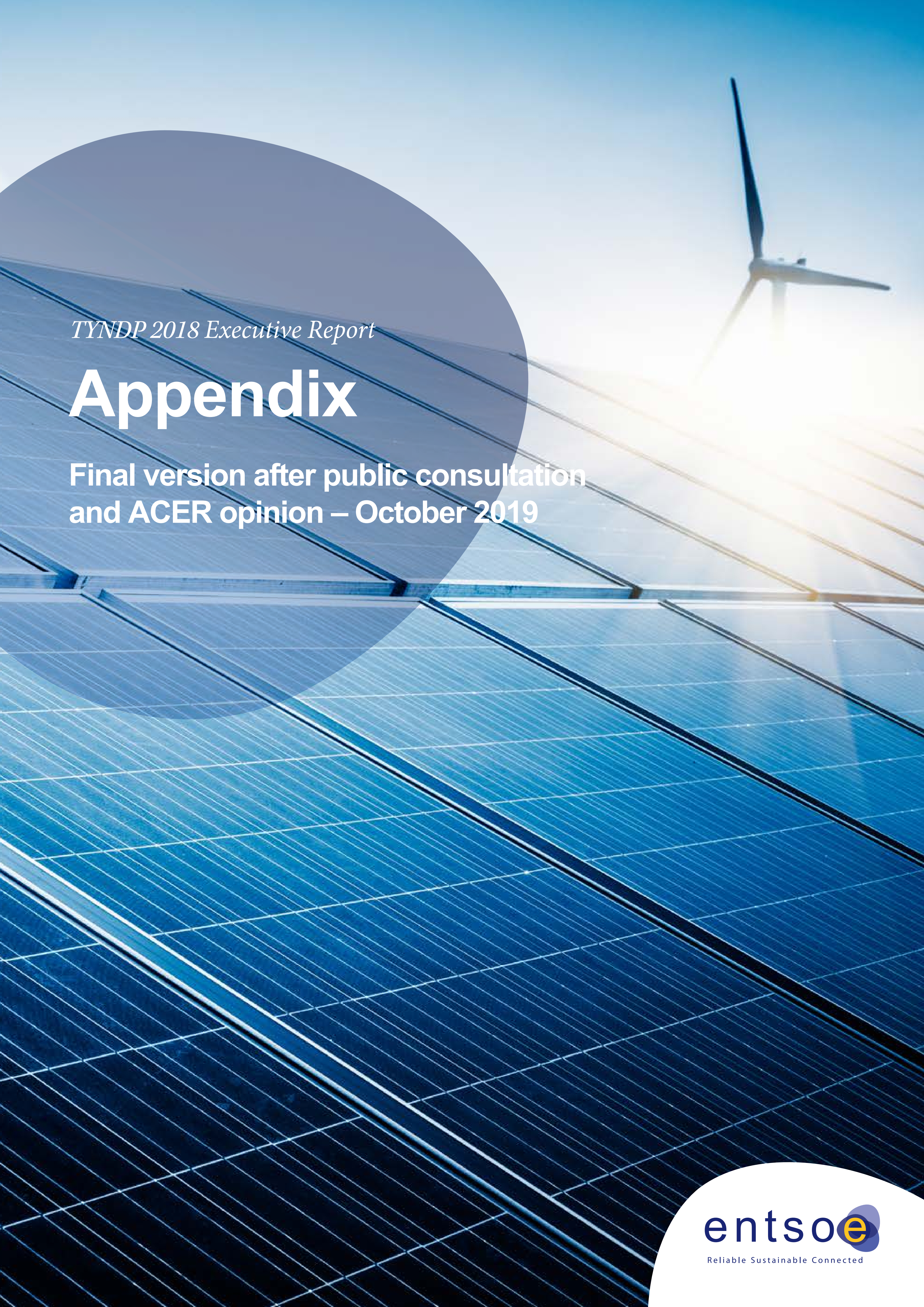


TYNDP 2018 Executive Report

Appendix

Final version after public consultation and ACER opinion – October 2019

entsoe

Reliable Sustainable Connected

Table of contents

Appendix I – Content of the TYNDP package

The TYNDP 2018 package is composed of the following elements. Each of these element goes through a public consultation process. The elements under consultation until 21 September 2018 are highlighted in blue below

- **Executive Report**
  presents the key findings, analysis and methodological elements which are further described in the TYNDP 2018 reports or presented I the project sheets. Explanations on project sheet elements, summarised methodologies, and an introduction to the innovative approaches we tested in the last two years are presented in the Annex.
- **The TYNDP project sheets**
  including for each transmission or storage projects, maps, description, analysis of relevant system needs, CBA results[1] and other information. Accessible through an online portal.
- **The scenario report (released in 2017)**
  presents the TYNDP scenario storylines, results and methodologies built with the gas association ENTSO-G and the contribution of stakeholders representing associations, the industry, policy makers, consumers and research groups.
- **Power system 2040: completing the map (released in February 2018)**
  presents a comprehensive analysis of the infrastructure which Europe would need in 2040 to keep the prices as low as possible and maintain a secure electricity system in a decarbonised world.
- **Six Regional Investment Plans (released in February 2018)**
  present acomprehensive analysis of the future challenges, system needs and proposed developments in six European Regions
- **Insight Report: Data and Expertise as key ingredients**
  gives an overview of the data, formats, and tools applied by ENTSO-E's experts in delivering the TYNDP 2018.
- **Insight Report: Improvements of TYNDP 2018**
  provides a high-level description of the rationale for and the main improvements of this 10-year plan in relation to earlier plans.
- **Insight Report: Available technologies report review TYNDP 2018**
  developed with the contribution of external stakeholders; provides the level of development of a range of transmission technologies and hence their viability for use in network development.
- **Insight Report: Stakeholder Engagement**
  provides an explanation of the engagement process, the forums for this, and how stakeholders influence the formation of the TYNDP and future network developments.
- **Insight Report: CBA Storyline**
  analysis of the difference between the CBA used in TYNDP 2016 and the CBA used in TYNDP 2018.
- **Insight Report: Viability of the Energy Mix**
  how can the proportion of renewable energy generation with extensive energy exchange continuously increase to higher percentages while maintaining secure system operation?

---

[1] A vast majority of TYNDP projects, but not all, were submitted for a cost benefit analysis. For instance, projects which are already under construction, or projects or are not mature enough to be assessed in a meaningful way were not assessed. They are TYNDP projects but do not have CBA results.

- **Regional Insight Report: Nordic and Baltic Sea**
  provides a high-level regional focus on the development needs and current development projects, their impact and effectiveness to meet regional and EU targets and policy. Notably this report looks at the status of Baltic synchronisation.
- **Regional Insight Report: North Sea Offshore Grid**
  provides a high-level regional focus on the development needs and current development projects, their impact and effectiveness to meet regional and EU targets and policy. Notably it looks at the status and interaction of offshore development in the North Sea.
- **Regional Insight Report: North South Interconnection East**
  provides a high-level regional focus on the development needs and current development projects, their impact and effectiveness to meet regional and EU targets and policy. Notably this changing energy mix impact on security of supply (SoS) for the region.
- **Regional Insight Report: North South Interconnection West**
  provides a high-level regional focus on the development needs and current development projects, their impact and effectiveness to meet regional and EU targets and policy. Notably this report looks a changing energy mix impact on SoS for the region.

In addition, the TYNDP 2018 package includes detailed methodologies for each of the studies conducted under the TYNDP umbrella. A detailed, step-by-step guidance to replicate the CBA of the projects will be released by ENTSO-E by October 2018.

ENTSO-E will also release full data-sets on the scenario, system modelled and projects assessed.

ENTSO-E hopes that many users across Europe will find the information useful and will use our work to conduct their own studies. Do not hesitate to let us know about it. We are also available should you need any further details on the methodologies followed or specific data requests.

Appendix II – European maps on price differences

The following European maps in Figure 1 show average hourly price differences for the four different scenarios and three different climate years analysed. Price differences above 2€/MWh are also highlighted as potential interconnection targets.

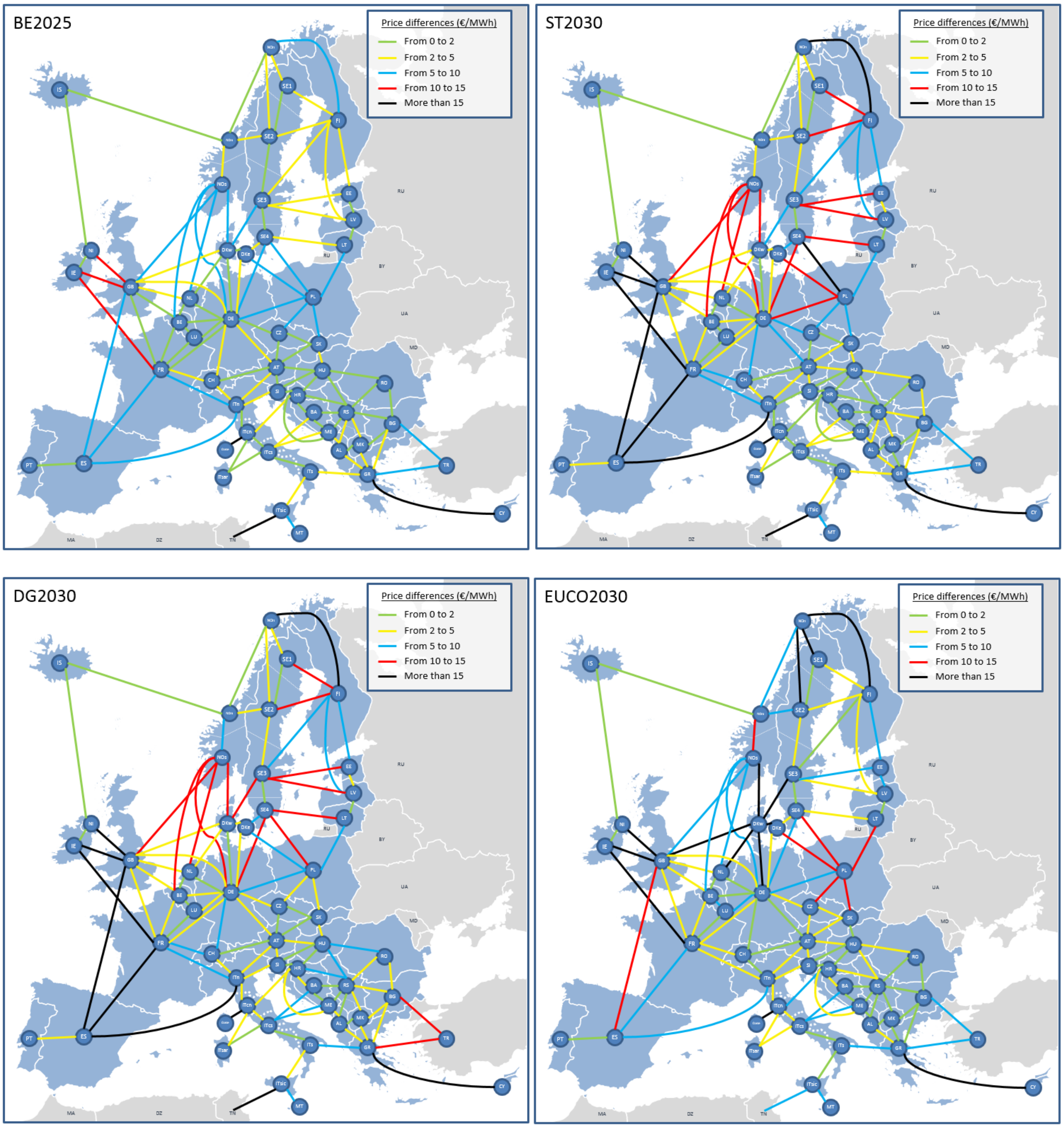


Figure 1: European maps showing average hourly price differences between market areas

Appendix III – Methodology

Methodological details for the system needs 2040 and scenarios development and computation are available in the Identification of Systems Needs Methodology Report.

Project assessment

Second CBA guideline

Regulation (EC) 347/2013 mandates ENTSO-E to draft the European Cost Benefit Analysis methodology which shall be used further for the assessment of the ENTSO-E Ten-Year Network Development portfolio. The Regulation is intended to ensure a common framework for multi-criteria CBA for TYNDP projects, which are the sole basis for the assessment of candidate Projects of Common Interest (PCI).

In addition, the CBA guideline is recommended to be used as the standard guideline for project-specific CBA, as required by Regulation (EU) 347/2013 Article 12(a) for the CBCA process. In this respect, all projects (including storage and transmission projects) and promoters (either TSO or third party) are treated and assessed in the same way.

ENTSO-E drafted the first official CBA methodology during 2013 and 2014, which was consequently approved and published by the European Commission on 5 February 2015.

The first CBA Guideline was used in the TYNDP 2014 (unofficially) and TYNDP 2016 (officially) project assessments. Based on the experience gained from these two applications, as well as the feedback received from external stakeholders, including the European Commission and ACER, ENTSO-E worked during 2015 and 2016 to improve this first CBA Guideline.

The draft second CBA Guideline (referred to as 'CBA 2.0') was then presented to stakeholders during the open workshop on 16 March 2016 and released for public consultation on 25 April 2016 (until 31 May 2016).
These stakeholders had the chance to provide their opinions regarding pre-defined aspects of the CBA, for example:

- The purpose of a European CBA methodology,
- Multi-criteria vs. one figure approach considering the variety of CBA users,
- Ease of use and understanding of the CBA,
- Ease of understanding the computation method for indicators and suggestions for improvements,
- The completeness of the set of indicators covering costs and benefits of a given project,
- Clustering rules,
- SoS indicator,
- Cost indicator,
- Losses indicator, and
- Storage assessment.

As well as opinions on these issues, stakeholders were invited to share their broader vision with ENTSO-E on the draft released for public consultation. Several comments were received from the public consultation relating to the storage projects assessment. Initially, ENTSO-E took these into account by harmonising the assessment of storage and transmission projects, while at the same time giving more specific guidance related to storage projects' contribution to flexibility.

Furthermore, comments were received on the lack of detail in the section on the assessment of System Stability in the SoS. In response, ENTSO-E has improved the respective indicators and added more explanation.

In general, the main changes compared to CBA 1.0 can be summarised as follows:

- Introduction of detailed explanations on Grid Transfer Capability (physical flow) and Net Transfer Capacity (market exchange) while finally reporting the delta Net Transfer Capacity;
- Generalise treatment of storage projects, to align with the evaluation of transmission projects;
- General review of the socio-economic welfare (RES, CO_2, societal well-being) concept and the need to show the part of SEW coming from RES-integration and CO_2 reduction;
- Greater detail on SoS calculations and division of the SoS indicator into three sub-indicators: first – system adequacy (i.e. adequacy to meet demand) (B6); second – system security, i.e. system flexibility (B7); and third – system stability (B8).

The reference grid

Projects in the TYNDP are assessed under assumptions that relate to generation and demand scenarios, and the future development of the network up to the year in which the project is studied (the reference grid). This reference grid (i.e. market model, node-to-node capacities, and network model physical elements) generally has a different topology than the present-day network. This is because new infrastructure will most likely be commissioned between the current year and the study year. The properties of the chosen reference grid generally have a major impact on the assessment.

Ideally, the reference grid reflects the exact state of the network in the future study year. In practice, this is often not clear because the future is uncertain (e.g. entirely new and unforeseen projects may come up between today and the study year, projects may be cancelled, etc.) and projects that are under assessment in the present study may affect each other's assessment results and (later) realisation.

The reference grid should include only capacities that are sufficiently certain (e.g. because projects are already defined and at a mature stage of development), while not being too conservative (e.g. by excluding capacities that can be reasonably expected to exist in the study year). It should include the present-day network and all projects that are in their final stage of development, which is defined as when the first construction permits have been obtained. Thus, all projects should be in the reference grid if they have a commissioning date before (including) 31.12.2030, according to one of the following requirements:

- Its project status is “commissioned”
- Its project status is “under construction”
- Planned projects able to prove by written acknowledgement by a competent body that application to the permitting phase has started (similar to the pre-application phase defined for PCIs defined in TEN-E).

This should keep the reference network limited to only those projects whose realisation is reasonably certain.

➢ Main changes between the first and second CBA guideline

In general, the following main changes can be summarised as follows:

- The treatment of storage projects was further generalised to align with the evaluation of transmission projects:
    - all projects, transmission and storage, are assessed using the same methodology
    - some specific benefits of storage projects have been highlighted and included.
- General review of the SEW (RES, CO_2, societal well-being) concept;
    - the SEW indicator is now labelled as B1 and shows as additional information the part that comes from RES integration and CO_2 reduction in monetary values
    - RES integration in *MW/MWh* and CO_2 reduction in *t* are given under B2 and B3
    - a new indicator was introduced under B4 – Societal well-being that includes the relationship between integrating RES and avoiding CO_2 emissions and the impact on societal well-being, such as long-term strategic energy-independence objectives, limiting the increase in global temperature and sea-level rise, or the effects from changed land use, etc.
- More details on SoS calculations were included and the SoS indicator was divided into three sub-indicators:
    - System adequacy, i.e. adequacy to meet demand (B6)
    - System security, i.e. system flexibility (B7)
    - System stability (B8).

For a more detailed overview of the changes from the first to the second CBA guideline, please see the accompanying documents that are included in the “Second CBA Guideline Package”.

Choice of climate years

Please see the IoSN Technical Appendix.

The CBA analysis performed in TYNDP 2018 have been developed in three different climate conditions selected in a climatic database of 34 different time series (Pan- European Climate Database - PECD) provided with the cooperation of Météo-France and the Technical University of Denmark. The time series available for the years between 1984 and 2014 are related to:

- precipitation
- wind
- temperature and/or
- exposure to sun.

To summarise, the climate years have been determined as being optimum and sufficiently adequate to demonstrate the impact of 34 climatic years on the results. The rationale for this is discussed in further detail below.

In order to select a limited number of climate conditions to be used in the analysis[5], “means clustering” analysis has been applied.

“*k-means clustering*” is a method of vector quantisation, originally from signal processing, that aims to partition *n* observations (living in an m-dimensional space) into *k* clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster.

The method is based on an iterative algorithm that divides the data into *k* groups so that observations within a group are similar whilst observations between groups are different. After each iteration, a parameter, R^2, is evaluated to indicate the proportion of the variance in the dependent variable that is predictable from the independent variable. The closer R^2 is to 1, the more representative the clustering is.

The main advantage is that it will yield *k* climate years that best represent all of the 34 climate years available in PECD.

In the specific framework of TYNDP 2018, the algorithm has been performed on four dimensions (load, wind, solar and hydro inflow) and by considering different zones aggregation, as reported in the following table:

Table 1 – regions defined

Macro Region	Zones										
Scandinavia	DKe	DKkf	DKw	FI	NOm	NOn	NOs	SE1	SE2	SE3	SE4
Baltic Countries	LV	EE	LT								
Central West 1 FR-BE-NL	BE	FR	NL								
Central West 2 DE - CH - AT -LU	DE	DEkf	AT	CH	LUb	LUf	LUg	LUv			
South West	ES	PT									
Central East	CZ	SK	HU	PL	RO						
GB+IE	GB	IE	NI								
South East	GR	CY	BG	MK	ME	MT	HR	SI	RS	AL	BA
South Central	ITcn	ITcs	ITn	ITs	ITsar	ITsic					

In addition:

- n = number of climate years (34 in this case);
- k = target number of climate years.

The input data are, for each year, and for each region: the difference between the value and the average of all years.

According to the data available and the feasibility of the work plan, three clusters (see Figure 2) have been considered at the end, as reported in the following figure (R^2 = 0.55). Each cluster will also be allocated a weight on the base of the number of years included in the same cluster. Inside the clusters, the different years can be considered with the same representation.

Therefore, to select the reference year, the most recent improvements in the technology and the quality of climatic surveys has been considered.

---

[5] The need to limit the number of climate conditions was to guarantee the feasibility of the overall TYNDP 2018 process work plan.

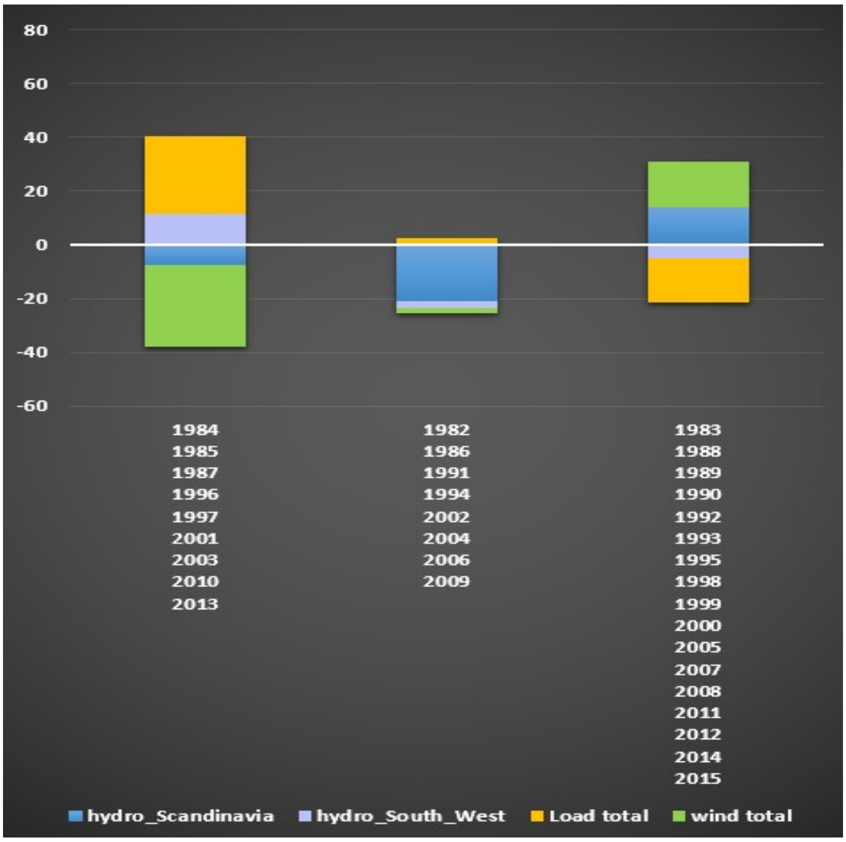


Figure 2: Definition of clusters

Market studies approach

Market studies are used to calculate the dispatch of generation units and load across the year on an hourly basis, using a very simplified model of the physical grid (this model is shown diagrammatically in Figure 10.4.2.2). This model uses bidding areas through a network of interconnected nodes and a single branch to represent the physical interconnections that exist between each pair of bidding areas. The main advantage of this approach is the possibility to highlight the structural, rather than incidental, bottlenecks and to measure the economy in generation costs enabled by investments in the grid (or in storage).

The purpose of these market studies is to investigate the impact of the new interconnection projects by comparing two different grid situations in terms of economic efficiency, the ability of the system to schedule plants to their intrinsic merit-order, the overall resulting variable generation costs as well as the overall amount of CO_2 emissions and volumes of energy that cannot be utilised or is ‘spilled’.

These studies are performed from a consistent dataset[6] for all ENTSO-E countries and every scenario. The datasets and assumptions of electricity demand, generation, fuel and CO_2 prices are harmonised, as well as the modelling of RES with the use of the PECD.

In order to perform this type of study, the system is modelled (see Figure 3) considering a single node in each country, with the exception of the following countries:

- Denmark
- Italy
- Luxembourg
- Norway
- Sweden

An economic optimisation, which assumes perfect market behaviour, is conducted for every hour of the year taking into account several constraints. These include flexibility and availability of thermal units, wind and solar profiles, load profile and transmission capacities between countries (no internal constraint within the node) .

In some cases, the modelling may be more complex with multiple interlinked restrictions driven by the structure of the grid. Total import or export possibilities for a country may be lower than the total capacity on all borders as both exchanges capacities may not be achieved simultaneously.

Three different climate years (1982, 1984 and 2007) have been considered for each scenario.

Several tools are used in parallel to take advantage of the beneficial capabilities of each (e.g. detailed modelling of hydro, detailed modelling of CHP, etc.) to guarantee the robustness of the CBA results, specifically:

- Antares
- Bid
- Powrsym
- Plexos
- Pymas
- Promed
- JMM

Results provided by the different tools have been compared and analysed by experts to identify possible mistakes and inconsistencies.

---

[6] http://tyndp.entsoe.eu/maps-data/

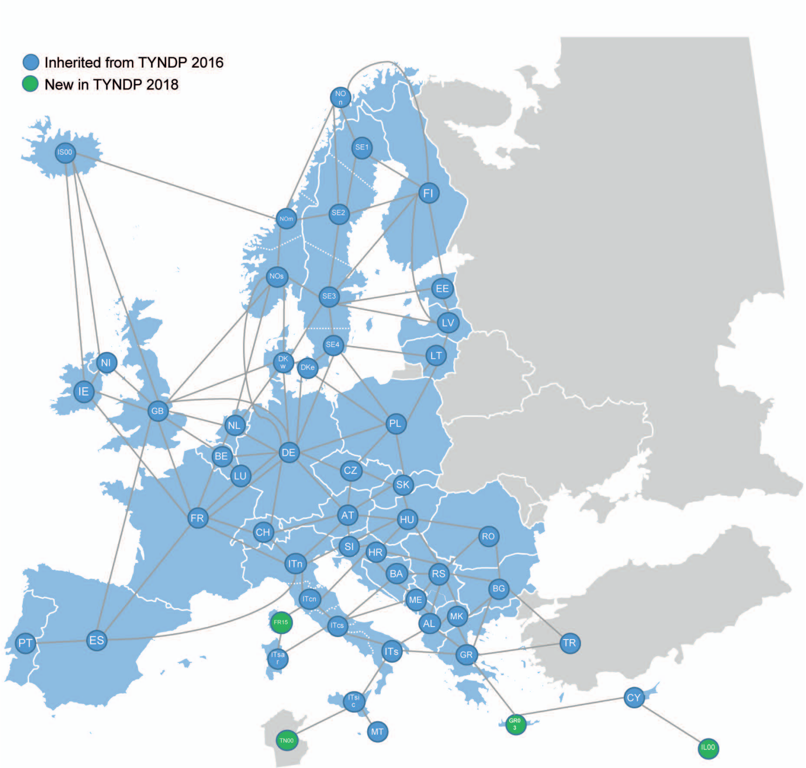


Figure 3: Market modelling representation

Network studies approach

Network study methodology

Network studies are based on the merging of national grid models. Models were merged per synchronous zone. Continental Europe was entirely modelled using three tools: Convergence, Integral7 and PSS\E. A merged model for Baltic countries and a merged model for the Nordic countries were also available. The Great Britain model was separate, as was Ireland/Norther Ireland.

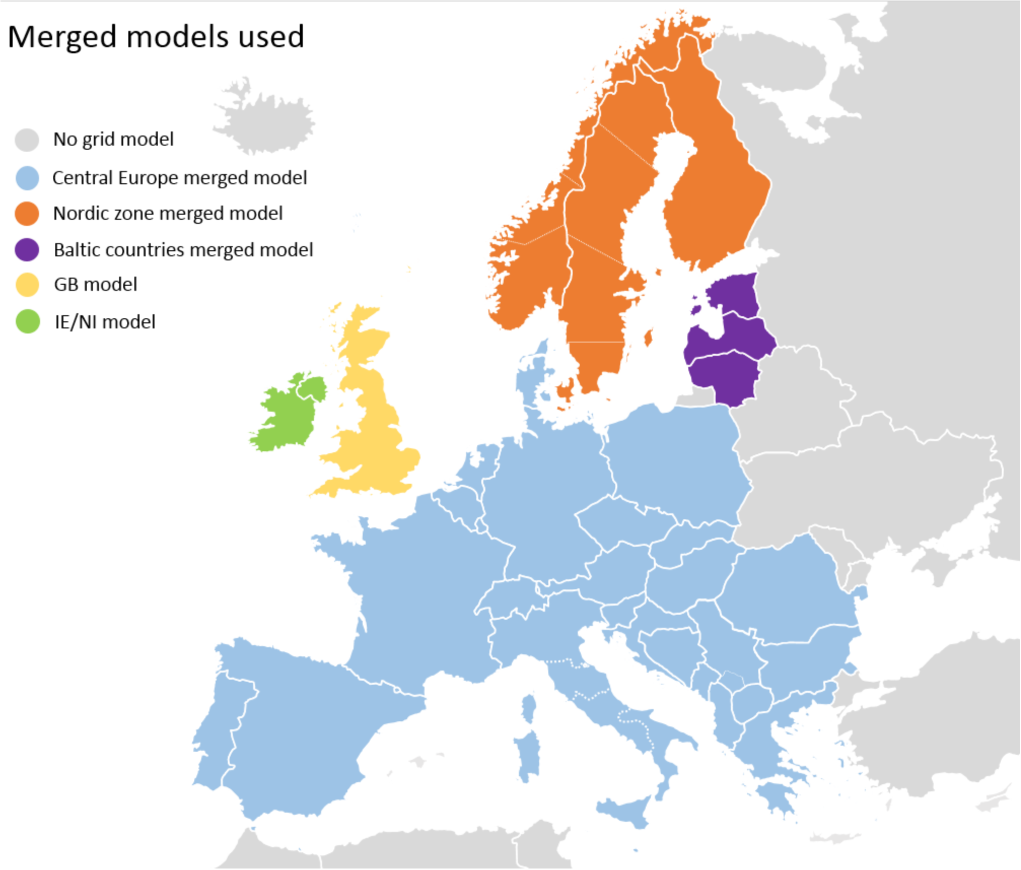


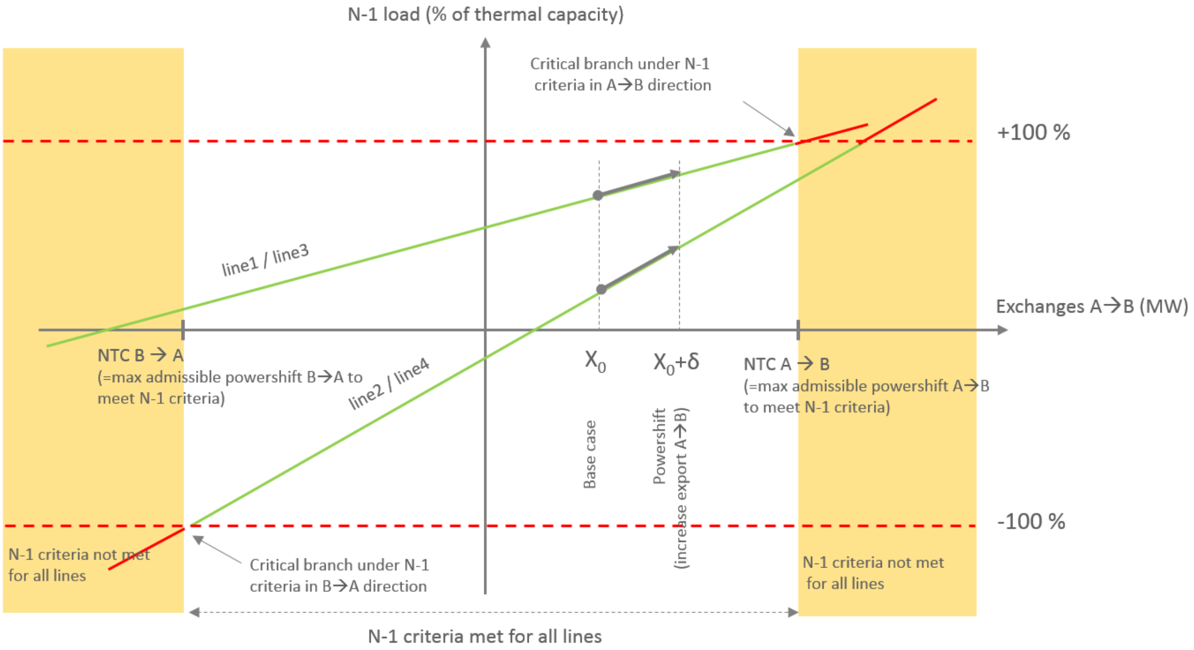
Figure 4: Merged models used

These models have been built from a consistent database. One model per scenario has been built to describe accurately the generation portfolio which differs (significantly sometimes) from one scenario to another.

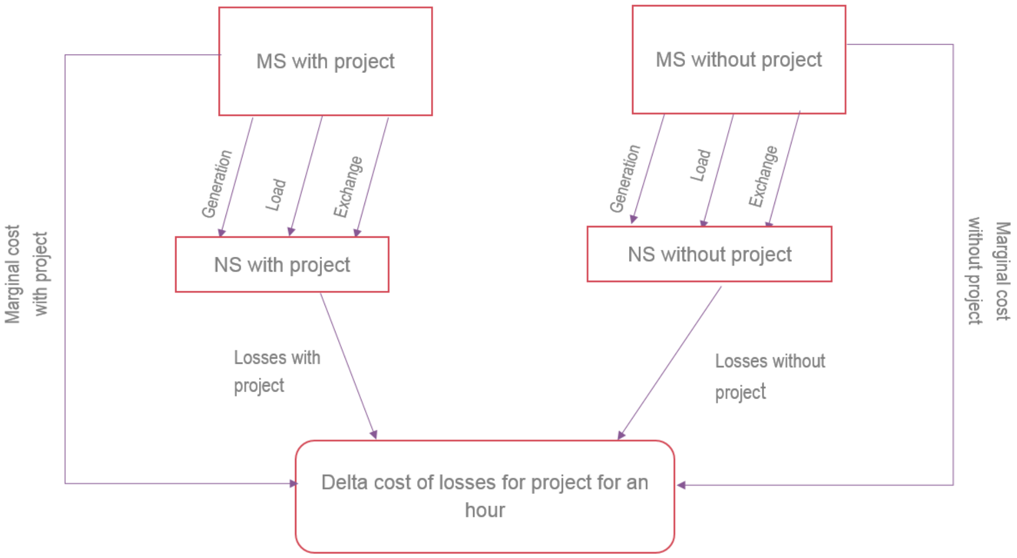
The network experts checked how the grid is loaded on an hour-by-hour load-flow basis. The simulations covered the whole year. The inputs comprise the market results on the climate year 2007 which is the most representative of the three climate years assessed by the marketing team. The detailed market results, hour by hour, country by country, fuel type by fuel type, enable the market behaviour to be implemented in a detailed way inside the grid model. This task was done using automatic scripts.

Before starting the computations, a test was performed on one project by all the simulators and the results provided by different tools were compared and analysed by experts in order to identify possible mistakes and inconsistencies. The volume of work was then shared among the simulators identified .

The network experts checked the delta NTC in N-1 conditions, which means there is no overload inside the grid even if grid failure occurs. The Delta NTC is computed for each hour of the year, taking into account the initial generation pattern and the critical branch that could differ from one hour to another. The value provided is the maximum valid 30% of the time.



For the computation of losses, only the N condition is considered, while the delta is achieved by comparing the flows (by extension, the losses which are related to the flows) within each element of the grid, with and without the project. The aim is to establish the impact of each individual project.



The monetisation of losses is the biggest improvement in the network assessment compared to the previous TYNDP. During this TYNDP, the losses were monetised on an hour-by-hour basis. Each hourly volume of losses in one country is multiplied by the marginal cost of the country, with and without the project.

As mentioned in the second CBA, the total losses in costs are calculated as the sum of hours h in each country i:

$$p'_{h,i} \cdot s'_{h,i} - p_{h,i} \cdot s_{h,i}\text{ , where}$$

$p'_{h,i}$ (with project) and $p_{h,i}$ (without project) the amount of losses in MWh
$s'_{h,i}$ (with project) and $s_{h,i}$ (without project) the marginal costs in €/MWh for an hour

This hour-by-hour approach may lead to counter-intuitive results; for example, different signs between volume and monetisation of losses. To explain such a result, we can take an example for one hour:

Assuming that Country 1 has dumped energy without the project (marginal cost is 0) and Country 2 has a marginal cost of 42€/MWh, a project between these two countries will help to reduce the energy dumped in Country 1, and Country 2 will incur a lower marginal cost by importing cheap energy from Country 1.

Project x	Country 1 losses GWh	Country 2 losses GWh	Country 1 MC €/MWh	Country 2 MC €/MWh
Without project	10	9	0	42
With project	12	10	0	36

Project x	Delta Losses GWh	Delta Losses €
Result With - Without	3	-18000

Losses are increased in both countries but by applying the formula mentioned in the second CBA, the monetised delta of losses is negative. Losses for the importing country should also decrease if the generation coming from an exporting country is closer to demand than the generation used initially, without the project, in the importing country.

As regards the computation of losses for projects connecting two synchronous zones (GB to the continent, for example), several simulators (one per synchronous zone) performed simulations on their model. The results were then combined, taking care to avoid double counting – for example, on the interconnections between the models.

Proposed methodology for the monetisation of the adequacy benefit of the SoS of TYNDP projects

Introduction

In the framework of the TYNDP2018, a methodology to monetise the adequacy component of the SoS benefit (B6 from CBA Guideline) of TYNDP projects was proposed and deployed. The approach calculates the expected energy not served (EENS) savings due to a project and monetises the saving using the value of lost load (VOLL). It allows for separate and complementary assessments of SEW and SoS.

The methodology has been applied to the TYNDP18 scenarios by a dedicated task force using the ANTARES and Plexos market/adequacy modelling tools. It incorporates adequacy assessment approaches that have been developed and extensively tested in the ENTSO-E Mid-Term Adequacy Forecast (MAF). The methodology utilises the following main steps:

1. Remove the project from the set-up if it is present in the TYNDP base case.

2. Adapt the portfolios in the two interconnected regions to a given generation adequacy standard[7].
3. Run the model with multiple climate years and forced outage patterns and calculate EENS.
4. Add the project to the model and rerun simulation to recalculate EENS.
5. Multiply the change in EENS by the VOLL[8] to give the monetised benefit.
6. Conduct a sanity check by assessing how much peak generation capacity the project could save.

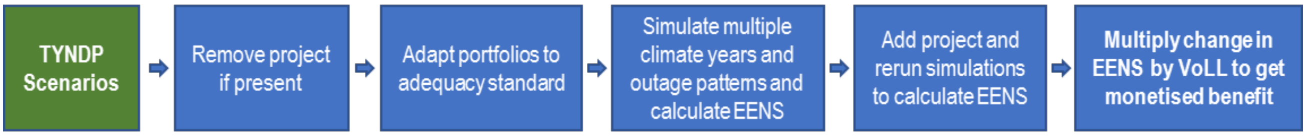


Figure 5: Project SoS monetisation methodology steps

The two modelling tools (ANTARES and Plexos) give stable results with very good convergence. A sanity check is carried out by comparing results with an investment reduction approach method. The capacity benefit realised by a project can be of the same order of magnitude as the socio-economic welfare (SEW) benefit[9]. That is, the SoS benefit can be a very significant component of the overall project benefit. This methodology appropriately monetises that benefit and is consistent with the welfare monetisation calculation specified in the "Implementation guidelines for TYNDP18 based on the 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects". The following sections outline the approach, including background, input assumptions, modelling set-up and methodology steps.

Presentation of the method

There are a number of potential approaches to generation adequacy assessments. These include deterministic, probabilistic and Monte-Carlo. The Mid-Term Adequacy Forecast utilises a Monte-Carlo approach as it is considered to be the "*state-of-the-art technique to represent probabilistic variables such as climate data and unplanned outages in electricity market models*"[10]. This adequacy assessment approach is favoured by the European Commission[11].

When performing adequacy assessments, it is important to model a large number of potential demand and generation availability scenarios. Demand scenarios are modelled using the regional demand profiles associated with the 34-climate-year demand dataset developed for the TYNDP (and MAF). These profiles include examples of expected demand in each region during extreme weather events. A wide range of generation availability scenarios is modelled by simulating multiple forced outage patterns. Variations in the availability of renewable resources such as hydro, wind and solar are captured by using the associated resource profiles for each climate year. Network availability may also be modelled through outage patterns. The demand and renewable profiles for each climate year have already been prepared for the

---

[7] Not all countries have a defined LOLE standard - portfolio adaptations are discussed in the Methodology Steps section.

[8] Monetisation will be sensitive to underlying VOLL assumptions.

[9] There is no double counting as EENS is not valued in the SEW indicator.

[10] Mid-Term Adequacy Forecast 2017 Edition

[11] Identification of Appropriate Generation and System Adequacy Standards for the Internal Electricity Market

TYNDP and applying them in an approach similar to the MAF simulates a wide range of demand and generation availability scenarios, which inherently includes some high-impact low-probability events.

When assessing the generation adequacy benefit of interconnectors, one of the key factors is to assess how simultaneous stress periods occur in the interconnected regions. Where an interconnector connects two regions which are unlikely to face coincident stress periods, it will have a larger benefit than an interconnector between two regions where periods of coincident stress are likely. Stress events in a region are usually driven by high demand and low generation availability and are appropriately modelled using this probabilistic approach.

Inputs and modelling set-up

As discussed, the methodology relies on existing TYNDP2018 scenarios and market models. The models are set up to read in the TYNDP 34-climate-year dataset and many probabilistic simulations are performed, combining (correlated) weather events and forced outage patterns. These simulations are not used for SEW computations, allowing some simplifications in order to decrease computation time. SEW computations describe average behaviours, so that far fewer simulations are needed to accurately measure it. As a result, SEW and SoS savings analyses may be separately computed. Simulation times can be large, but parallel processing functionality/multiple computers can be utilised as Monte-Carlo year simulations are independent.

Methodology steps

This section gives some more details for each of the steps involved in the methodology.

- TYNDP market models are used as base models for assessment. Depending on the model, some set-up may be required to incorporate the ENTSO-E 34-climate-year demand and renewable dataset and multiple forced outage patterns. Some models may already be set up for this.

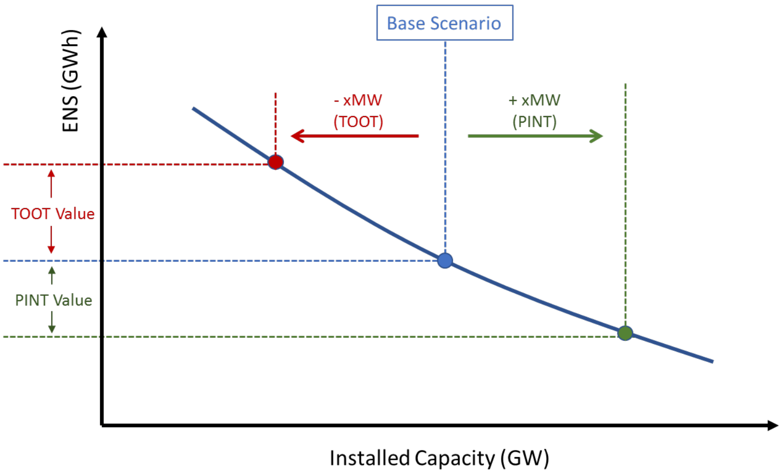


Figure 6: Illustration of the variance of EENS with installed capacity and the TOOT vs. PINT approaches

- As the relationship between EENS and installed capacity in a region is non-linear the SoS benefit of a project will depend on the initial level of loss of load expectancy (LOLE) in each region. As has been observed in previous TYNDP studies, if a region has a large generation surplus the addition of extra generation or interconnector capacity brings little additional SoS benefit. On the other hand, if a country initially has a too high LOLE that would not be accepted by the country, the assessment of the EENS saved could be biased because of the sensitivity it has to the initial LOLE.

Given the above, it is preferable to bring the interconnected regions to a predefined generation adequacy standard prior to the benefit assessment[12]. If regions have a defined LOLE adequacy standard this is used and if no defined standard is available for a region 3hrs has been be used.

Bringing the interconnected regions to an adequacy standard has been achieved by the removal/addition of peaking generators (e.g. light oil)[13] in the region. As these are peaking units, this adjustment is expected to have a negligible impact on the (SEW). The adjustment is just for adequacy studies and would have no impact on the market studies14

- Once any adaptations have been made, the assessment simulations can be performed. A simulation of each of the 34 climate years with multiple forced outage patterns is performed. The average annual EENS value from all the simulations is used as the measure of EENS without the project.
- The project is then added and the simulations are rerun for the same climate years and forced outage patterns. Again, the average annual EENS value from all these simulations is used as the measure of EENS with the project.
- The change in the EENS caused by the addition of the project is calculated using the results of the previous two steps. The change in EENS (MWh) is multiplied by VoLL (€/MWh) to give the monetised SoS value of the project. This aligns with the welfare loss monetisation calculation specified in the "Implementation guidelines for TYNDP18 based on the 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects".
- A sanity check is performed to account for the fact that maybe, instead of decreasing EENS, the project would lead to decreasing peak power plant capacity. The project effectively avoids these peak power plants investments[15] which can be monetised through avoided investment cost. The exact form of the sanity check performed depends on whether the project benefits more than one country (Case 1) or just one country (Case 2):
  - Case 1 – The interconnector project brings significant benefits to more than one country: In this case, the value is capped at twice the installed capacity of the interconnector multiplied by the cost of peaking capacity. The rationale here is that if there are no

---

[12] The underlying assumption is that the peak generation fleet would have dynamically adapted and reached the standard but that the current scenario building process does not fully take this aspect into account.

[13] Only making adaptations on peaking units to keep the integrity of scenarios, in other words baseload and mid-merit generation assumptions, are considered valid (economically viable, which is supposedly guaranteed by TF scenario building for DG2030, for example).

[14] This has been checked on test projects.

[15] Third countries may be impacted by the project but we assume that, when adding the peak power plants to the two countries, the impact on third countries is at least as good as the project's impact.

coincident scarcity events, from a SoS perspective the interconnector would effectively be as beneficial as the same level of conventional generation installed in each of the two interconnected regions which should act as a cap on the value.

    - Case 2 – The significant project benefits are only on one side of the interconnector:
      In this case, the value is capped at the installed capacity of the project multiplied by the cost of peaking capacity. The rationale here is that if significant benefit is only observed on one side of the interconnector, the value should be capped at the value of the same level of peaking capacity in the country from the beneficial side.

- The sanity check approach set out in the previous bullet point enables the systematic assessment of the large number of projects studied. For dedicated/specific studies, there is also potential for a more refined sanity check. Rather than capping the SoS value relative to the size of the project (as set out in Case 1 and Case 2 above) an iterative approach would be used to evaluate the more precise quantity of peaking capacity that would be required to achieve the same level of SoS benefit (LOLE/ENS reduction) as achieved by the project being assessed. This is a more computationally expensive and time-consuming approach, but any values calculated using this enhanced iterative approach could be used as the reported values.

- The assessment strategy has been to use a uniform approach that uses standardised parameters including a uniform VOLL (10,000 €/MWh) and one value for the annualised cost of a peaking unit (40,000 €/MW/Yr). This enables a systematic assessment within the common TYNDP framework. The economic parameters that have been used are set at conservative levels to minimise any risk of overestimation. For dedicated/specific studies, these parameters could be replaced should other appropriate official values be available.

- The minimum value between the monetised EENS saved and the avoided peak generation cost is used as the final reported SoS value for the project.

Overview of the methodology deployment

The methodology described above has been applied within the framework of TYNDP 2018. The paragraphs hereafter illustrate step-by-step the deployment of the method that led to the provision of the B6 alternative values displayed in the project sheet. As the method has been applied in parallel with the existing process and deployed for the first time, it has not been possible to cover the whole project list. However, it is expected that most of the projects showing a potential value from this indicator have been assessed.

Calibration of the simulation

The method uses the reference scenarios as a starting point. The models used in SEW assessment are enhanced with some additional features to enable the robust adequacy assessments.

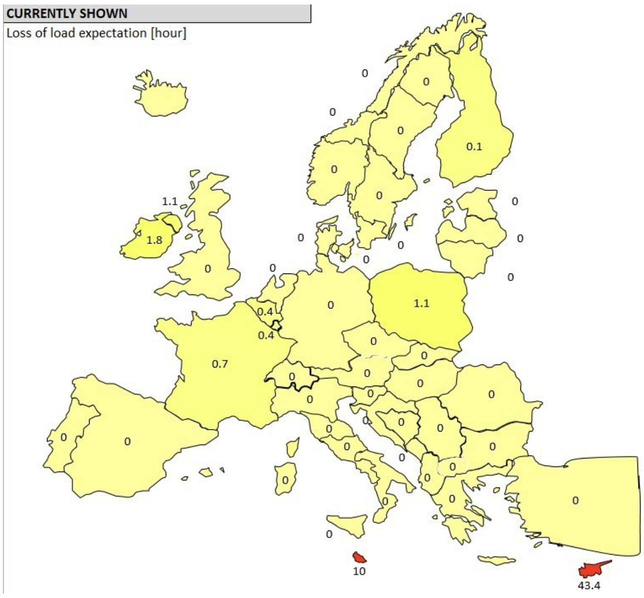
- the full climate database is used (34 climate years vs. 3-9 in the SEW process)
- multiple outage patterns on thermal units and HVDC interconnectors are introduced (randomised).

The simulations are performed over 510 Monte-Carlo years (34 climate years * 15 outage patterns) which enables the robust assessment of standard adequacy indicators[16].

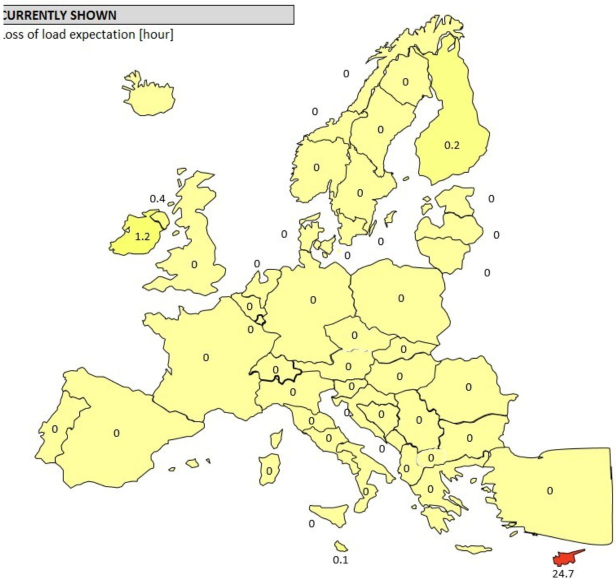
SoS landscape with the reference scenarios (with the starting grid)

Results of the adequacy assessments using the enhanced model are illustrated in the following maps displaying the LOLE (hrs/year) over the 510 Monte-Carlo years simulated for each of the four scenarios/horizons studied within the CBA.

BE 2025



EUCO 2030



---

[16] For adequacy studies within the PAN EU system, it is recommended to extend the Monte Carlo scheme to a couple of hundred simulation years in order to obtain a robust estimate of adequacy indicator such as LOLE or EENS. SEW, on the other hand, does tend to converge more rapidly, allowing the process to be run on a significantly lower number of years.

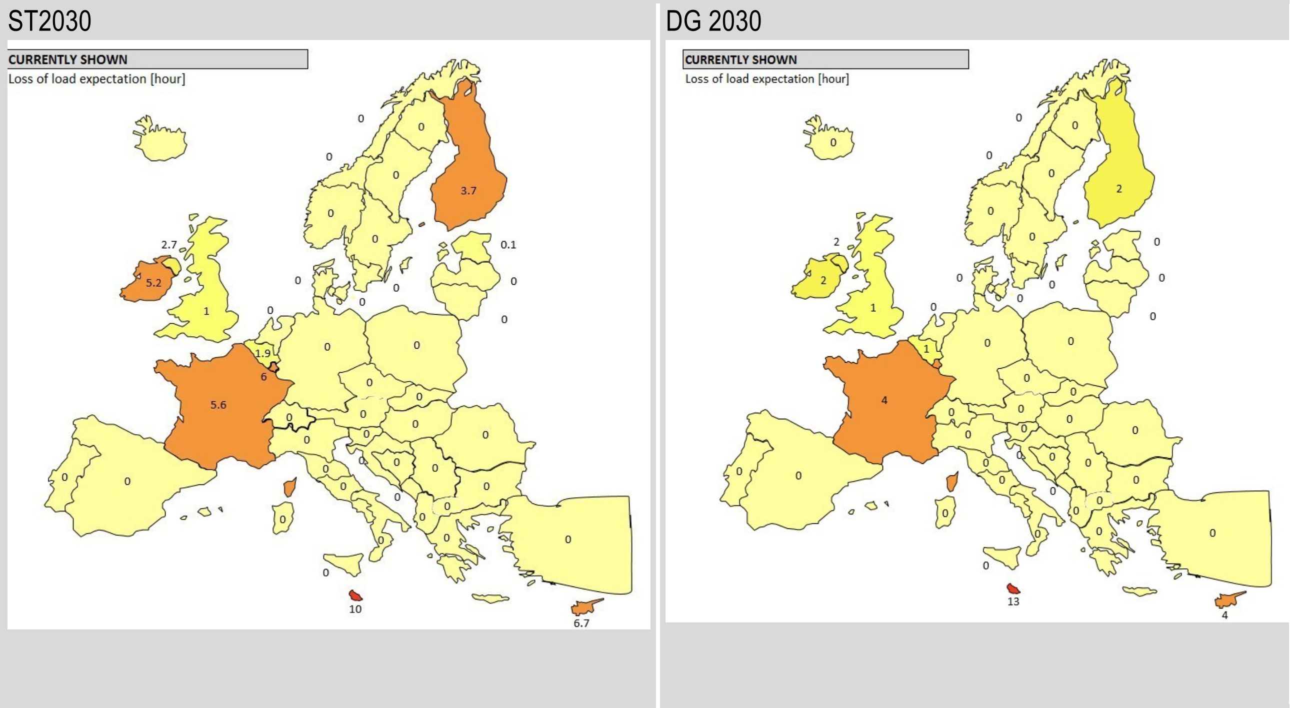


Figure 7: LOLE for the four scenarios

Portfolio adaptation on the starting grid

The role of the generation portfolio adaptation in the reference scenario is two-fold:

- Some countries are exceeding their standard (national value[17] if it exists, default standard LOLE < 3hrs) in the base case. The rationale for the adaptation in this case is that countries will be, at worse, at their standard prior to interconnector arrival. It also tends to find a reasonable SoS value (especially for small countries very sensitive to the starting point).
- Countries having a LOLE of 0 in the base case may have non-viable peaking units (very low running hours).

These adaptations prove necessary as a complementary step to the current scenario-building process which does not take this aspect fully into account[18]. It should also be noted that thermal fleet reduction performed accounts for less than 2% of the total installed thermal capacity in all four scenarios.

The adaptation is made with the TYNDP2018 reference grid, thus enabling a direct assessment of PINT projects. For TOOT projects, it has proven necessary for some projects to readapt the generation portfolio in the situation without the project to better estimate contribution (see methodology and impact of starting point).

The portfolio adaptation is achieved through an iterative process, as illustrated below:

---

[17] e.g. 3 hrs for France, Belgium; 8hrs for Ireland (Republic of Ireland and Northern Ireland).

[18] It is also worthwhile reminding readers that scenarios Best Esimate 2025 and Sustainable Transition 2030 are bottom-up scenarios resulting from the data collection; EUCO 2030 is a scenario provided by the European Commission.

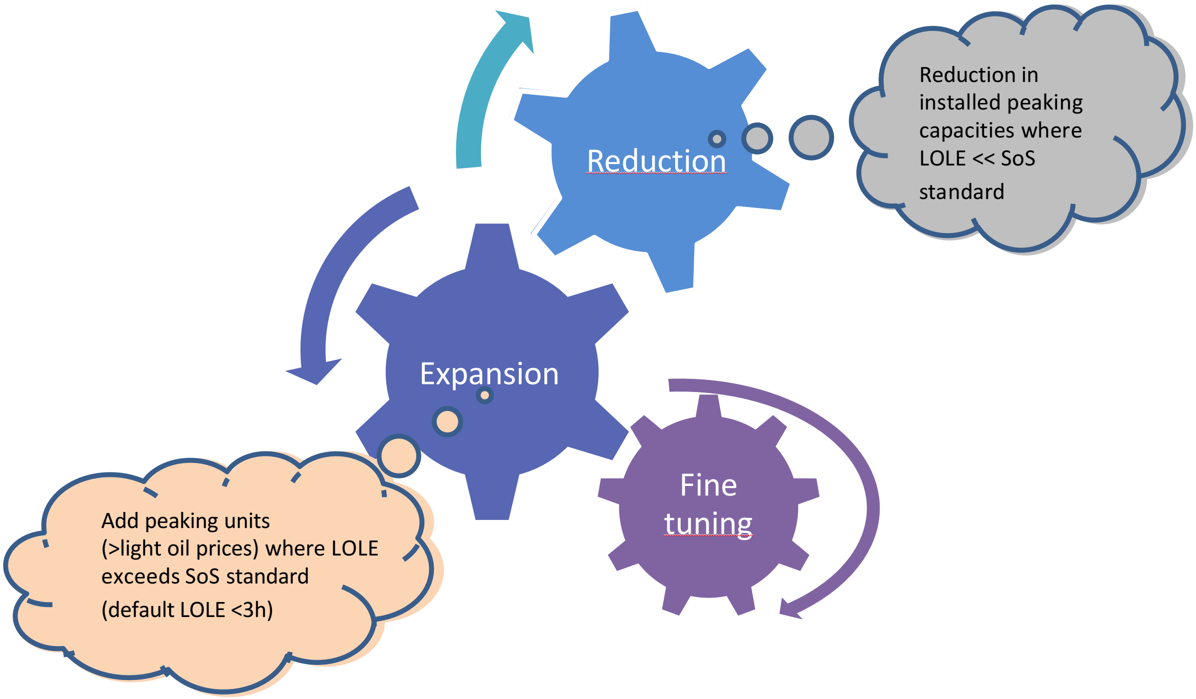
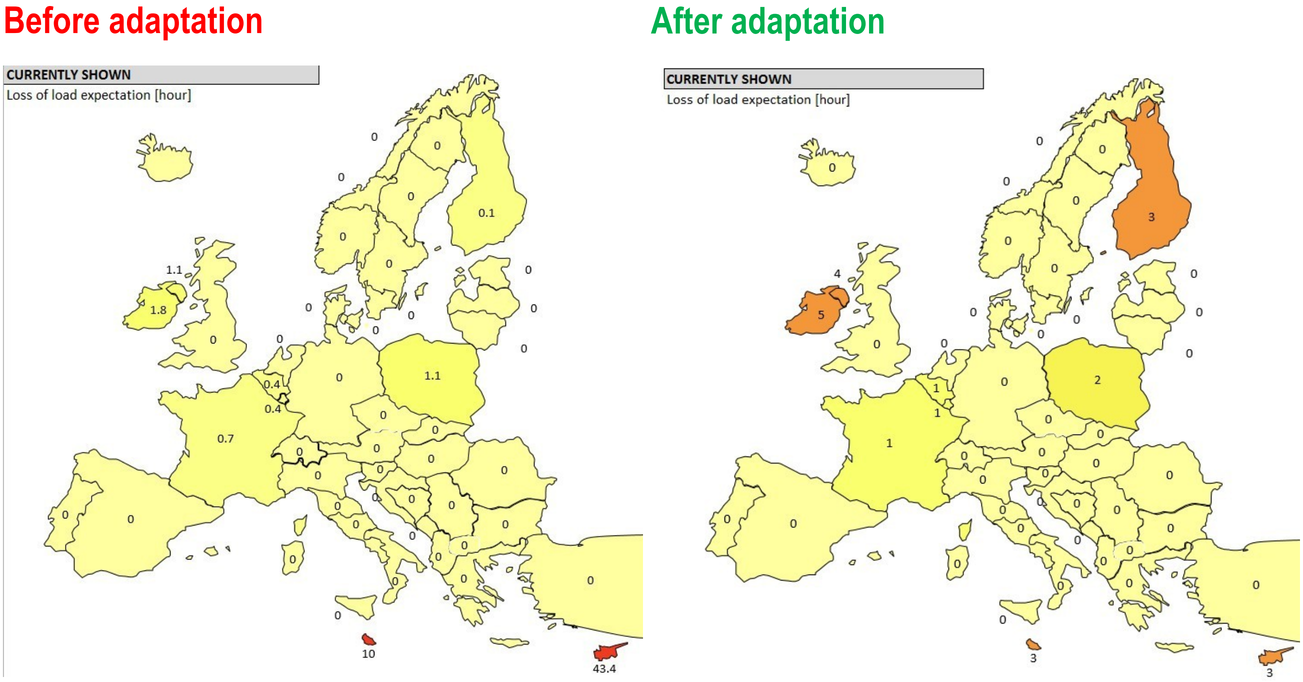


Figure 8: Overview of the generation portfolio adaptation process

A limited number of areas required the addition of peaking capacities to reach their standard (for example, France, Cyprus and Crete).

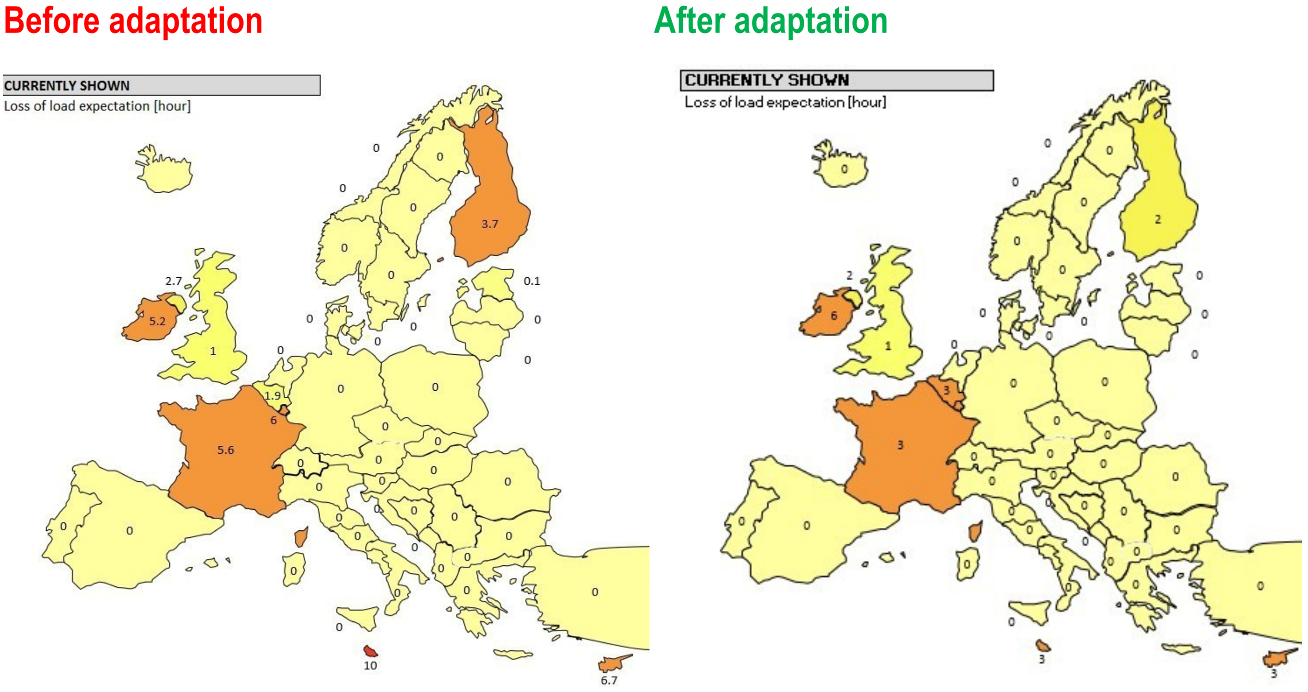
The effect of the portfolio adaptation applied to the whole perimeter for the base case (starting grid) is illustrated for two scenarios in the following figures:



Before adaptation

After adaptation

Figure 9: Effect of the adaptation on the BE 2025 scenario



Before adaptation

After adaptation

Figure 10: Effect of the adaptation on the ST 2030 scenario

Even before the detailed model simulations, an assessment of these maps already gives a good indication of where projects are likely to have significant SoS value. An interconnector project added between two areas (PINT) showing a LOLE at zero is likely to provide little benefit, if any, in terms of ENS savings. Nevertheless, a TOOT project will provide savings whenever the project removal leads to LOLE (ENS) in the areas neighbouring the project.

The portfolio adaptation is limited to peaking units and does not necessarily bring all countries to their or the default adequacy standard. Two potential reasons for this are:

- Some countries structurally have a zero LOLE due, for instance, to large hydro capacities, limited sensitivity to climate conditions, or a very high level of interconnection with hydro-dominated areas.
- It is possible that in some countries a more detailed analysis of the mid-merit generation portfolio could show that there are some potentially non-viable capacities. Given that one of the principles of this methodology was to only make very minor changes to the starting portfolio, no mid-merit generation has been removed.

Monetisation illustration

The monetisation of the detailed simulation results comprises the following steps:

- **Step 1:** The EENS saved in GWh by the project is assessed by calculating the difference in EENS between the two simulations (i.e. without the project/with the project).
- **Step 2:** The EENS saved is monetised using the proposed VoLL of 10,000 €/MWh.
- **Step 3:** A sanity check is performed where the benefit estimated in step 2 is compared to the investment avoided in peaking units to reach the same level of SoS without the interconnector (the annualised cost for a peaking unit is set at 40,000 €/MW/Yr). The exact form of the sanity check performed depends on whether the project benefits more than one country (Case 1) or just one country (Case 2):
    - **Case 1 –** The interconnector project brings significant benefits to more than one country:
      In this case, the value is capped at twice the installed capacity of the interconnector multiplied by the cost of peaking capacity. The rationale here is that if there are no coincident scarcity events, from an SoS perspective, the interconnector would effectively be as beneficial as the same level of conventional generation installed in each of the two interconnected regions, which should act as a cap on the value.
        - Sanity check cap = 2 × MW size of the interconnector (MW) × 40,000 €/MW/Yr
    - **Case 2 –** The significant project benefits are only on one side of the interconnector:
      In this case, the value is capped at the installed capacity of the project multiplied by the cost of peaking capacity. The rationale here is that if significant benefit is only observed on one side of the interconnector, the value should be capped at the value of the same level of peaking capacity in the country from the beneficial side.
        - Sanity check cap = 1 × MW size of the interconnector (MW) × 40,000 €/MW/Yr

The proposed final monetised SoS benefit of the project is the minimum value of the monetised EENS saved and the sanity check cap. The rationale here is that the reported SoS value of the project should not exceed the lowest cost option of achieving the SoS benefit.

In order to illustrate the monetisation process, two simplified three-region examples are given below. Both examples use a 1,000 MW interconnector project between regions A and B. Region C is connected to both A and B. In example 1, all of the three regions appear to benefit from the project and the sanity check cap does not affect the final reported value. In example 2, only two regions appear to benefit from the project and the sanity check cap sets the final reported value.

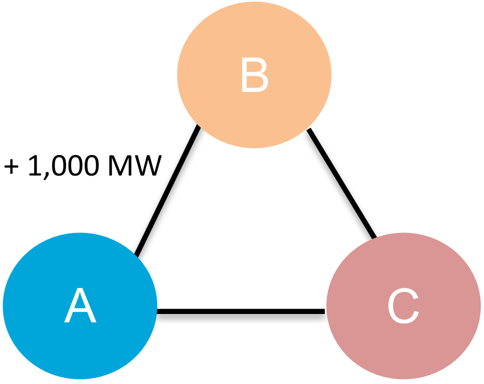


Figure 11: Simplified three-region model used to illustrate the monetisation approach

Example 1 – all three regions appear to benefit from the project: The table below gives the SoS levels (EENS and LOLE) before and after the inclusion of the 1,000 MW interconnector project between regions A and B. In this example, both A and B benefit and even though region C is not directly connected to the interconnector it benefits via its connections with A and B.

	REGION A		REGION B		REGION C	
	EENS (MWh)	LOLE (h)	EENS (MWh)	LOLE (h)	EENS (MWh)	LOLE (h)
WITHOUT PROJECT	5,000	3	4,000	3	500	1
WITH PROJECT	3,000	2.7	2,800	2.7	400	0.8
CHANGE IN EENS AND LOLE	2,000	0.3	1,200	0.3	100	0.2

Table 1: Overview of SoS

The benefit can now be monetised by multiplying the EENS saved by VoLL (10,000 €/MWh). The resulting value for each region and the total value are given below:

	REGION A	REGION B	REGION C
Value of EENS saved (M€/Yr)	20	12	1
TOTAL (M€/Yr)	**33**		

Table 2: EENS saved monetisation in millions of euro

The next step is to calculate the sanity check cap; in this case, the sanity check cap to be applied would be calculated as follows:

2 × 1,000 MW × 40,000 €/MW/Yr = 80 M€/Yr[19]

The final value reported would be the minimum of the monetised EENS and the sanity check cap, which means that this project would report a value of 33 M€.

Example 2 – only regions B and C benefit from the project because region A faces no risk of shortage. The table below gives the SoS levels (EENS and LOLE) before and after the inclusion of the 1,000 MW interconnector project between regions A and B. As there is no unserved energy in region A in the scenario without the project, there is no SoS benefit for region A. Region B shows a large benefit and again region C benefits via its connections with A and B.

	REGION A		REGION B		REGION C	
	EENS (MWh)	LOLE (h)	EENS (MWh)	LOLE (h)	EENS (MWh)	LOLE (h)
WITHOUT PROJECT	0	0	6000	3	500	1
WITH PROJECT	0	0	1800	0.2	400	0.8
CHANGE IN EENS AND LOLE	0	0	4200	2.8	100	0.2

Table 3: Overview of SoS

The benefit can now be monetised by multiplying the EENS saved by VOLL (10,000 €/MWh). The resulting value for each region and the total value is given below:

	REGION A	REGION B	REGION C
Value of EENS saved (M€/Yr)	0	42	1
TOTAL (M€/Yr)	**43**		

Table 4: EENS saved monetisation in millions of euro

The next step is to calculate the sanity check cap and in this case as there is only benefit on one side of the interconnector the sanity check cap to be applied would be calculated as follows:

1 × 1,000 MW × 40,000 €/MW/Yr = 40 M€/Yr

The final value reported would be the minimum of the monetised EENS and the sanity check cap, so this project would have a value of 40 M€ reported.

---

[19] In more detail, in each area the ENS savings cannot exceed 40 M€ (investment cost savings). If it was the case for only one area, the reported value for the benefit provided by the project would be the cap in this area are added to the ENS saving where it is not active.

Project assessment phase

Based on the adapted scenarios, projects contribution to SoS is obtained in most cases[20] by a single extra simulation. Detailed benefits per scenario per project can be found in the dedicated project sheet section. The following map gives a quick overview of the potential per border. This map is in line with the expectations, in that the value is significant when at least one of the neighbouring regions showed ENS. In the same way, storage or generation projects show benefits when located in a region with ENS or next to such regions.

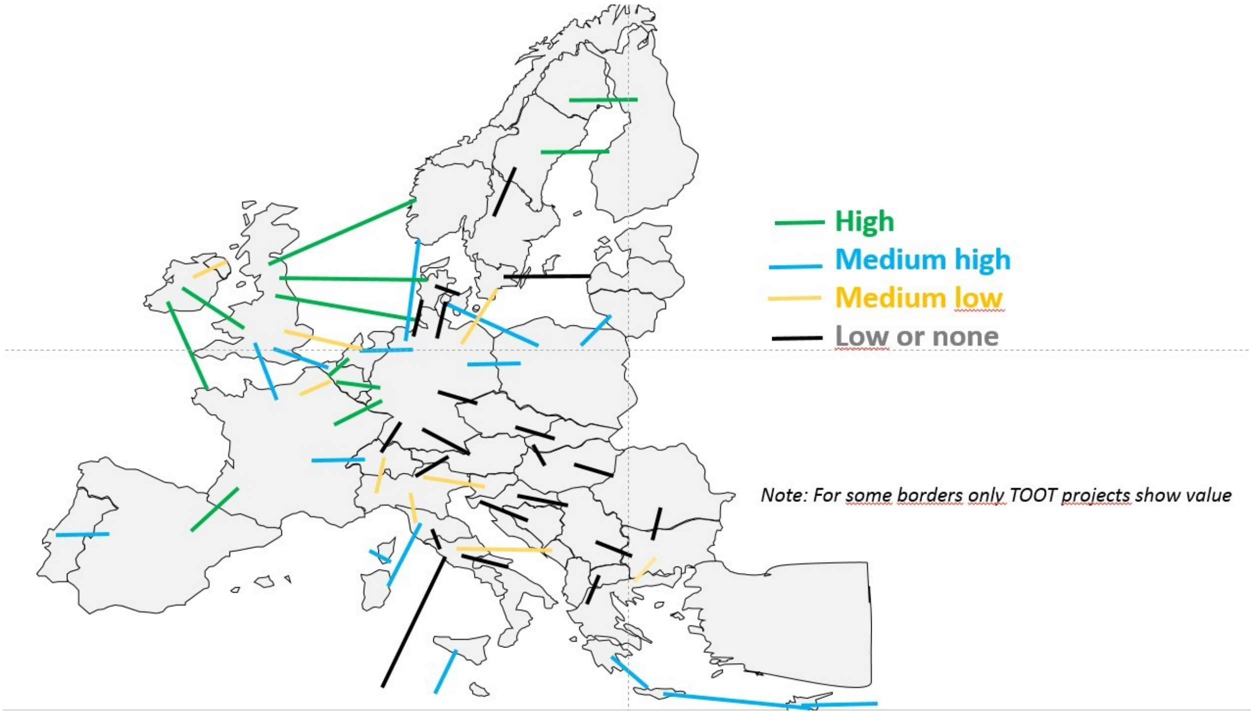


Figure 12: Overview of the results per border

Lessons learnt

The method has been successfully deployed within TYNDP2018 and enhances the CBA analysis in the field of SoS which was a key indicator expected from this edition. The use of an extended climate database covering all key weather data such as temperature, wind, solar radiation coupled with different patterns of hydrological conditions through an extended Monte-Carlo Scheme, has enabled the phenomenon to be better captured and aligned with ENTSO-E adequacy assessment (Mid Term Adequacy Forecast) standards.

---

[20] Only TOOT projects for which removal will lead to a standard violation will require extra runs to readapt portfolios.

The TYNDP2018 portfolios showed less overcapacity than in previous TYNDP editions. Yet, they have required some minor adaptations in order to better assess projects' SoS benefits. The next TYNDP will aim to incorporate this adequacy calibration of the scenarios earlier in the scenario-building process.

This approach is consistent with the ongoing works for CBA 3.0.

SEW/NTC curves methodology

The main purpose of the SEW/NTC study is to identify needs and to give a general overview of the relation between SEW and transfer-capacity increase at boundaries composed of clustered borders between relevant market areas at the ENTSO-E perimeter. The main aim of the study is to render a series of TYNDP 2018 scenarios with both increasing and decreasing transfer capacities at the boundary being considered, as in the example below:

The benefits actually covered by this exercise only correspond to the part of the projects' overall SEW covered by the CBA. It does not show the overall benefits of a project (including RES integration, SoS, ancillary services contribution). As such, it is only a partial analysis and is strongly dependent on the assumptions made, in particular with the reference grid.

List of boundaries

In TYNDP 2018, the analysis for the following main boundaries (already analysed in TYNDP 2016) has been provided:

No	1	2	3	4	5	6	7	8	9	10	Regional I	Regional II	Regional III
Name	Ireland - Great-Britain and Continental Europe	Great-Britain – Continental Europe and Nordics	Nordics - Continental Europe West	Nordic/Baltic to Continental Europe East	Baltic Integration	Central East integration	Iberian Peninsula integration	Italian Peninsula integration	South East integration	Eastern Balkan	*Turkey – South Balkan*	*Italy – Balkans*	*Italy – North Africa*

	GB-IE	GB-BE	NOs-DKw	PL-SE4	EE-FI	DE-PLI	ES-FR	ITn-FR	AT-HU	AL-GR	BG-TR	ITcs-ME	ITsic-TN00
	IE-GB	BE-GB	DKw-NOs	SE4-PL	FI-EE	PLE-DE	FR-ES	FR-ITn	HU-AT	GR-AL	GR-TR	ME-ITcs	TN00-ITsic
	IE-FR	GB-DKw	DKE-SE4	PL-LT	LT-PL	PL-PLE		ITn-CH	CZ-SK	MK-GR	TR-BG		
	FR-IE	DKw-GB	SE4-DKE	LT-PL	LT-SE4	PLI-PL		CH-ITn	SK-CZ	GR-MK	TR-GR		
	GB-NI	GB-FR	DE-SE4	DKe-PL	PL-LT	PLE-CZ		ITn-AT	AT-SI	MK-BG			
	NI-GB	FR-GB	SE4-DE	PL-DKe	SE4-LT	CZ-PLI		AT-ITn	SI-AT	BG-MK			
		GB-NL	NL-NOs			PLE-SK		ITn-SI	HU-SI	RS-BG			
		NL-GB	NOs-NL			SK-PLI		SI-ITn	SI-HU	BG-RS			
		GB-NOs	DE-NOs							RS-RO			
		NOs-GB	NOs-DE							RO-RS			
		GB-DE	DKW-SE3							HU-RO			
		DE-GB	SE3-DKW							RO-HU			

Three additional secondary borders will be included in the relevant Regional Insight Reports: Italy/Balkan, Italy/North Africa, and Turkey/South Balkans.

Methodology, start and end points of the simulations
The study is performed as a sequence of market studies with steps of 1,000 MW NTC change.

- Base case simulation: 2030 scenarios and TYNDP 2018 CBA reference capacity;
- Take one boundary and change capacity in steps of 1,000 MW, in both directions, equally divided among the interconnectors, starting from the reference capacity;
- Up to the point where delta SEW/GTC no longer does curve saturates (based on expert knowledge);
- Down to the present NTC level.

Scenario data is based on the dataset published as ‘final scenarios’ in March 2018.

All detailed analyses start from the reference capacities published in March 2018 and used in the project assessments.

Appendix IV – Cross-border capacities

The table below shows capacities for different years and scenarios at the border level.

	NTC 2020		CBA capacities				IoSN identified capacities					
			CBA reference grid (2027)		NTC - All TYNDP projects commissioned before 2035		NTC ST 2040		NTC DG 2040		NTC GCA 2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
AL-GR	250	250	250	250	250	250	350	350	350	350	350	350
AL-ME	350	350	400	400	400	400	900	900	400	400	400	400
AL-MK	500	500	500	500	500	500	500	500	500	500	1,000	1,000
AL-RS	650	500	500	500	500	500	1,260	830	760	330	1,760	1,330
AT-CH	1,200	1,200	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
AT-CZ	900	800	1,000	1,200	1,000	1,200	1,000	1,200	1,000	1,200	1,000	1,200
AT-DE	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
AT-HU	800	800	1,200	800	1,200	800	1,200	800	1,200	800	1,200	800
AT-ITn	405	235	1,050	850	1,650	1,350	1,605	1,335	1,605	1,335	1,605	1,335
AT-SI	950	950	1,200	1,200	1,950	1,800	2,200	2,200	2,200	2,200	2,700	2,700
BA-HR	750	700	1,250	1,250	1,894	1,548	1,844	1,812	1,844	1,812	2,344	2,312
BA-ME	500	400	800	750	800	750	500	400	500	400	500	400
BA-RS	600	600	1,100	1,200	1,100	1,200	1,100	1,200	1,100	1,200	1,100	1,200
BE-DE	1,000	1,000	1,000	1,000	2,000	2,000	1,000	1,000	2,000	2,000	2,000	2,000
BE-FR	1,800	3,300	2,800	4,300	3,800	5,300	4,300	5,800	3,800	5,300	4,300	5,800
BE-GB	1,000	1,000	1,000	1,000	2,400	2,400	2,500	2,500	2,000	2,000	2,000	2,000
BE-LUB	380	0	380	0	380	500	380	0	380	0	380	0
BE-LUG	300	180	300	180	800	180	300	180	300	180	800	680
BE-NL	2,400	1,400	3,400	3,400	4,400	4,400	4,900	4,900	4,400	4,400	4,900	4,900
BG-GR	600	400	1,350	800	1,350	800	1,728	1,032	3,228	2,532	3,228	2,532
BG-MK	400	100	500	500	500	500	400	100	400	100	900	600
BG-RO	300	300	1,100	1,500	1,100	1,500	1,400	1,500	1,400	1,500	1,400	1,500
BG-RS	500	200	350	200	1,080	386	1,600	1,350	2,100	1,850	2,100	1,850
BG-TR	700	300	1,200	500	1,200	500	2,400	2,000	2,400	2,000	2,400	2,000
CH-DE	4,600	2,700	5,600	3,300	6,600	4,300	6,500	4,100	6,500	4,100	6,500	4,100
CH-FR	1,300	3,150	1,300	3,700	1,900	5,200	2,800	5,200	3,800	6,200	3,800	6,200
CH-ITn	4,240	1,910	6,000	3,700	6,000	3,700	6,000	3,700	6,000	3,700	6,000	3,700

	NTC 2020		CBA capacities				IoSN identified capacities					
			CBA reference grid (2027)		NTC- All TYNDP projects commissioned before 2035		NTC ST 2040		NTC DG 2040		NTC GCA 2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
CY-GR	0	0	0	0	0	0	2,000	2,000	2,000	2,000	2,000	2,000
CZ-DE	2,100	1,500	26,00	2,000	2,600	2,000	2,600	2,000	2,600	2,000	2,600	2,000
CZ-PLE	0	800	0	600	0	600	0	800	0	800	0	800
CZ-PLI	600	0	600	0	600	0	600	0	600	0	600	0
CZ-SK	1,800	1,100	1,800	1,100	2,290	1,650	2,100	1,100	2,100	1,100	2,600	1,600
DE-DEkf	400	400	400	400	400	400	400	400	400	400	400	400
DE-DKe	600	585	600	585	1,200	1,185	600	600	600	600	600	600
DE-DKw	1,500	1,780	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3000
DE-FR	2,300	1,800	4,500	4,500	4,800	4,800	4,800	4,800	5800 ,	5,800	4,800	4,800
DEkf-DKkf	400	400	400	400	400	400	400	400	400	400	400	400
DE-LUG	1,000	1,000	1,000	1,000	2,000	2,000	2,000	2,000	2,000	2,000	3,000	3,000
DE-LUv	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
DE-NL	4,250	4,250	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
DE-NOs	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
DE-PLE	0	2,500	0	3,000	0	3,000	0	3,000	0	3,000	0	3,000
DE-PLI	500	0	2,000	0	2,000	0	4,500	0	3,500	0	4,500	0
DE-SE4	615	615	1,315	1,300	2,015	2,000	1,815	1,815	2,315	2,315	2,315	2,315
DKe-DKkf	400	600	600	600	600	600	400	600	400	600	400	600
DKe-DKw	600	590	600	600	1,200	1,200	1,100	1,090	1,100	1,090	1,100	1,090
DKe-PL	0	0	0	0	600	600	500	500	1,500	1,500	500	500
DKe-SE4	1,700	1,300	1,700	1,300	1,700	1,300	1,700	1,300	2,700	2,300	2,700	2,300
DKw-GB	0	0	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
DKw-NL	700	700	700	700	700	700	700	700	700	700	700	700
DKw-NOs	1,640	1,640	1,700	1,640	1,700	1,640	2,140	2,140	1,640	1,640	2,640	2,640
DKw-SE3	740	680	740	680	740	680	740	680	740	680	740	680
EE-FI	1,016	1,000	1,016	1,016	1,016	1,016	1,016	1,000	1,016	1,000	1,516	1,500
EE-LV	900	900	1,379	1,379	1,379	1,379	1,350	1,250	1,850	1,750	1,350	1,250
ES-FR	2,600	2,800	5,000	5,000	8,000	8,000	9,000	9,000	10,000	10,000	9,000	9,000
ES-FR-GB	0	0	0	0	0	8,000	0	0	0	0	0	0

	NTC 2020		CBA capacities				IoSN identified capacities					
			CBA reference grid (2027)		NTC - All TYNDP projects commissioned before 2035		NTC ST 2040		NTC DG 2040		NTC GCA 2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
ES-PT	4,200	3,500	4,200	3,500	4,200	3,500	4,700	4,000	4,700	4,000	5,700	5,000
FI-NOn	0	0	0	0	0	0	0	0	0	0	1,000	1,000
FI-SE1	1,100	1,200	2,000	2,000	2,000	2,000	2,500	2,500	2,500	2,500	2,500	2,500
FI-SE2	0	0	0	0	800	800	800	800	800	800	800	800
FI-SE3	1,200	1,200	1,200	1,200	1,200	1,200	800	800	800	800	800	800
ITcn-ITCO	300	300	400	400	400	400	400	400	400	400	400	400
FR-GB	2,000	2,000	6,800	6,800	8,800	8,800	6,900	6,900	5,900	5,900	5,900	5,900
FR-IE	0	0	0	0	700	700	700	700	1,200	1,200	1,200	1,200
FR-ITn	4,350	2,160	4,350	2,160	4,350	2,160	4,350	2,160	4,350	2,160	5,350	3,160
FR-LUF	380	0	380	0	380	0	380	0	380	0	380	0
GB-IE	500	500	500	500	1,000	1,000	1,500	1,500	500	500	500	500
GB-IS	0	0	0	0	0	0	0	0	0	0	0	0
GB-NI	450	80	450	280	450	280	500	500	500	500	500	500
GB-NL	1,000	1,000	1,000	1,000	3,000	3,000	2,500	2,500	1,000	1,000	2,000	2,000
GB-NOs	0	0	2,800	2,800	2,800	2,800	1,400	1,400	2,900	2,900	2,400	2,400
GR-ITs	500	500	500	500	500	500	500	500	500	500	500	500
GR-MK	1,100	850	1,200	1,200	1,200	1,679	1,600	1,350	2,100	1,850	2,100	1,850
GR-TR	660	580	660	580	660	580	2,200	2,100	2,200	2,100	2,200	2,100
HR-HU	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
HR-ITn	0	0	0	0	0	0	0	0	0	0	0	0
HR-RS	600	600	600	600	600	600	2,100	2,100	2,100	2,100	2,100	2,100
HR-SI	1,500	1,500	2,000	2,000	2,000	2,000	2,500	2,500	3,000	3,000	3,500	3,500
HU-RO	1,000	1,100	1,300	1,400	2,417	2,085	1,300	1,400	1,800	1,900	2,800	2,900
HU-RS	600	600	600	600	600	600	1,100	1,100	2,100	2,100	2,100	2,100
HU-SI	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
HU-SK	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
IE-NI	300	300	1,250	1,200	1,820	1,770	1,100	1,100	1,100	1,100	1,100	1,100
ITcn-ITcs	1,400	2,600	1,750	3,200	2,750	4,200	2,750	4,200	2,750	4,200	2,750	4,200
ITcn-ITn	1,550	3,750	2,100	4,100	2,100	4,100	2,100	4,100	2,100	4,100	2,100	4,100

	NTC 2020		CBA capacities				IoSN identified capacities					
			CBA reference grid (2027)		NTC - All TYNDP projects commissioned before 2035		NTC ST 2040		NTC DG 2040		NTC GCA 2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
ITcn-ITCO	300	300	400	400	400	400	400	400	400	400	400	400
ITcs-ITs	9,999	4,500	9,999	5,700	9,999	5,700	9,999	5,700	9,999	5,700	10,999	6,700
ITcs-ITsar	700	900	700	900	700	900	700	900	700	900	700	900
ITcs-ME	600	600	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
ITn-SI	680	730	1,660	1,895	1,660	1,895	1,660	1,895	1,660	1,895	1,660	1,895
ITsic-ITsar	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000
ITsic-MT	200	200	200	200	200	200	200	200	200	200	200	200
ITsic-TN	0	0	600	600	600	600	600	600	600	600	600	600
ITs-ITsic	1,100	1,200	1,100	1,200	1,100	1,200	1,100	1,200	1,100	1,200	1,100	1,200
ITcs-Itsic	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000
LT-LV	1,200	1,500	1,200	1,500	1,200	1,500	1,200	1,500	1,200	1,500	1,200	1,500
LT-PL	500	500	1,000	1,000	1,000	1,000	500	500	1,000	1,000	1,000	1,000
LT-SE4	700	700	700	700	700	700	700	700	700	700	700	700
ME-RS	500	600	700	700	700	700	1,000	1,100	1,000	1,100	1,500	1,600
MK-RS	650	800	750	750	750	750	650	800	1,650	1,800	1,650	1,800
NL-NOs	700	700	700	700	700	700	1,700	1,700	1,700	1,700	1,700	1,700
NOm-NOn	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
NOm-NOs	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,900	1,900
NOm-SE2	600	1,000	600	1,000	600	1,000	600	1,000	600	1,000	600	1,000
NOn-SE1	700	600	700	600	700	600	700	600	700	600	700	600
NOn-SE2	250	300	250	300	250	300	250	300	250	300	750	800
NOs-SE3	2,145	2,095	2,145	2,095	2,145	2,095	2,145	2,095	2,145	2,095	2,145	2,095
PLE-SK	990	0	990	0	990	0	990	0	990	0	990	0
PLI-SK	0	990	0	990	0	990	0	990	0	990	0	990
PL-PLE	2,500	0	3,000	0	3,000	0	3,000	0	3,000	0	3,000	0
PL-PLI	0	500	0	2,000	0	2,000	0	4,500	0	3,500	0	4,500
PL-SE4	600	600	600	600	600	600	600	600	600	600	1100	1100
RO-RS	1,000	800	1,300	1,300	1,647	1,922	1,450	1,050	1,950	1,550	2,950	2,550
SE1-SE2	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300

	NTC 2020		CBA capacities				IoSN identified capacities					
			CBA reference grid (2027)		NTC - All TYNDP projects commissioned before 2035		NTC ST 2040		NTC DG 2040		NTC GCA 2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
SE2-SE3	7,800	7,800	7,800	7,800	9,300	9,300	8,300	8,300	8,300	8,300	8,300	8,300
SE3-SE4	6,500	3,200	7,200	3,600	7,200	3,600	7,200	3,600	7,200	3,600	7,200	3,600
ITsar-ITCO	350	300	500	450	500	450	500	450	500	450	500	450
FRc-ITCO	50	150	150	200	150	200	150	200	150	200	150	200
DE-GB	0	0	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400