% of their installed generation capacity”. This goal was confirmed at the European Council of March 2002 in Barcelona and chosen as an indicator the EU Regulation 347/2013 (Annex Annex IV 2.a) The interconnection ratio is obtained as the sum of importing GTCs/total installed generation capacity

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

3.4 GRID TRANSFER CAPABILITY CALCULATION

The calculation of GTC increase is obtained starting from stressed network situations that are suitable for highlighting the contributions of the reinforcement. A common network model is used to assess the future grid transfer capability and the resilience in stressed grid situations, taking into account the security criteria described in chapter 4. The increase in GTC obtained by the project takes into account congestions in the grid (observed in network studies), both inside and between bidding areas.

3.5 COST AND ENVIRONMENTAL LIABILITY ASSESSMENT

C.1. Total project expenditure

For each project, costs and uncertainty ranges have to be estimated. The following items should be taken into account:

- Expected cost for materials and assembly costs (such as masts/ basement/ wires/ cables/ substations/ protection and control systems);
- Expected costs for temporary solutions which are necessary to realise a project (e.g. a new overhead line has to be built in an existing route, and a temporary circuit has to be installed during the construction period);
- Expected environmental and consenting costs (such as environmental costs avoided, mitigated or compensated under existing legal provisions[27], cost of planning procedures, and dismantling costs at the end of the life time);
- Expected costs for devices that have to be replaced within the given period (regard of life-cycles) ;
- Dismantling costs at the end of life of the equipment.
- Maintenance costs and costs of the technical life cycle.

For transmission projects (and the same applies to most storage projects), time horizon is generally shorter than the technical life of the assets. Transmission assets have a technical lifetime up to 80 years, hydro dams over 100 years, but uncertainty regarding the evolution of generation and consumption at such horizons is so large that no meaningful cost-benefit analysis can be performed. An appropriate residual value will therefore be included in the end year, using the standard economic depreciation formula used by each TSO or project promoter.

As far as environmental costs are concerned, only the costs of measures taken to mitigate the impacts are considered here. Some impacts may remain after these measures, which are then included in the indicators S1 and S2 that are discussed hereunder. This split ensures that all measurable costs are taken into account, and that there is no double-accounting between these indicators.

[27] These costs vary from one TSO to another because of different legal provisions. They may include mitigation costs for avian collisions of overhead lines, landscape integration of power stations or impact on water and soils for cables, compensation costs for land use or visual impact etc…

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

S.1. Environmental impact

Environmental impact characterises the local impact of the project on nature and biodiversity as assessed through preliminary studies. It is expressed in terms of the number of kilometres an overhead line or underground/submarine cable that (may) run through environmentally 'sensitive' (as defined in Annex 7: Environmental and social impact) areas. This indicator only takes into account the residual impact or a project, i.e. the portion of impact that is not fully accounted for under C.1. The assessment method is described in Annex 7.

For storage projects, these indicators are less well defined. They have to be looked at project by project.

S.2 Social impact

Social impact characterises the project impact on the (local) population, as assessed through preliminary studies. It is expressed in terms of the number of kilometres an overhead line or underground/submarine cable that (may) run through socially 'sensitive' (as defined in Annex 7) areas. This indicator only takes into account the residual impact or a project, i.e. the portion of impact that is not fully accounted for under C.1. The assessment method is described in Annex 7.

As for the environmental impact, these indicators are less well defined for storage projects, and have to be looked at project by project.

3.6 BOUNDARY CONDITIONS AND MAIN PARAMETERS OF BENEFIT ASSESSMENT

3.6.1 GEOGRAPHICAL SCOPE

The rationale behind system modelling is to use very detailed information within the studied area, and a decreasing level of detail when deviating from the studied area. The geographical scope of the analysis is an ENTSO-E Region at minimum, including its closest neighbours. In any case, the study area shall cover all Member States and third countries on whose territory the project shall be built, all directly neighbouring Member States and all other Member States significantly impacted by the project[28]. Finally, in order to take into account the interaction of the pan-European modelled system, exchange conditions will be fixed using hourly steps, based on a global market simulation[29].

Project appraisal is based hence on analyses of the global (European) increase of welfare[30]. This means that the goal is to bring up the projects which are the best for the European power system.

[28] Annex V, §10 Regulation (EU) 347/2013
[29] Within ENTSO-E, this global simulation would be based on a pan-European market data base.
[30] Some benefits (socio-economic welfare, CO_2…) may also be disaggregated on a smaller geographical scale, like a member state or a TSO area. This is mainly useful in the perspective of cost allocation, and should be calculated on a case by case basis, taking into account the larger variability of results across scenarios when calculating benefits related to smaller areas. In any cost allocation, due regard should be paid to compensation moneys paid under ITC (which is article 13 of Regulation 714 (see also Annex 1 for caveats on Market Power and cost allocation).

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

3.6.2 TIME FRAME

The results of cost benefit analysis depend on the chosen period of study. The period of analysis starts with the commissioning date and extends to a time frame covering the study horizons. It is generally recommended to study two horizons, one midterm and one long term (see chapter 2). To evaluate projects on a common basis, benefits should be aggregated across years as follows:

- For years from year of commission (start of benefits) to midterm (if any), extend midterm benefits backwards.
- For years between midterm and long term, linearly interpolate benefits between the midterm and long term values.
- For years beyond long term horizon (if any), maintain benefits at long term value.

All costs and benefits are discounted to the present, and expressed in the price base of that year.

3.6.3 DISCOUNT RATE

The purpose of using a single discount rate all over Europe is to convert future monetary benefits and costs into their present value, so that they can be meaningfully used for comparison and evaluation purposes.

Discounting is a technique which allows the assessor to bring costs and monetised benefits of a particular project to a common price base, so that they can be compared consistently and obtain the project's net present value (NPV). In particular, calculating the difference between the present value of costs and present value of benefits provides the NPV of a project.

Common Discounting Method

A prudent approach to discounting requires defining key parameters, such as discount rate, assessment period and residual value, as identified by ACER in their Opinion on ENSTO-E's previous version of the CBA Methodology.

The assessment period is typically driven by the expected economic asset life of the proposed project without considerable replacement cost. Empirical evidence suggests that a typical transmission project has an asset life of approximately 40years. Such an assumption can be readily adopted across Europe or further afield.

However, in practice discount rates are quite different across different Regional Groups in Europe. Even within a specific Regional Group discount rates could be different for each component country, as they could be driven by their National Regulatory Authority. Furthermore, depreciation assumptions which are used to estimate residual values of an asset could be different within a single country.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Within this context, a common pan-European discounting approach is proposed by the Commission and ACER in their relevant Opinions to this CBA Methodology[31]and accepted by ENTSO-E to be used for PCI and TYNDP projects assessments. In fact, in the electricity sector one single discount rate shall be used for all of Europe to compute the socio-economic benefits of a project. This shall be a real discount rate of 4 % for 25-years lifetime, and a residual value of zero.

3.6.4 Benefit analysis

Two possible ways for project assessment can be adopted:

- **Take Out One at the Time (TOOT)**method, that consists of excluding grid element projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement (a new line, a new substation, a new PST, ...);
- **Put IN one at the Time (PINT)**method, that considers each new item grid element on the given network structure one-by-one and evaluates the network flows over the lines with and without the examined network reinforcement.

The TOOT method provides an estimation of benefits for each project, as if it was the last to be commissioned. In fact, the TOOT method evaluates each new development investment/project into the whole forecasted network. The advantage of this analysis is that it immediately appreciates every benefit brought by each investment, without considering the order of investments. All benefits are considered in a precautionary way, in fact each evaluated project is considered into an "already developed" environment, in which are present all programmed development projects and are reported conditions in which the new investment shall operate. Hence, this method allows analyses and assessments at TYNDP level, considering the whole future system environment and every future network evolution.

However, it should be noted that strictly competitive projects assessment, i.e. projects delivering the same service to the grid, may need several steps:

- TOOT method: if the benefit is significant, then all the projects are useful.
- But poor benefits in this first TOOT assessment does not necessarily mean that none of the projects should be undertaken. Indeed one should take the reference network without ALL competing projects (but keeping all projects elsewhere in Europe), and adding them one by one. This will allow to determine the right level of development to reach in this part of the grid.

[31] ACER Opinion on ENTSO-E CBA Methodology - Jan 2014

This conclusion will apply to ANY of the competitive projects. The assessment will not conclude which one should be preferred, but how much of this kind of project is useful.

The TOOT methodology is recommended for cost-benefit analysis of a transmission plan such as the TYNDP, whereas the PINT methodology is recommended for individual project assessments outside the TYNDP process. The TYNDP network is then considered as the reference grid.

For all the analyses third-party projects are to be assessed in the same way as projects between TSOs.

3.7 METHODOLOGY FOR EACH BENEFIT INDICATOR

According to (EU) 347/2013 Regulation, the present CBA Guideline establishes a methodology for project identification and for characterisation of the impact of projects. This Methodology includes all the elements described both in Article 11 and the Annexes IV and V of the above-mentioned Regulation.

3.7.1 B1. SECURITY OF SUPPLY

Introduction

Security of Supply is the ability of a power system to provide an adequate and secure supply of electricity in ordinary conditions, in a specific area. The assessment must be performed for a geographically delineated area (see Fig. 12) with an annual electricity demand of at least 3 TWh[32]. The boundary of the area may consist of the nodes of a quasi-radial sub-system or semi-isolated area (e.g. with a single 400 kV injection). Two examples are provided below (project indicated in orange[33]).

[32] This value is seen as a significant threshold for electricity consumption for smart grids in the EU Regulation 347/2013 (Annex IV, 1e)

[33] One should notice that although the definition of a 'delimited geographical area' that is made subject to Security of Supply calculation may be considered an arbitrary exercise, the indicator score (see below) is determined proportionally to the size of the area (i.e. its annual electricity demand). In order to be scored the same, a larger geographic area thus requires a larger absolute improvement in Security of Supply compared to a smaller area.

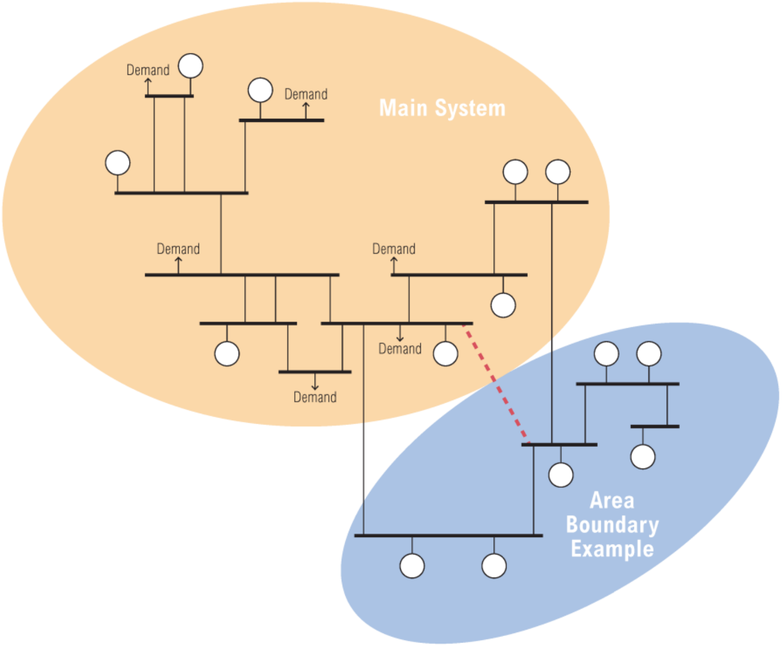


Figure 13: Illustration of delimited area for security of supply calculations

The criterion measures the improvement to security of supply (generation or network adequacy) brought about by a transmission project. It is calculated as the difference between the cases with and without the project, with the defined indicator being either Expected Energy Not Supplied (EENS) or the Loss of Load Expectancy (LOLE).

Methodology

Depending on the issue at stake, market or network models are used for the assessment calculations. When dealing with generation adequacy issues the market models are used to determine the contribution of a project to deliver power that was generated somewhere in the system to this specific area. Network models, on the other hand, are preferred for network adequacy issues, i.e. to determine the contribution of a project to network robustness (risk of network failures leading to lost load). The benefit analysis methodology from Section 3.6.4 is used in both cases.

For network studies, performance assessment is based on the technical criteria defined in Chapter 4. Analysis of representative cases without the project may, for example, identify risk of loss of load for ordinary contingencies. The EENS indicator will then show whether the inclusion of the project triggers a significant improvement of security of supply (see scale below).

The market studies rely on the same system tests, but use a simplified network representation. This assessment examines the likelihood of risks to the security of supply across an entire year in a wide range of stochastic scenarios regarding load and generation, and therefore may determine the probability of a critical system state. As such, this analysis will yield an Expected Energy Not Supplied (EENS) measure in MWh/year or a Loss of Load Expectancy (LOLE) in hours/year. Similar to the network studies, the inclusion of the project will identify the contribution that the project makes to either the EENS or LOLE indicators.

Both kinds of indicators may be used for the project assessment, depending on the issues at stake in the area. However, the method that is used must be reported (see table below).

Monetisation

In theory, the unreliability cost could be obtained using the EENS index and the unit interruption cost (i.e. Value of Lost Load; VOLL). In reality, however, the monetisation of system unreliability and security of supply using VOLL cannot be performed uniformly on a Union-wide basis. There is a large variation in the value that different customers place on their supply[34] and this variation can differ greatly across the Union, as it depends largely on regional and sectorial composition and the role of the electricity in the economy[35]. Additional factors such as time, duration and number of interruptions over a period also influence VOLL. The CEER has set out European guidelines[36] in the domain of nationwide studies on estimation of costs due to electricity interruptions and voltage disturbances, recommending that "*National Regulatory Authorities should perform nationwide cost-estimation studies regarding electricity interruptions and voltage disturbances*[37]*"*.

Given the high variability and complexity of the VOLL, calculating project benefit using market-based assessment will only provide indicative results which cannot be monetised on a Union-wide basis. VOLL will therefore not be used as a basis for comparative EENS or LOLE calculations.

Parameter	**Source of calculation**[38]	**Basic unit of measure**	**Monetary measure (externality or market-based?)**	**Level of coherence**
Loss Of Load Expectancy (LOLE)	Market studies (Generation adequacy)	Hours or MWh	Value of Lost Load	National
Expected Energy Not Supplied (ENS)	Network studies (network adequacy/secure system operation)	MWh	Value of Lost Load	National

[34] The University of Bath, in the framework of the European project CASES ("WP5 Report (1) on National and EU level estimates of energy supply externalities") states that "it is safe to conclude that VOLL figures [in 2030] lay in a range of 4-40 $/kWh for developed countries" (estimation based on a literature review).
[35] Cf. CIGRE study, 2001.
[36] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010
[37] However, this has not been done everywhere. Hence, there is no full set of available and comparable national VOLLs across Europe.
[38] Cf Annex IV, 2c.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

3.7.2 B2. SOCIO-ECONOMIC WELFARE

Introduction

A project that increases GTC between two bidding areas allows generators in the lower-priced area to export power to the higher-priced area, as shown below in Fig 13. The new transmission capacity reduces the total cost of electricity supply. Therefore, a transmission project can increase socio- economic welfare.

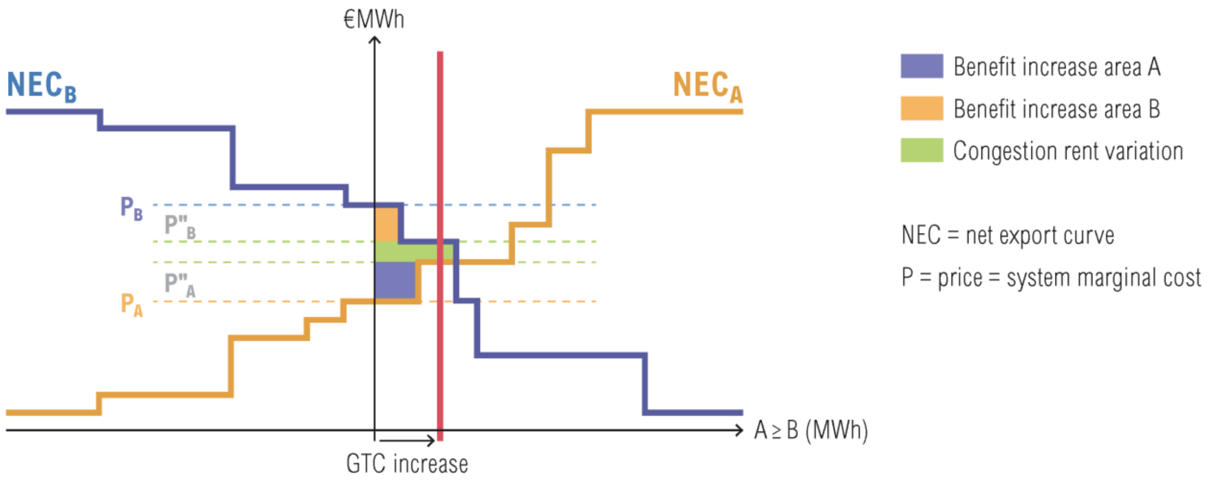


Figure 14: Illustration of benefits due to GTC increase between two bidding areas

In this chapter it is considered a perfect Market with the following assumptions:

- Equal access to information by market participants
- No barriers to enter or exit
- No market power

In general, two different approaches can be used for calculating the increased benefit from socio-economic welfare:

- The generation cost approach, which compares the generation costs with and without the project for the different bidding areas.
- The total surplus approach, which compares the producer and consumer surpluses for both bidding

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

areas, as well as the congestion rent between them, with and without the project[39].

If demand is considered inelastic to price, both methods will yield the same result. If demand is considered as elastic, modelling becomes more complex. The choice of assumptions on demand elasticity and methodology of calculation of benefit from socio-economic welfare is left to ENTSO-E's regional groups.

Most of the European countries are presently considered to have price inelastic demand. However, there are various developments that appear to cause a more elastic demand-side.

Both the development of smart grids and smart metering, as well as a growing flexibility needs from the changing production technologies (more renewables, less thermal and nuclear) are drivers towards a more price-elastic demand.

There are two ways of taking into account greater flexibility of demand when assessing socio-economic welfare, the choice of the method being decided within ENSTO-E’s regional groups:

1) The demand that will have to be supplied by generation is estimated through various scenarios, reshaping the demand curve (in comparison with present curves) to model the future introduction of smart grids, electric vehicles...etc. The demand response will not be exactly demand elasticity at each hour, but a movement of energy consumption from hours of (potential) high prices to hours of (potential) low prices. The generation costs to supply a known demand are minimised through the generation cost approach. This assumption simplifies the complexity of the models, in that demand can be treated as a time series of loads that ‘has to be met’, while at the same time considering different scenarios of demand side management.
2) Introduce hypotheses on level of price elasticity of demand. Again, two methods are possible:
    a. Using the generation cost approach, price elasticity could be taken into account via the modelling of curtailment as generators. The “willingness to pay” would then for instance be established at very high levels for domestic consumers, and at lower levels for a part of industrial demand.
    b. Using the total surplus method, the modelling of demand flexibility would need to be based on a quantification of the link between price and demand for each hour, allowing a correct representation of demand response in each area.

<u>Generation cost approach</u>[40]

The socio-economic welfare benefit is calculated from the reduction in total generation costs associated with the GTC variation created by the project. There are three aspects to this benefit.

a. By reducing network bottlenecks that restrict the access of generation to the full European market,

[39] More details about how to calculate surplus are provided in Annex 3

[40] It is acknowledged that transmission expansions have an influence on investments in generation investment. Instead of estimating the consequences of projects on such investments in each individual TYNDP, this effect is dealt with by the dynamic nature of the TYNDP process in which successive publications include developments in generation capacity as the basis for their adapted scenarios.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

a project can reduce costs of generation restrictions, both within and between bidding areas.

b. A project can contribute to reduced costs by providing a direct system connection to new, relatively low cost, generation. In the case of connection of renewables, this is directly expressed by Benefit Category B3 'RES Integration'. In other cases, the direct connection figures will be available in the background scenarios.

c. A project can also facilitate increased competition between generators, reducing the price of electricity to final consumers. Our methods do not consider market power (see Annex 1), and as a result our expression of socio-economic welfare is the reduction in generation costs under (a).

An economic optimisation is undertaken to determine the optimal dispatch cost of generation, with and without the project. The benefit for each case is calculated from:

Benefit (for each hour) = Generation costs without the project – Generation costs with the project

The socio-economic welfare can be calculated for internal constraints by considering virtual smaller bidding areas (with different market prices) separated by the congested internal boundary inside an official bidding area.

The total benefit for the horizon is calculated by summarising the benefit for all the hours of the year, which is done through market studies.

Total surplus approach

The socio-economic welfare benefit is calculated by adding the producer surplus, the consumer surplus and the congestion rents for all price areas as shown in Fig 14. The total surplus approach consists of the following three items:

a. By reducing network bottlenecks, the total generation cost will be economically optimized. This is reflected in the sum of the producer surpluses.

b. By reducing network bottlenecks that restrict the access of import from low-price areas, the total consumption cost will be decreased. This is reflected in the sum of the consumer surpluses.

c. Finally, reducing network bottlenecks will lead to a change in total congestion rent for the TSOs.

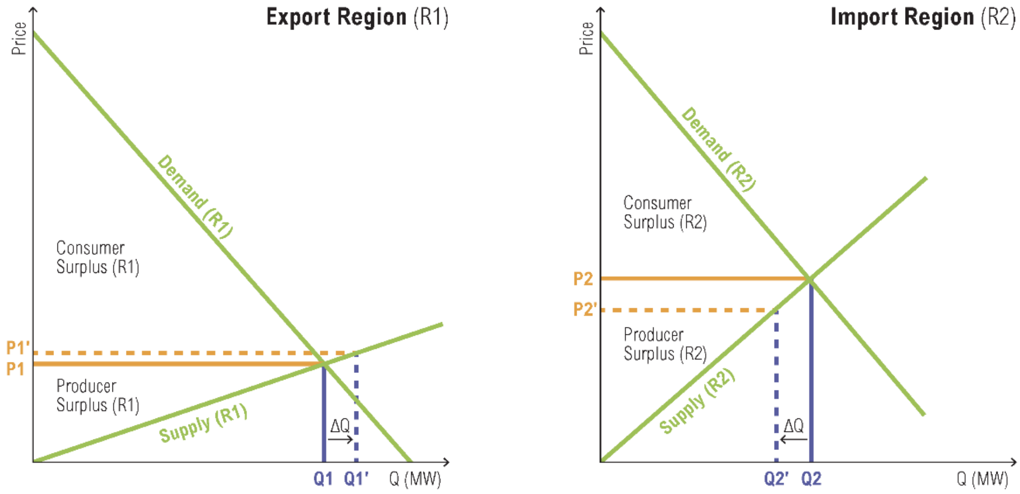


Figure 14: Example of a new project increasing GTC between an export and an import region.

An economic optimisation is undertaken to determine the total sum of the producer surplus, the consumer surplus and the change of congestion rent, with and without the project. The benefit for each case is calculated by:

Benefit (for each hour) = Total surplus with the project – Total surplus without the project

The total benefit for the horizon is calculated by summarizing the benefit for all the hours of the year, which is done through market studies.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Parameter	Source of calculation[41]	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence of monetary measure
Reduced generation costs/ additional overall welfare	Market studies (optimisation of generation portfolios across boundaries)	€	idem	European
Internal dispatch costs	Network studies (optimisation of generation dispatch within a boundary considering grid constraints)	€	idem	National

3.7.3 B3. RES INTEGRATION[42]

Introduction

The integration of both existing and planned RES is facilitated by:

1. Connection of RES generation to the main system,
2. Increasing the GTC between one area with excess RES generation to other areas, in order to facilitate higher level of RES penetration.

This indicator intends provides a standalone value associated with additional RES available for the system. It measures the reduction of renewable generation curtailment in MWh (avoided spillage) and the additional amount of RES generation that is connected by the project. An explicit distinction is thus made between RES integration projects related to (1) the direct connection of RES to the main system and (2) projects that increase GTC in the main system itself.

Methodology

Although both types of projects can lead to the same indicator scores, they are calculated on the basis of different measurement units. Direct connection (1) is expressed in $MW_{RES\text{-}connected}$ (without regard to actual avoided spillage), whereas the GTC-based indicator (2) is expressed as the avoided curtailment (in MWh)

[41] Cf Annex IV, 2a.

[42] Calculating the impact of RES in absolute figures (MW) facilitates the comparison of projects throughout Europe when considering the sole aspect of RES integration. Relative numbers (i.e the contribution of a project compared to the objectives of the NREA) can easily be calculated ex-post for analysis at a national level.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

due to (a reduction of) congestion in the main system. Avoided spillage is extracted from the studies for indicator B2. Connected RES is derived from network studies, and only calculated for specific RES integration projects. Both kinds of indicators may be used for the project assessment, provided that the method used is reported (see table below). In both cases, the basis of calculation is the amount of RES foreseen in the scenario or planning case.

Monetisation

Any monetisation of this indicator will be reported by B2. The benefits of RES in terms of CO2 reduction will be reported by B5.

Parameter	Source of calculation	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence of monetary measure
Connected RES	Market or network studies	MW	None	European
Avoided RES spillage	Market or network studies	MWh	Included in generation cost savings (B2)	European

3.7.4 B4. Variation in Losses (Energy Efficiency)

Introduction
The energy efficiency benefit of a project is measured through the reduction of thermal losses in the system. At constant transit levels, network development generally decreases losses, thus increasing energy efficiency. Specific projects may also lead to a better load flow pattern when they decrease the distance between production and consumption. Increasing the voltage level and the use of more efficient conductors also reduce losses. It must be noted, however, that the main driver for transmission projects is currently the higher need for transit over long distances, which increases losses.

Methodology
Variation in losses can be calculated by a combination of market and network modelling tools. The losses in the system are quantified for each planning case (covering seasonal variations) on the basis of network studies. This is done both with and without the project, while taking into account the change of dispatch that may occur by means of market studies. The variation in losses is then calculated as the difference between both values, which can be monetised (see below).

Monetisation

Monetisation of losses is based on forecasted marginal costs in the studied horizon. These marginal costs are derived from market studies, which must ensure that input parameters are coherent with the parameters and assumptions indicated in chapter 2.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Parameter	Source of calculation[43]	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence of monetary measure
Losses	Network studies	MWh	€/year (market-based)	European

3.7.5 B5. Variation in CO2 emissions

Introduction

By relieving congestion, reinforcements may enable low-carbon generation to generate more electricity, thus replacing conventional plants with higher carbon emissions. Considering the specific emissions of CO2 for each power plant and the annual production of each plant, the annual emissions at power plant level and perimeter level can be calculated and the standard emission rate established (see chapter 2).

Methodology

Generation dispatch and unit commitment used for calculation of socio-economic welfare benefit with and without the project is used to calculate the CO2 impact, taking into account standard emission rates.

Monetisation

The monetisation of CO2 is based on forecasted CO2 prices for electricity in the studied horizon. The price is derived from official sources such as the IEA for the studied perimeter (see chapter 2). As the cost of CO2 is already included (internalised) in generation costs (B2), the indicator only displays the benefit in tons in order to avoid double accounting.

However, it is possible that the prices of CO2 included in the generation costs (B2) under-state the full long-term societal value of CO2. Accordingly, a sensitivity analysis (see chapter 3.8) could be performed for this indicator B5, under which CO2 is valued at a long-term societal price. To perform this sensitivity without double-counting against B2:

- Derive the delta volume of CO2, as above.
- Consider the CO2 price internalised in B2.
- Adopt a long-term societal price of CO2.
- Multiply the volume of (a) by the difference in prices (c) minus (b). This represents the monetisation of this sensitivity of an increased value of CO2[44].

[43] Cf Annex IV, 2c.

[44] Note: for this sensitivity to B5, one does not adjust the merit order and the dispatch for B2 for the higher Carbon price. If one were to perform that exercise, that would represent a full re-run of indicator B2, against the different data assumption of a higher forecast carbon price included in the generation background and merit order.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Parameter	Source of calculation	Basic unit of measure	Monetary measure	Level of coherence
CO_2	Market and network studies (substitution effect)	tons	CO_2 price derived from generation costs (internalised in B2)	European

3.7.6 B6. Technical resilience/system safety margin

Introduction

Making provision for resilience while planning transmission systems, contributes to system security during contingencies and extreme scenarios. This improves a project's ability to deal with the uncertainties in relation to the final development and operation of future transmission systems. Factoring resilience into projects will impact positively on future efficiencies and on ensuring security of supply in the European Union.

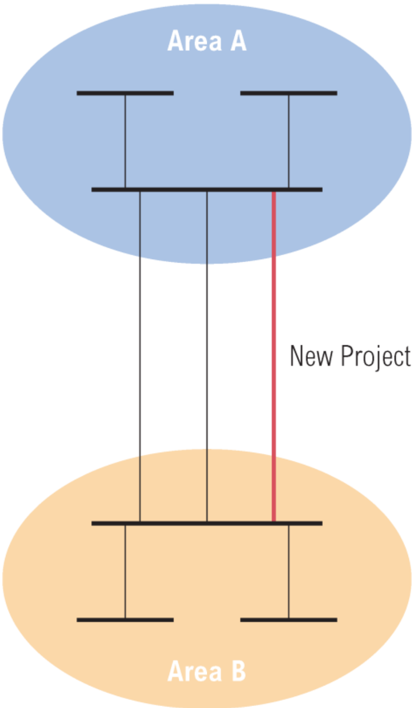
A quantitative summation of the technical resilience and system safety margins of a project is performed by scoring a number of key performance indicators (KPI) and aggregating these to provide the total score of the project.

KPI	Score (either ++/+/0)
Able to meet the recommendation R.1 (failures combined with maintenance) set out in chapter 4 (as applicable)	
Able to meet the recommendation R.2 (steady state criteria) set out in chapter 4 (as applicable)	
Able to meet the recommendation R.3 (voltage collapse criteria) set out in chapter 4 (as applicable)	

A Union-wide list of projects of common interest will be of a wide type and range. Given this high degree of variability and the complexity of assessing the contribution of a project to resilience, the technical resilience benefit will be based on professional power engineering judgement rather than only an algorithmic calculation.

More specifically, the KPI score will be determined by experts from the regional groups, on the basis of demonstrable results from network studies that are performed using detailed network models of the area under consideration. The KPI may therefore be supported by additional studies which demonstrate this benefit. The general rule is as follows:
The assessment of each KPI will be undertaken in TOOT for planning cases that are representative of the relevant year (see chapter 2). If a particular project contributes positively in the assessment of at least one KPI then it should score at least a single '+'. If the project does not completely meet the recommendations of a particular KPI then it cannot score a '++'.

Methodology



Based on the analyzed new project's ability to comply with failures combined with maintenance (n-1 during maintenance) (R.1), the analyzed project should be evaluated with a score that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analyzed new project's ability to comply with steady state criteria in case of exceptional contingencies (R.2), the analyzed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analysed new project's ability to cope with voltage collapse criteria (R.3), the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Scores for all KPIs are added.

Indicative signs are assigned as follows:

- 0: the score of KPIs is 0
- +: the score of KPIs is < or = 3+
- ++: the score of KPIs is > 3

3.7.7 B7. Robustness/flexibility

Introduction

The robustness of a transmission project is defined as the ability to ensure that the needs of the system are met in a future scenario that differs from present projections (sensitivity scenarios concerning input data set[45]). The provision and accommodation of operational flexibility, which is needed for the day-to-day running of the transmission system, must also be acknowledged. The robustness and flexibility of a project will ensure that future assets can be fully utilised in the longer term because the uncertainties related to development and transmission needs on a Union-wide basis are dealt with adequately. Moreover, special emphasis is given to the ability to facilitate the sharing of balancing services, as we suppose that there will be a growing need for this in the coming years.

A qualitative summation of the robustness and flexibility of a project is performed using TOOT by scoring a number of key performance indicators and aggregating these to obtain the total impact of the project.

KPI	**Score** (either ++/+/0)
Ability to comply with all cases analysed using a probabilistic, multi-scenario approach as set out in chapter 2 (as applicable)	
Ability to comply with all cases analysed taking out some of the foreseen reinforcements as set out in chapter 2 (as applicable)	
Ability to facilitate sharing of balancing services on wider geographical areas, including between synchronous areas	

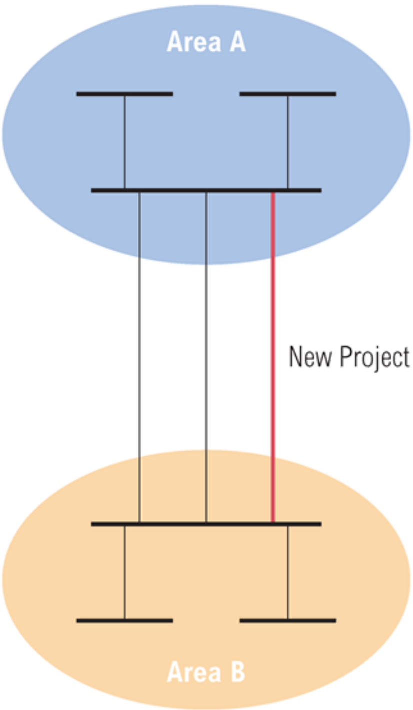
Given the highly variable and complex nature of each project, and the prohibitive number of possible future developments on a Union-wide scale, it is infeasible to accurately calculate or monetise the performance of each project with respect to flexibility. The benefits are therefore defined by a tabulated scoring system (outlined above) which is completed by professional power engineering judgement rather than by algorithmic calculation.

Scores for each KPI are added to the table and are summated to give an overall score for the project. Each KPI can be given a score of 0, ‘+’, or '++'. The methodology for the scoring of each KPI is outlined below.

[45] See chapter 2 for definition of a sensitivity scenario.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Methodology



Based on the analysed new project's ability to comply with important sensitivities, the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

⇩

Based on the analysed new project's ability to comply with commissioning delays and local objection to the construction of the infrastructure, the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

⇩

Based on the analysed new project's ability to share balancing services in a wider geographical area (including between synchronous areas), the analyzed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Scores for all KPIs are added.

Indicative signs are assigned as follows:

- 0: the score of KPIs is 0
- +: the score of KPIs is < or = 3+
- ++: the score of KPIs is > 3+

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

3.8 OVERALL ASSESSMENT AND SENSITIVITY ANALYSIS

3.8.1 OVERALL ASSESSMENT

The overall assessment is displayed as a multi-criteria matrix in the TYNDP, as shown in chapter 3.3. All indicators are quantified. Costs, socio-economic welfare and variation of losses are displayed in Euros. The other indicators are displayed through the most relevant units ensuring both a coherent measure all over Europe and an opposable value, while avoiding double accounting in Euros. Indeed, some benefits like avoided CO2 and RES integration are already internalised in socio-economic welfare.

Furthermore, each indicator is qualified on a multiple level colour scale, expressing negative, neutral, minor positive, medium positive or high positive impact. This scale allows displaying the results in various formats, such as the "classical" table (see Figure 11) or radar formats as shown below in Fig. 15.

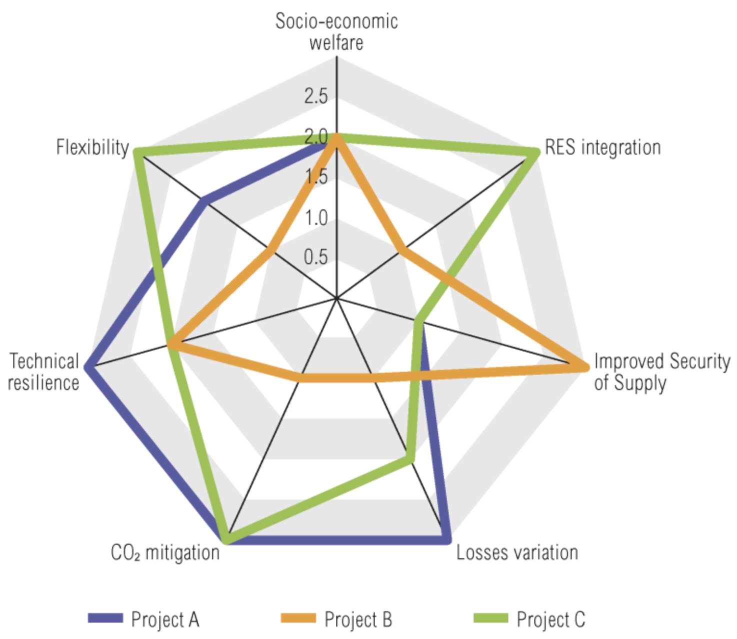


Figure 16: illustration of overall assessment

3.8.2 SENSITIVITY ANALYSIS

Transmission system planners face an increasing number of uncertainties. At the macroeconomic level, future evolution of the volume and the type of generation, trends in demand growth, energy prices and exchange patterns between bidding areas are uncertain, and greatly influence the need for transmission capacity. At the level of the study area, generation location and availability, as well as network evolution and availability, also have a major impact on network structure and location. The cost benefit methodology addresses these uncertainties in several ways:

- Benefit indicators are generally expected values, i.e. values obtained through a range of planning cases[46].
- Projects are assessed in at least two carefully considered macro-economic scenarios;
- The robustness of each project against variation of different scenarios or cases is assessed through indicator B7.

Additional sensitivity analysis (varying selected key assumptions whilst fixing all of the other assumptions) may be carried out, and the following parameters could for instance be considered for sensitivity analysis:

- Demand forecast;
- Fuel costs and RES value;
- CO2 price;
- Discount rate;
- Commissioning date.

The results may be reported as ranges in addition to the reference value.

[46] With probabilistic market tools, the expected values may even be the results of hundreds of scenarios.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

4 TECHNICAL CRITERIA FOR PLANNING

Technical methods and criteria are defined to be used when assessing the planning scenarios, in order to identify future problems and determine the required development of the transmission grid. These assessments take into account the outcomes from the scenarios analysis.

The general methodology implies:

Grid analysis:

- Investigation of base case topology (all network elements available).
- Different type of events (failures of network elements, loss of generation,…) are considered depending on their probability of occurrence.

Evaluation of results:

- Evaluation of consequences by checking the main technical indicators:
    - Cascade tripping
    - Thermal limits
    - Voltages
    - Loss of demand
    - Loss of generation
    - Short circuit levels
    - Stability conditions.
    - Angular difference
- Acceptable consequences can depend on the probability of occurrence of the event.

Currently deterministic criteria are used in the planning of the grid.

4.1 DEFINITIONS[47]

D.1. **Base Case for grid analysis.** Data used for analysis are mainly determined by the planning cases. For any relevant point in time, the expected state of the whole system, "with all network equipment available", forms the basis for the analysis ("Base case analysis").

D.2. **Contingencies**. A contingency is the loss of one or several elements of the transmission grid. A differentiation is made between ordinary, exceptional and out-of-range contingencies. The wide range of climatic conditions and the size and strength of different networks within

[47] For all definitions, see also ENTSO-E's draft Operational Security Network Code (https://www.entsoe.eu/resources/network-codes/operational-security/)

ENTSO-E mean that the frequency and consequences of contingencies vary among TSOs. As a result, the definitions of ordinary and exceptional contingencies can differ between TSOs. The standard allows for some variation in the categorisation of contingencies, based on their likelihood and impact within a specific TSO network.

- An ordinary contingency is the (not unusual) loss of one of the following elements:
  - Generator.
  - Transmission circuit (overhead, underground or mixed).
  - A single transmission transformer or two transformers connected to the same bay.
  - Shunt device (i.e. capacitors, reactors, etc.).
  - Single DC circuit.
  - Network equipment for load flow control (phase shifter, FACTS …).
  - A line with two or more circuits on the same towers if a TSO considers this appropriate and includes this contingency in its normal system planning

- An exceptional contingency is the (unusual) loss of one of the following elements:
  - A line with two or more circuits on the same towers if a TSO considers this appropriate and does not include this contingency in its normal system planning
  - A single bus-bar.
  - A common mode failure with the loss of more than one generating unit or plant.
  - A common mode failure with the loss of more than one DC link.

- An out-of-range contingency includes the (very unusual) loss of one of the following:
  - Two lines independently and simultaneously.
  - A total substation with more than one bus-bar.
  - Loss of more than one generation unit independently.

D.3. **N-1 criterion for grid planning.** The N-1 security criterion is satisfied if the grid is within acceptable limits for expected supply and demand situations as defined by the planning cases, following a temporary (or permanent) outage of one of the elements of the ordinary contingency list (see D2 and chapter 4.2.2).

4.2 COMMON CRITERIA

4.2.1 STUDIES TO BE PERFORMED

C.1. **Load flow analysis**

- **Examination of ordinary contingencies.** N-1 criterion is systematically assessed taking into account each single ordinary contingency of one of the elements mentioned above.

- **Examination of exceptional contingencies.** Exceptional contingencies are assessed in order to prevent serious interruption of supply within a wide-spread area. This kind of assessment is done for specific cases based on the probability of occurrence and/or based on the severity of the consequences.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

- **Examination of out-of-range contingencies.** Out-of-range contingencies are very rarely assessed at the planning stage. Their consequences are minimised through Defence Plans.

C.2. **Short circuit** analysis. Maximum and minimum symmetrical and single-phase short-circuit currents are evaluated according to the IEC 60 909, in every bus of the transmission grid

C.3. **Voltage collapse.** Analysis of cases with a further demand increase by a certain percentage above the peak demand value is undertaken. The resulting voltage profile, reactive power reserves, and transformer tap positions are calculated.

C.4. **Stability analysis.** Transient simulations and other detailed analysis oriented to identifying possible instability shall be performed only in cases where problems with stability can be expected, based on TSO knowledge.

4.2.2 Criteria for assessing consequences

C.5. **Steady state criteria**

- **Cascade tripping.** A single contingency must not result in any cascade tripping that may lead to a serious interruption of supply within a wide-spread area (e.g. further tripping due to system protection schemes after the tripping of the primarily failed element).

- **Maximum permissible thermal load.** The base case and the case of failure must not result in an excess of the permitted rating of the network equipment. Taking into account duration, short term overload capability can be considered, but only assuming that the overloads can be eliminated by operational countermeasures within the defined time interval, and do not cause a threat to safe operation.

- **Maximum and minimum voltage levels.** The base case and the case of failure shall not result in a voltage collapse, nor in a permanent shortfall of the minimum voltage level of the transmission grid, which are needed to ensure acceptable voltage levels in the sub-transmission grid. The base case and the case of failure shall not result in an excess of the maximum admissible voltage level of the transmission grids defined by equipment ratings and national regulation, taking into account duration.

C.6. **Maximum loss of load or generation** should not exceed the active power frequency response available for each synchronous area.

C.7. **Short circuit criteria.** The rating of equipment shall not be exceeded to be able to withstand both the initial symmetrical and single-phase short-circuit current (e.g. the make rating) when energising on to a fault and the short circuit current at the point of arc extinction (e.g. the break rating). Minimum short-circuit currents must be assessed in particular in bus-bars where a HVDC installation is connected in order to check that it works properly.

C.8. **Voltage collapse criteria.** The reactive power output of generators and compensation equipment in the area should not exceed their continuous rating, taking into account transformer tap ranges. In addition the generator terminal voltage shall not exceed its

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

admissible range.

C.9. **Stability criteria.** Taking into account the definitions and classifications of stability phenomena[48], the objective of stability analysis is the rotor angle stability, frequency stability and voltage stability in case of ordinary contingencies (see section 3.1), i.e. incidents which are specifically foreseen in the planning and operation of the system..

- **Transient stability.** Any 3-phase short circuits successfully cleared shall not result in the loss of the rotor angle and the disconnection of the generation unit (unless the protection scheme requires the disconnection of a generation unit from the grid).

- **Small Disturbance Angle Stability**. Possible phase swinging and power oscillations (e.g. triggered by switching operation) in the transmission grid shall not result in poorly damped or even un-damped power oscillations.
- **Voltage security**. Ordinary contingencies (including loss of reactive power in-feed) must not lead to violation of the admissible voltage range that is specified by the respective TSO (generally 0.95 p.u. – 1.05 p.u.

4.2.3 BEST PRACTICE

R1. **Load flow analysis. Failures combined with maintenance.** Certain combinations of possible failures and non-availabilities of transmission elements may be considered in some occasions. Maintenance related non-availability of one element combined with a failure of another one may be assessed. Such investigations are done by the TSO based on the probability of occurrence and/or based on the severity of the consequences, and are of particular relevance for network equipment that may be unavailable for a considerable period of time due to a failure, maintenance, overhaul (for instance cables or transformers) or during major constructions.

R2. **Steady state analysis.** Acceptable consequences depend on the type of event that is assessed. In the case of exceptional contingencies, acceptable consequences can be defined regarding the scale of the incident, and include loss of demand. Angular differences should be assessed to ensure that circuit breakers can re-close without imposing unacceptable step changes on local generators.

R3. **Voltage Collapse analysis:** The aim of voltage collapse analysis is to give some confidence that there is sufficient margin to the point of system collapse in the analysed case to allow for some uncertainty in future levels of demand and generation.

[48] Definition and Classification of Power System Stability, IEEE/CIGRE Joint Task Force, June 2003

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

End note.

System development tools are continuingly evolving, and it is the intention that this document will be reviewed periodically pursuant to Regulation (EU) n.347/2013, Art.11 §6, and in line with prudent planning practice and further editions of the TYNDP document of ENTSO-E.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

5 ANNEX 1: IMPACT ON MARKET POWER

Context

The Regulation (EU) n.347/2013 project requires that this CBA Methodology takes into account the impact of transmission infrastructures on market power in Member States. This paper analyses this indicator and its limits, as well as the necessary methodology to construct it.

Basics on methodology

Market power is the ability to alter prices away from competitive levels. It is important to point out that **this ability is potential**: a market player can have market power without using it. Only when it is actually used, market power has negative consequences on socio-economic welfare, by reducing the overall economic surplus to the benefit of a single market player. Taking into account market power in a CBA therefore requires three steps:

- To define carefully which asset(s)/ will be assessed. The Calculation of the index will be made with and without this object, and the difference on this two calculus will be the outcome of the CBA
- To define the market on which the index will be applied: geographic extension, how to take into account interconnections and market coupling, treatment of regulated market segments, market products to consider.
- To define a market power index, which requires choosing an index among existing possibilities such as Residual Supply Index (RSI) or Herfindahl-Hirschman Index (HHI). Each of these has its advantages and disadvantages ;

All of these choices affect the results of a market power analysis, i.e. the perceived market power is highly dependent on how it is defined.

Limits of market power indicators

First, it must be highlighted that **the calculation of all these indexes requires confidential data as input**. Thus, a balance has to be found between the necessary confidentiality of these data and the need for transparency that is required for CBA, as this is a necessary condition to obtain EU permitting and financial assistance.

Furthermore, monetisation of this market power index requires that the impact of a change in the market power index on socio-economic welfare is estimated. This requires that one is able to model the functioning of a future market under the hypothesis of imperfect competition, despite the fact that the validity of such a model is virtually impossible to prove. The inevitable model assumptions can radically change the results.

The results of a CBA in terms of market power can therefore only be qualitative, and its use as a reference for cost allocation would raise many objections.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

A CBA study is classically performed by evaluating the impact of a project during its whole life cycle. This requires to make a complete set of hypothesis on the future, for instance on the evolution of the level of consumption. Unfortunately, **market power evolution cannot be modelled**, as it is dependent on individual and regulatory decisions. Market structure could change dramatically in the future, for instance as the result of a merger. A solution to this issue could be to assess the impact of the infrastructure on the observed situation only. However, it should be noted that evaluating market power in a different hypothesis framework from the other aspects of the CBA would imply that the results are not consistent, and should not be compared.

Building infrastructures may have a positive impact on market power issues, but it is not the only solution. One should note that **an infrastructure project takes more time to complete is more costly than a decision affecting regulation/competition**. In case a market power issue is identified in a Member State, the national regulator should undertake relevant actions to force market players to respect the rules, rather than trying to solve the problem by expanding the infrastructure. Indeed, regulatory solutions are much more adapted to such an issue.

The instability of market power compared to the other aspects of a CBA has a crucial impact on its relevance as part of a decision making process. Dealing with generator ownership structures 10 or 20 years from now adds a highly uncertain dimension to the evaluation of European benefits of a given asset. Taking the impact of infrastructure capacity on market power into account in a CBA can heavily affect the identification of priority projects. Moreover, a change in the market structure can completely change the decision of building a particular infrastructure. **This is all the more important considering that there are other, faster ways to solve market power issues: through regulation**. By the time a project is completed, it is very likely that the market power issue has already been tackled by the regulator, and the infrastructure will not bring any benefit on this aspect. **Taking market power into account in a CBA can thus lead to sub-optimal decisions**.

Conclusion

The impact of future assets on current market power (which is generally positive) is an important indication, but this short-term aspect cannot be used in the assessment of an investment decision which is, by definition, a long-term commitment;

National markets have already begun to merge, through market coupling, and a reporting of benefits on market power by Member States is already outdated.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

6 ANNEX 2: MULTI-CRITERIA ANALYSIS VS COST BENEFIT ANALYSIS

Goals of any project assessment method

- Transparency : the assessment method must provide transparency in its main assumptions, parameters and values
- Completeness : all relevant indicators (representing EU energy policy, as outlined by the criteria specified in annexes IV and V of the draft Regulation) should be included in the assessment framework,
- Credibility/opposability : if a criterion is weighted, the unit value must stem from an external and credible source (international or European reference)
- Coherence: if a criterion is weighted, the unit value must be coherent within the area under consideration (Europe or Regional Group).

The limits of a « pure » cost benefit analysis

A single criterion provides less information (and is less transparent) then a multi-criteria balance sheet. Moreover, it is not well adapted in the case of a multi-actor governance, such as the one foreseen by the Regulation (EU) No 347/2013, where the actors will need information on each of the criteria in order to take common decisions.

A « pure « CBA cannot cover all criteria specified in annexes IV and V of the Regulation (EU) No 347/2013, since some of the benefits are difficult to monetise.

- This is the case for High Impact / Low Probability events such as « disaster and climate resilience » (multiplying low probabilities and very high consequences have little meaning) ;
- Other benefits, such as, "operational flexibility », have no opposable monetary value today (they qualify robustness and flexibility rather than a quantifiable economic value) ;
- Some benefits have opposable values at a national level, but no common value exists in Europe. This is case with, for instance, the value of lost load, which depends on the structure of consumption in each country (tertiary sector versus industry, importance of electricity in the economy etc…)
- Some benefits (e.g. CO2) are already internalised (e.g in socio-economic welfare). Displaying a value in tons provides additional information and prevents double accounting.

As stated in the EC Guide to Cost Benefit Analysis (2008): "In contrast to CBA, which focuses on a unique criterion (the maximisation of socio-economic welfare), Multi Criteria Analysis is a tool for dealing with a set of different objectives that cannot be aggregated through shadow prices and welfare weights, as in standard CBA" ; "Multi-criteria analysis, i.e. multi-objective analysis, can be helpful when some objectives are intractable in other ways and should be seen as a complement to CBA ».

This is why ENTSO-E favours a combined multi-criteria and cost benefit analysis that is well adapted to the proposed governance and allows an evaluation based on the most robust indicators, including monetary values if an opposable and coherent unit value exists on a Europe-wide level. This approach allows for a homogenous assessment of projects on all criteria (e.g MWh RES is the priority of the region is RES integration).

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

7 ANNEX 3: TOTAL SURPLUS ANALYSIS

A project with a GTC variation between two bidding areas with a price difference will allow generators in the low price bidding area to supply load in the high price bidding area.

In a perfect market, the market price is determined at the intersection of the demand and supply curves.

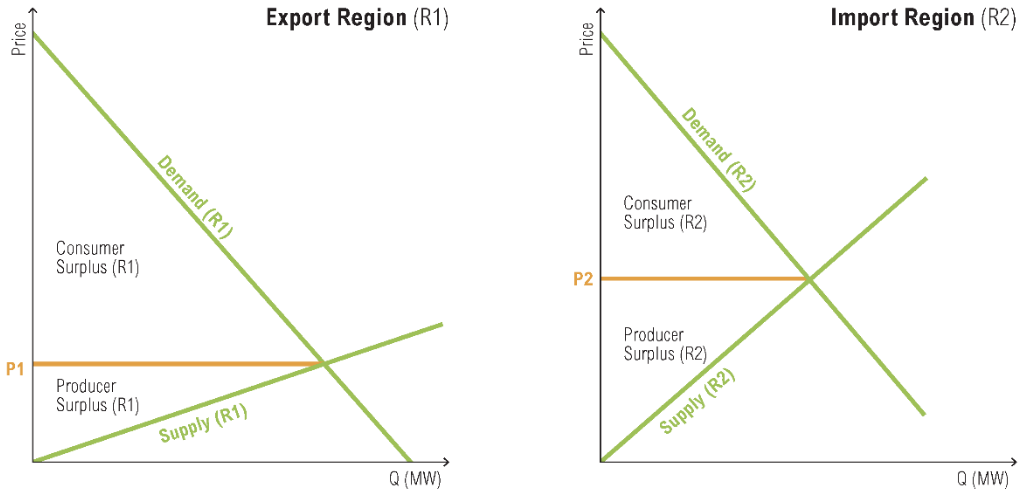


Figure 3.1: Example of an export region (left) and an import region (right) with no (or congested) interconnection capacity (elastic demand)

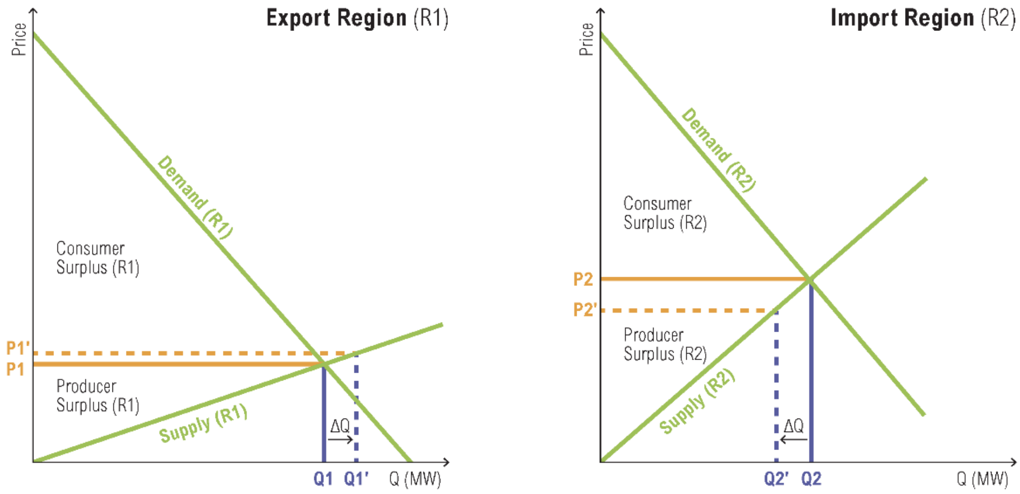


Figure 3.2: Example of an export region and an import region, with a new project increasing the GTC between the two regions (elastic demand)

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

The new project will change the price of both bidding areas. This will lead to a change in consumer and producer surplus in both the export and import area. Furthermore, the TSO revenues will reflect the change in total congestion rents on all links between the export and import areas.

The benefit of the project can be measured through the change in socio-economic welfare. The change in welfare is calculated by:

Change in welfare = change in consumer surplus + change in producer surplus + change in total congestion rents

The total benefit for the horizon is calculated by summing the benefit for all hours of the year.

Inelasticity of demand

In the case of the electricity market, short-term demand can be considered as inelastic, since customers do not respond directly to real-time market prices (no willingness-to-pay-value is available).

The change in **consumer surplus**[49] can be calculated as follows:

For inelastic demand: change in **consumer surplus** = change in prices multiplied by demand

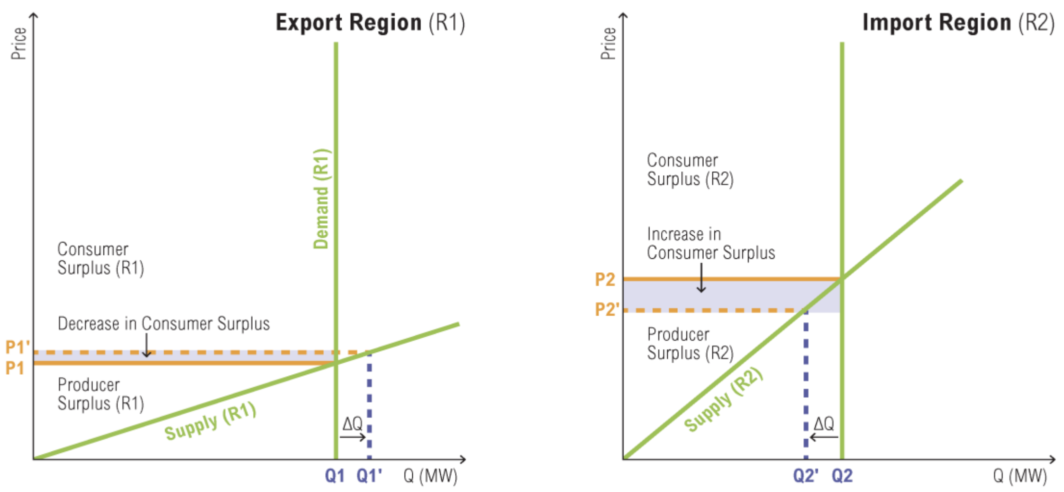


Figure 3.3: Change in consumer surplus

[49] When demand is considered as inelastic, the consumer surplus cannot be calculated in an absolute way (it is infinite). However, the variation in consumer surplus as a result of the new project can be calculated nonetheless. It equals the sum for every hour of the year of :(marginal cost of the area x total consumption of the area)$_{\text{with the project}}$ – marginal cost of the area x total consumption of the area)$_{\text{without the project}}$

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

The change in **producer surplus** can be calculated as follows:

Change in **producer surplus** = generation revenues[50] – generation costs

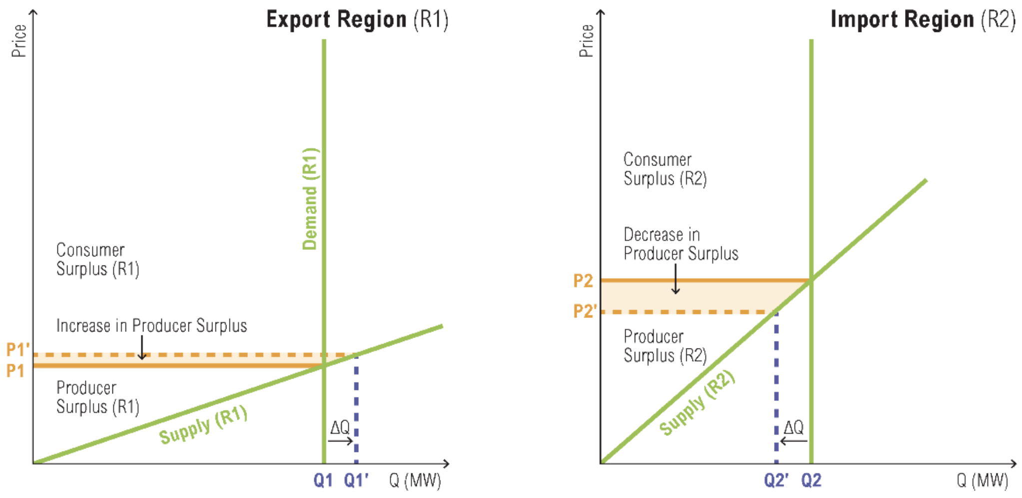


Figure 3.4: Change in producer surplus

The congestion rents with the project can be calculated by the price difference between the importing and the exporting area, multiplied by the additional power traded by the new link[51].

The change in **total congestion rent** can be calculated as follows:

Change in **total congestion rent** = change of congestion rents on all links between import and export area

[50] Generation revenues equal: (marginal cost of the area x total production of the area).

[51] In a practical way, it's calculated as the absolute value of (Marginal cost of Export Area – Marginal cost of Import Area) x flows on the interconnector

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

8 ANNEX 4: VALUE OF LOST LOAD

Value of Lost Load (VoLL) is a measure of the cost of unserved energy (the energy that would have been supplied if there had been no outage) for consumers. It is generally normalised in €/kWh. It reflects the mean value of an outage per kWh (long interruptions) or kW (voltage dips, short interruptions), appropriately weighted to yield a composite value for the overall sector or nation considered. It is an externality, since there is no market for security of supply.

The accurate calculation of a single value of VOLL cannot be performed uniformly on a Union-wide basis. Experience has demonstrated that VOLL can vary significantly from one country to another, within countries or from one economic region to another. Large variations can occur due to differences in the nature of load composition, the type of affected consumers, the level of dependency on electricity in the geographical area impacted, differences in reliability standards, the time of year and the duration of the impact.

The level of VoLL should reflect the real cost of outages for system users, hence providing an accurate basis for investment decisions. In this respect, too high a level of VoLL would lead to over-investment. Conversely, if the value were too low, it would lead to inadequate security of supply. There is an optimal level, expressing the consumer's willingness to pay for security of supply, therefore VoLL should allow for striking the right balance between transmission reinforcements (which have a cost, reflected in the tariff) and outage costs. Transmission reinforcements contribute to the improvement of security and quality of electricity supply, reducing the probability and gravity of outages, and thus the costs for consumers.

The energy figure expressed in MWh, which ENTSO-E provides as the security of supply indicator in the CBA evaluation of each project, allows all interested parties to monetise by using the preferred VOLL available. Using a general uniform estimation for VOLL would lead to less transparency and inconsistency and greatly increase uncertainties compared to presenting the physical units. ENTSO-E does not intend to reduce the accuracy or level of information provided by its assessment results through the application of an estimated VOLL.

The CEER has set out European guidelines[52] for nationwide studies on estimation of costs due to electricity interruptions and voltage disturbances, recommending that "*National Regulatory Authorities should perform nationwide cost-estimation studies regarding electricity interruptions and voltage disturbances*". Applying these guidelines throughout Europe would help establishing correct levels of VOLL, enabling comparable and

[52] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010. Other reports have also established such guidelines, such as CIGRE (2001) and EPRI

References:

1) CIGRE Task Force 38.06.01: "Methods to consider customer interruption costs in power system analysis". Technical Brochure, August 2001
2) Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010

consistent project assessments all over Europe. However, this is not yet the case, and a R&D program would be a pre-condition for adopting VOLL for consistent TYNDP or PCI assessments

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

9 ANNEX 5: ASSESSMENT OF ANCILLARY SERVICES

Exchange and sharing of ancillary services, in particular balancing resources, is crucial both to increase RES integration and to enhance the efficient use of available generation capacities. However, today, there is a great diversity of arrangements for ancillary services throughout Europe[53]. Common rules for cross border exchanges of such services are foreseen within the future Network Code on Electricity Balancing. In the absence of such a code, any homogenous assessment of the value of transmission for exchange of ancillary services remains difficult.

Some principles established by ACER's Framework Guidelines on Balancing Services provide a possible **scope** for cost benefit analysis of ancillary services:

- Frequency containment reserves[54] are shared and commonly activated in synchronous areas through the reliability margin foreseen for that purpose. These margins may be included in SEW calculations, and could lead to double-counting.
- The Network Code on Electricity Balancing shall set all necessary features to facilitate the development of cross-border exchanges of balancing energy and stipulate that these are made possible on every border, in the limits defined by Network Code on Load Frequency Control and Reserves concerning abroad procurement of Ancillary Services such as frequency restoration reserves (FRR) and replacement reserves (RR). However, reservation of cross-border capacity for the purpose of balancing energy from FRR and RR is generally forbidden, except for cases where TSOs can demonstrate that such reservation would result in increased overall social welfare.

Generally, increase of cross border capacities between bidding zones through grid development would therefore only lead to additional value in terms of balancing energy from frequency restoration reserves and replacement reserves ("Reserves") during non-congested hours. Moreover, the value could only be monetised in certain **conditions**, described below.

Many transmission projects, especially new interconnectors between or within coordinated markets, can provide the benefit of good liquidity of Reserves, provided only that the sending market has spare Reserve capacity being held. The technical capability of an interconnector to deliver Reserves, at various timescales should be carefully evaluated, considering both the technical characteristics of the interconnector and the technical definitions of Reserve products in the markets. If at least one of the interconnected markets has market-based approach in balancing services, such that a price of balancing services can be sensibly projected over a forecast horizon, then a question of monetisation of a balancing services benefit arises.

[53] See for instance ENTSO-E's survey on *Ancillary Services Procurement and Electricity Balancing Market Design* https://www.entsoe.eu/resources/network-codes/electricity-balancing/.

[54] *Frequency containment reserves* are operating *reserves* necessary for constant containment of frequency deviations (in order to constantly maintain the power balance in the whole synchronously interconnected system. This category typically includes operating *reserves* with the activation time up to 30 seconds. Operating *reserves* of this category are usually activated automatically.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

If these conditions are fulfilled, the following guidance could be given:

- If the transmission project lies entirely within one control area, which has a market-based approach in balancing services, then the benefit of that project, in terms of permitting greater access to market of Reserve services should be assessed using forecast prices of Reserve within the control area. We note that such prices are normally low – it is unusual to have Reserve sources significantly limited by transmission, such that differential prices of Reserves are released by extra transmission.
- If the transmission project interconnects two control areas, both of which have a market-based approach in balancing services and similar Reserve products, then the Reserve benefits of that project should be assessed using forecast prices of Reserve within each bidding zone. Note the benefits are two-way; for example, if the interconnectors is floating at one hour, then it can let Reserve from control area A contribute to the requirement in control area B and simultaneously let Reserve from control area B contribute into control area A. But of course, if the interconnector is flowing fully from A to B at that hour, then no Reserve benefit in control area B can be also claimed ; in general, the Reserve benefit will be lower than the Trading benefit evaluated under SEW (benefit B2).
- If the transmission project interconnects one control area A, which has a market-based approach in balancing services, with a second control area B which does not, or Reserve products are very dissimilar, then great care should be exercised in attempting to quantify any Reserve benefit. Obviously, zero benefit can be claimed for delivery of Reserves from control area A into control area B if control area B does not have a marked based approach in balancing services. A Reserve benefit can only be claimed, if it is thought likely to be able to establish the holding of a Reserve service in control area B able to meet the technical requirements of Reserve in control area A. Further, a prudent forecast should be made of the price of holding the Reserve in control area B, and this forecast deducted from the forecasted Reserve price in control area A. If in doubt, it should be assumed that the price of holding in control area B exceeds the value in control area A, such that zero Reserve benefit is claimed.
- Finally, if the transmission project interconnects two control areas which have no market-based approach in balancing services, then obviously, zero benefit can be claimed for delivery of Reserves into either market.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

10 ANNEX 6: ASSESSMENT OF STORAGE

The principles and procedures described in this document, for combined Multi-criteria and Cost Benefit Analysis, may be used for the evaluation of centralised[55] storage devices on transmission system. These Multi-criteria and Cost Benefit Analysis are applicable both to storage systems planned by TSOs and both by private promoters, even if a distinction on different roles and operation uses between these two types must be done. In fact the possibility to install storage plants on the transmission grid by TSO is strictly connected to the objective of improving and preserving system security and guaranteeing cheapness of network operation without affecting internal market mechanisms and influence any market behaviour.

The location of storage plants is decisive to the service storage will provide. Therefore, before carrying out the CBA, an assessment of the maximum power of the storage device at different points in time (for the injection and withdrawal of electricity to/from the grid) taking into account local grid capacity, should be undertaken, in the same way as the GTC is calculated for transmission.

Storage plants can be very easily introduced in market studies, since the existing facilities of this type are already modelled. Hence it can take into account some functioning constraints, and the losses between stored and retrieved energies.

Business models for storage are often categorised by the nature of the main target service, distinguishing between a deregulated-driven business model (income from activities in electricity markets), and a regulated-driven business model (income from regulated services). The CBA will not account for these differences[56]. As for transmission, it will yield monetised benefits of storage using a perfect market assumption (including perfect foresight), and account for non-monetised benefits using the most relevant physical indicators.

The characterisation of the impact of storage projects can be evaluated in terms of added value for society as improvement of security of supply, increase of capacity for trading of energy and balancing services between bidding areas, RES integration, variation of losses and CO_2 emission, resilience and flexibility. The remainder of this Annex will describe the assessment of storage in the same way the CBA indicators were applied in the main document

B1. Security of supply: Energy storage may improve security of supply by smoothening the load pattern ("peak shaving"): increasing off-peak load (storing the energy during periods of low energy demand) and lowering peak load (dropping it during highest demand periods).Market studies will account for the value provided at the level of a European Region (specific cases of very large storage devices). These global analysis will be

[55] At least 225 MW and 250 GWh/year as defined by the published EC Regulation (EU) No 347/2013

[56] It should be noted the following the regulatory systems, the owners of storage will not be likely to capture the full value of storage. Hence, in some countries, a TSO owner will not be able to capture any arbitrage value, whereas a private owner will not be able to capture any system service value.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

completed by Network studies, enabling to assess this service in regional networks, not represented in market studies. Both will be measured as variations in EENS or LOLE.

B2. Socio-economic welfare: The impact of storage on socio-economic welfare is the main claimed benefit of large-scale storage. In fact the use of storage systems on the network can generate opportunities in terms of generation portfolio optimisation (arbitrage) and congestion solutions that imply cost savings on users of whole transmission system. Market studies will be able to assess this value based on an hourly resolution, which is consistent with current market models. Indeed, storage can take advantage of the differences in hourly peak and off-peak electricity prices by storing electricity at times when prices are low, and then offering it back to the system when the price of energy is greater, hence increasing socio-economic welfare.

B3. RES integration: Storage devices provide resources for the electricity system in order to manage RES generation and in particular to deal with intermittent generation sources. As for transmission, this service will be measured by avoided spillage, using market studies or network studies, and its economic value is internalised in socio-economic welfare.

B4. Variation in losses: Depending on the location, the technology and the services provided by storage may increase or decrease losses in the system. This effect is measured by network studies.

B5. Variation in CO_2 emissions: As for transmission, the CO_2 indicator is directly derived from the ability of the storage device to impact generation portfolio optimisation. Its economic value is internalised in socio-economic welfare.

B6. Technical resilience/system safety: Electricity storage systems can be employed to control power fluctuations and to improve management of large incidents occurring on power transmission structures, providing voltage support or frequency regulation. As for transmission, specific studies or expert assessments will help evaluating these effects.

B7. Flexibility: As for transmission, the ability of storage to provide value for society across various scenarios may be assessed. Moreover, storage can provide balancing services[57] as an alternative or complement to energy arbitrage.

Storage also has costs and environmental impact. The same indicators as in the main document will be used.

C.1. Total project expenditure of storage includes investment costs, costs of operation and maintenance during the project lifecycle as well as environmental costs (compensations, dismantling costs etc.).

---

[57] See Annex Annex 5

S.1. Environmental impact: The environmental impact of a storage project is different from transmission, and highly dependent on technology. The assessment must take into account national legal provisions regarding environmental impact assessment and mitigation measures.

S.2. Social impact: The social impact of a storage project is different from transmission, and highly dependent on technology.The assessment must take into account national legal provisions regarding social impact assessment and mitigation measures.The CBA of storage will use the same boundary conditions, parameters, overall assessment and sensitivity analysis techniques as the CBA for transmission. In particular, the TOOT methodology implies that the assessment will be carried out including all storage projects outlined in the TYNDP, taking out one storage project at the time in order to assess it benefits.

The methodology performed shall be used for storage project appraisals carried out for the TYNDP and for individual storage project appraisals undertaken by TSOs or project promoters.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

11 ANNEX 7: ENVIRONMENTAL AND SOCIAL IMPACT

A stated in chapter 1, the main objective of transmission system planning is to ensure the development of an adequate transmission system which:

- Enables safe system operation;
- Enables a high level of security of supply;
- Contributes to a sustainable energy supply;
- Facilitates grid access for all market participants;
- Contributes to internal market integration, facilitates competition, and harmonisation;
- Contributes to improving the energy efficiency of the system.
- Enables cross-country transmissions

The TYNDP highlights the way transmission projects of European Significance contribute to the EU's overall sustainability goals, such as CO_2 reduction or integration of renewable energy sources (RES). On a local level, these projects may also impact other EU sustainability objectives, such as the EU Biodiversity Strategy (COM 2011 244) and landscape protection policies (European Landscape Convention). Moreover, new infrastructure needs to be carefully implemented though appropriate public participation at different stages of the project, taking into account the goals of the Aarhus Convention (1998) and the measures foreseen by the Regulation on Guidelines for trans-European energy infrastructure (EU n° 347-2013).

As a rule, the first measure to deal with the potential negative social and environmental effects of a project is to avoid causing the impact (e.g. through routing decisions) wherever possible. Steps are also taken to minimise impacts through mitigation measures, and in some instances compensatory measures, such as wildlife habitat creation, may be a legal requirement. When project planning is in a sufficiently advanced stage, the cost of such measures can be estimated accurately, and they are incorporated in the total project costs (listed under indicator C.1).

Since it is not always possible to (fully) mitigate certain negative effects, the indicators 'social impact' and 'environmental impact' are used to:

- indicate where potential impacts have not yet been internalized i.e. where additional expenditures may be necessary to avoid, mitigate and/or compensate for impacts, but where these cannot yet be estimated with enough accuracy for the costs to be included in indicator C.1.
- indicate the *residual* social and environmental effects of projects, i.e. effects which may not be fully mitigated in final project design, and cannot be objectively monetised;

Particularly in the early stages of a project, it may not be clear whether certain impacts can and will eventually be mitigated. Such potential impacts are included and labelled as *potential impacts*. In subsequent iterations of the TYNDP they may either disappear if they are mitigated or compensated for, or lose the status of *potential* impact (and thus become *residual*) if it becomes clear that the impact will eventually not be mitigated or compensated for.

When insufficient information is available to indicate the (potential) impacts of a project, this will be made clear in the presentation of project impacts in a manner that 'no information' cannot be confused with 'no impact'.

In its report on *Strategic Environmental Assessment for Power Developments*, the International Council on Large Electric Systems (CIGRÉ, 2011) provides an extensive overview of factors that are relevant for performing Strategic Environmental Assessment (SEA) on transmission systems. Most indicators in this report were already covered by ENTSO-E's cost-benefit analysis methodology, either implicitly via the additional cost their mitigation creates for a project, or explicitly in the form of a separate indicator (e.g. CO_2 emissions). Three aspects (‘biodiversity’, ‘landscape’, and ‘social integration of infrastructure’), however, could not be quantified objectively and clearly via an indicator or through monetisation. Previously, these were addressed in the TYNDP by an expert assessment of the risk of delays to projects, based on the likelihood of protests and objections to their social and environmental impacts. Particularly for projects that are in an early stage of development, this approach improves assessment transparency as it provides a quantitative basis for the indicator score.

To provide a meaningful yet simple and quantifiable measure for these impacts, the new methodology improves on this indicator by giving an estimate of the number of kilometres of a new overhead line (OHL), underground cable (UGC) or submarine cable (SMC) that might have to be located in an area that is sensitive for its nature or biodiversity (environmental impact), or its landscape or social value (social impact) (for a definition of "sensitive": see below).

When first identifying the need for additional transmission capacity between two areas, one may have a general idea about the areas that will be connected, while more detailed information on, for instance, the exact route of such an expansion is still lacking, since routing decisions are not taken until a later stage. In the early stages of a project it is often thus difficult to say anything concrete about the social and environmental consequences of a project, let alone determine the cost of mitigation measures to counter such effects. The quantification on these indicators will thus be presented in the form of a range, of which the ‘bandwidth’ tends to decrease as information increases as the project progresses in time. In the very early stages of development, it is possible that the indicators are left blank in the TYNDP and are only scored in a successive version of the TYNDP when some preliminary studies have been done and there is at least some information available to base such scoring upon. A strength of this type of measure is that it can be applied at rather early stages of a project, when the environmental and social impact of projects is generally not very clear and mitigation measures cannot yet be defined. In subsequent iterations of the TYNDP, as route planning advances and specification of mitigation measures becomes clearer, the costs will be internalised in ‘project costs’ (C.1), or indicated as ‘residual’ impacts.

Once one has a global idea of the alternative routes that can be used, a range with minimum and maximum values for this indicator can be established. These indicators will be presented in the TYNDP along with the other indicators as specified in ENTSO-E's CBA methodology, with a link to further information. The scores for social and environmental impact will not be presented in the TYNDP by means of a colour code. These impacts are highly project specific and it is difficult to express these completely, objectively, and uniformly on the basis of a single indicator. This consideration led to the use of "number of kilometres" as a measure to provide information about projects in a uniform manner, while respecting the complexity of the underlying factors that make up the indicators. Attaching a colour code purely on the basis of the notion "number of kilometres" would imply that a "final verdict" had been passed regarding social and environmental sensitivity of the project, which would not be right since the number of kilometres a line crosses through a sensitive area is only one aspect of a project's true social and environmental impact.

Considering that translating the project score to a colour code would make the indicator appear to be simpler and more objective than it actually is, and would undermine its main intention, which is to provide full information to decision makers and the public, scoring is carried out in the following manner:

Assessment system for residual environmental impact

- Stage: Indicate the stage of project development. This is an important indication for the extent to which environmental impact can be measured at a particular moment.
- Basic notion: amount of km that might have to run "in" sensitive areas. An area can be sensitive to (nearby) infrastructure because of the potential effects this infrastructure will have on nature and biodiversity[58]
- Type of sensitivity: Define why this area is considered sensitive.

Example:

Project	Stage	Impact Potentially crosses environmentally sensitive area (nb of km)	Typology of sensitivity	Link to further information
A	Planned	Yes (a. 50 to 75 km; b. 30 to 40 km)	a. Birds Directive; b. Habitats Directive	e.g. Big Hill SPA www.…
B	Design & permitting	No		www.…
C	Planned	Yes (20 km)	Habitats Directive	www.…
D	Under consideration	N.A	N.A	www.…

58 The EC has formulated its headline target for 2020 that "Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss."

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Assessment system for residual social impact

- Stage: Indicate the stage of project development. This is an important indication for the extent to which social impact can be measured at a particular moment.
- Basic notion: # of km "in" sensitive area. An area can be sensitive to (nearby) infrastructure if it is densely populated or protected for its landscape value.
- Type of sensitivity: Define why this area is considered sensitive.

Example:

Project	Stage	Impact Crosses dense area (nb of km)	Sensitivity Typology of sensitivity	Link to further information
A	Design & permitting	Yes (20 to 40km)	Dense area	www….
A	Planned	Yes (100 km)	European Landscape Convention:	www…
B	Planned	No	Submarine cable	www….
C	Under construction	Yes (50 km)	Dense area, OHL	www….

Definitions:

This section provides an overview of impacts that may qualify an area as environmentally or socially 'sensitive'.

Environmental impact

- Sensitivity regarding biodiversity:
    - Land protected under the following Directives or International Laws:
        - Habitats Directive (92/43)
        - Birds Directive (2009/147)
        - RAMSAR site
        - IUCN key biodiversity areas
        - Other areas protected by national law
    - Land within national parks and areas of outstanding natural beauty
    - Land with cultural significance

Social impact

- Sensitivity regarding population density:
    - Land that is close to densely populated areas (as defined by national legislation). As a general guidance, a dense area should an area where population density is superior to the national

mean.
    - Land that is near to schools, day-care centres, or similar facilities
- Sensitivity regarding landscape: protected under the following Directives or International Laws:
    - World heritage
    - Other areas protected by national law