Methodology:

Generation Adequacy Benefit Monetization

Final version after public consultation and ACER opinion - October 2019

Proposed Methodology for Monetization of Security of Supply Adequacy Benefit of TYNDP Projects

1. Introduction

In the framework of the TYNDP2018, a methodology to monetise the adequacy component of the security of supply 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 SEW and SoS savings assessments.

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 setup if it is present in the TYNDP base case
2. Adapt the portfolios in the two interconnected regions to a given generation adequacy standard[1]
3. Run the model with multiple climate years and forced outage patterns and calculate Expected Energy Not Served
4. Add the project to the model and re-run simulation to re-calculate EENS
5. Multiply the change in EENS by the Value of Lost Load[2] to give the monetized benefit
6. Conduct a sanity check by assessing how much peak generation capacity the project could save

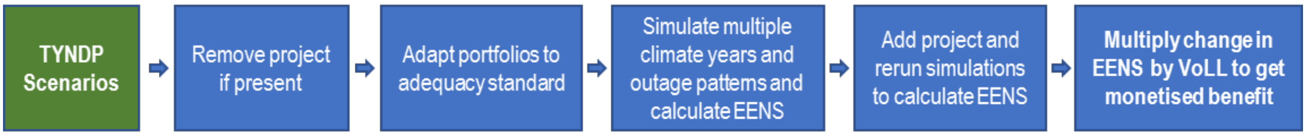


Figure 1: Project Security of Supply Monetization Methodology steps

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[3]. That is, the security of supply benefit can be a very significant component of the overall project benefit. This methodology appropriately monetises that benefit and is consistent 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". The following sections outline the approach, including background, input assumptions, modelling setup and methodology steps.

2. 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*"[4]. This adequacy assessment approach is favoured by the European Commission[5].

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

[1] Not all countries have a defined LOLE standard - portfolio adaptations are discussed in the Methodology Steps section
[2] Monetization will be sensitive to underlying VOLL assumptions
[3] There is no double counting as EENS is not valued in the SEW indicator
[4] Mid-Term Adequacy Forecast 2017 Edition
[5] Identification of Appropriate Generation and System Adequacy Standards for the Internal Electricity Market

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 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.

2.1 Inputs and Modelling Set-up

As discussed, the methodology relies on existing TYNDP2018 scenarios and market models. It is possible to remove some of the model complexity that is required for pricing as adequacy assessments are concerned with loss of load events that should not be impacted by market prices. Removing these complexities is not essential, but it significantly decreases simulation times. 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 much 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.

2.2 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 setup 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 setup for this.

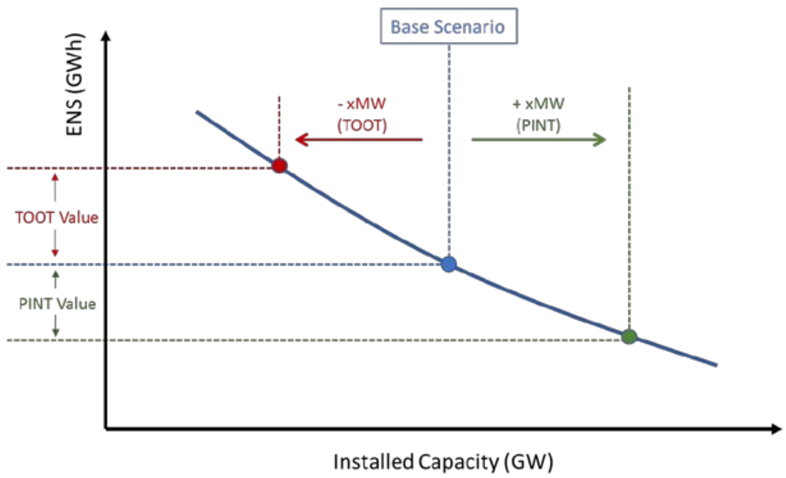


Figure 2: Illustration of the variance of EENS with Installed Capacity and the TOOT vs PINT approaches.

- As the relationship between EENS and installed capacity in a region is non-linear (see figure 2) the security-of-supply 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 security-of-supply 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 initial LOLE.

Given the above, it is preferable to bring the interconnected regions to a predefined generation adequacy standard prior to the benefit assessment[6]. 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)[7] in the region. As these are peaking units, this adjustment should have little impact on the socio-economic welfare (SEW). The adjustment is just for adequacy studies and would have no impact on the market studies.[8]

- 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 re-run 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 monetized security of supply 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[9], which can be monetized 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 coincident scarcity events, from a security of supply perspective the interconnector would effectively be as beneficial as the same level of conventional generation installed in each of the two interconnected regions and this 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.

[6] 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

[7] 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)

[8] This has been checked on test-projects

[9] 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.

- 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 standardized parameters including a uniform VoLL (10,000 €/MWh) and one value for the annualized cost of a peaking unit (40,000 €/MW/Yr). This enables a systematic assessment within in the common TYNDP framework. The economic parameters that have been used are set at conservative levels to minimize any risk of over-estimation. For dedicated/specific studies, these parameters could be replaced should other appropriate official values be available.

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

3. 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 of 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.

3.1 Calibration of the simulation

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

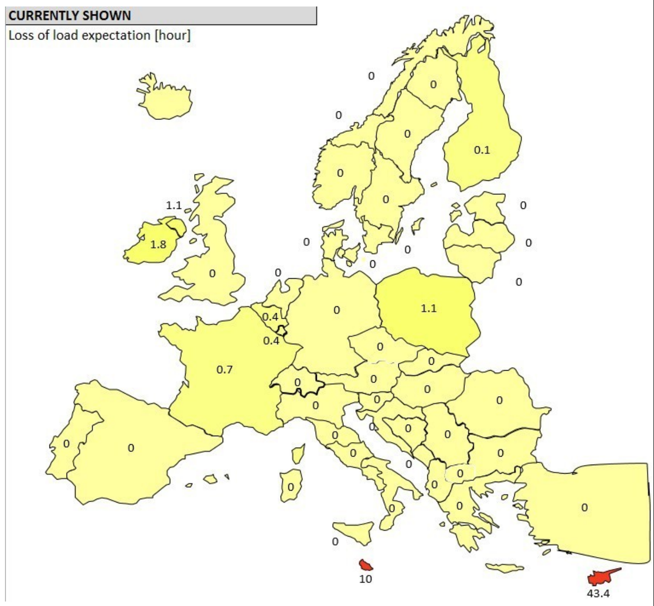
- the full climate data base is used (34 vs 3-9 in the SEW process)
- multiple outage patterns on thermal units and HVDC interconnectors are introduced (randomized)

The simulations are performed over 510 Monte Carlo years (34 climates years * 15 outage patterns) which enables the robust assessment of standard adequacy indicators[10].

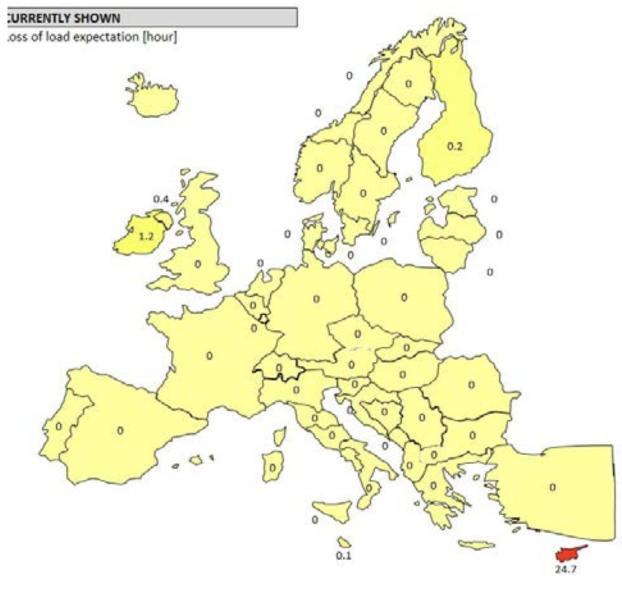
3.2 SoS landscape with the reference scenarios (with the starting grid)

Results of the adequacy assessments using the enhanced model are illustrated in the following maps displaying the Loss of Load Expectation (hrs/year) over the 510 Monte Carlo years simulated for each of the 4 scenarios/horizons studied within the CBA.

BE2025



EUCO 2030



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[10] 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.

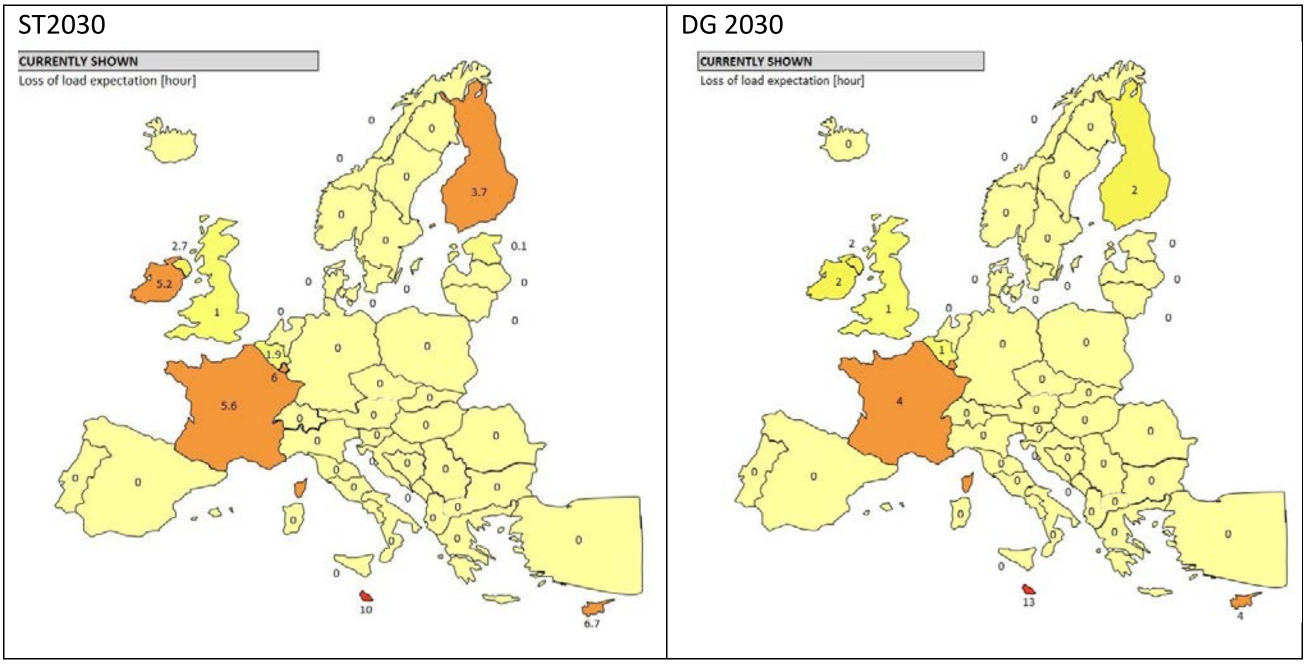

Figure 3: Loss of Load Expectation for the four scenarios

3.3 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[11] if it exists, default standard LOLE < 3hrs) in the base case. The rationale of 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 starting point, see figure 2)
- Countries having a Loss Of Load Expectation 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 yet fully take this aspect into account[12]. It should also be noted that thermal fleet reduction performed account 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 proved necessary for some projects to re-adapt 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.

[11] e.g : 3hrs for France, Belgium ; 8hrs for Ireland (Republic of Ireland and Northern Ireland)
[12] It is also worthwhile reminding that scenarios Best Esimate 2025 and Sustainable Transition 2030 are bottom-up scenarios resulting from the data collection; EUCO2030 is a scenario provided by European Commission;

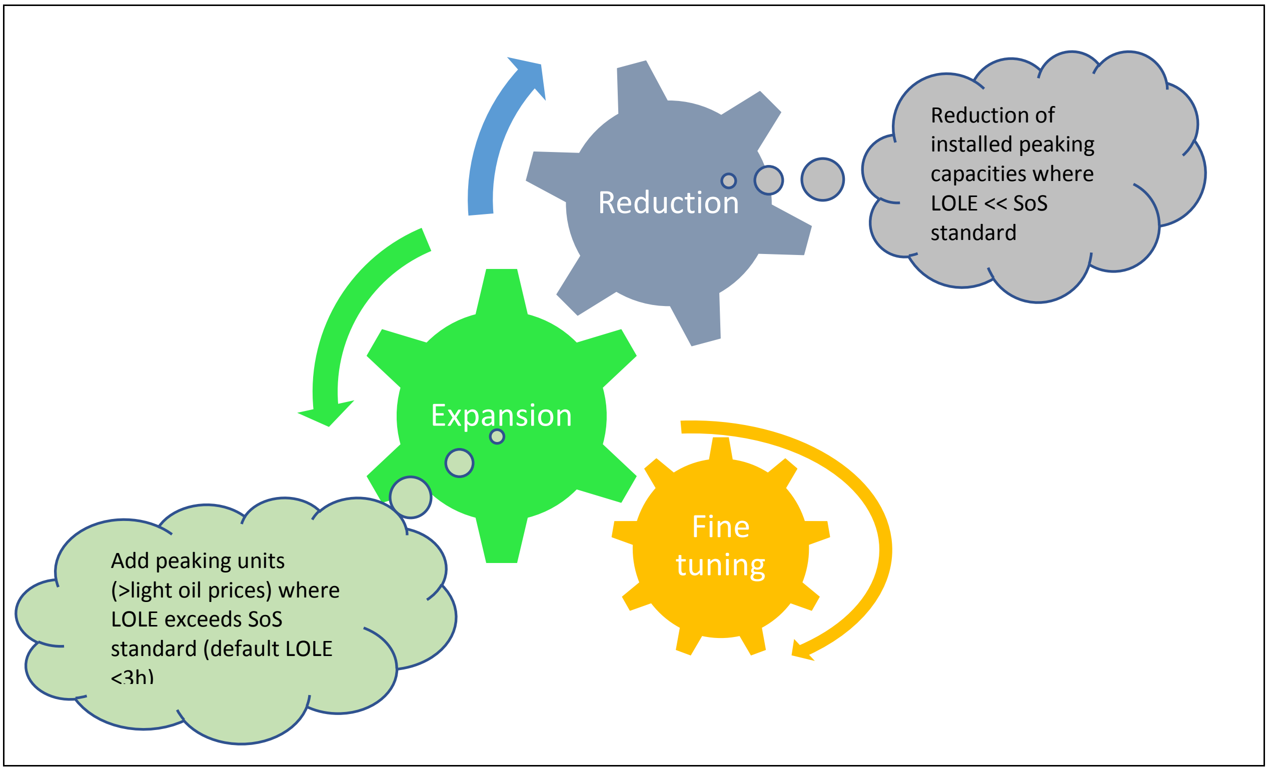

Figure 4: overview of the generation portfolio adaptation process

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

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

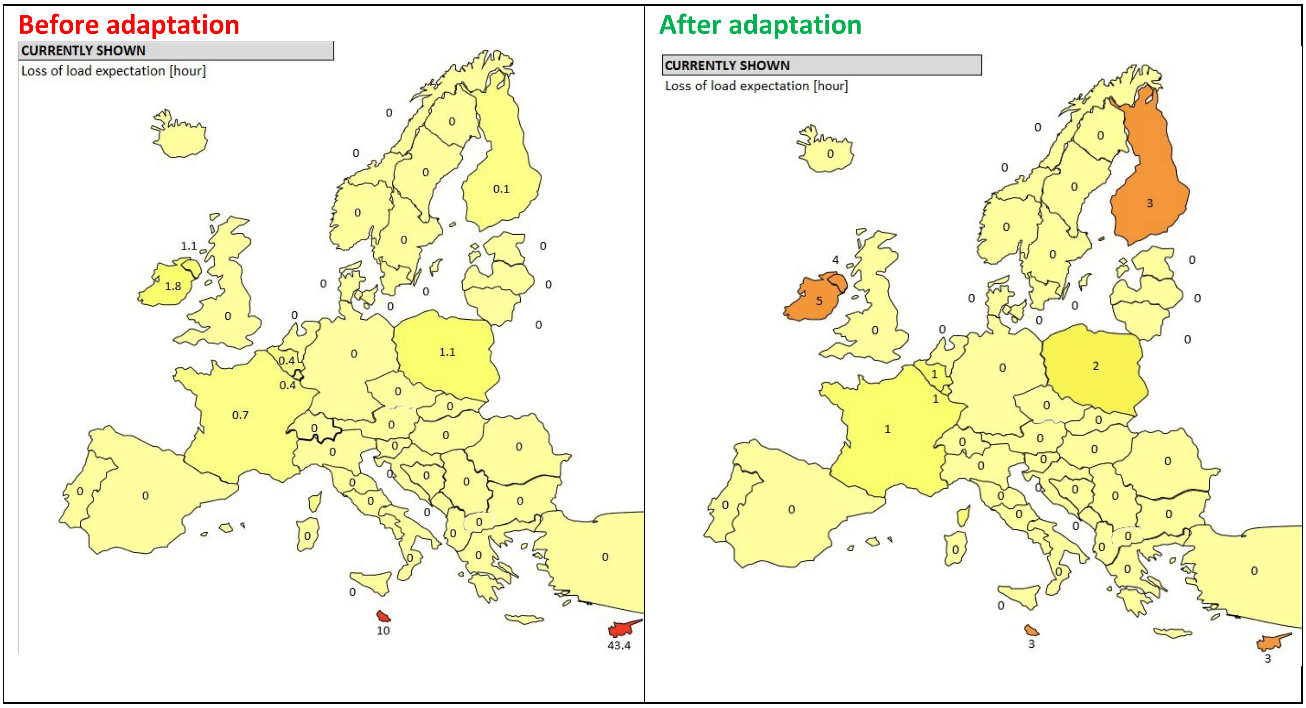

Figure 5: Effect of the adaptation on scenario Best Estimate 2025

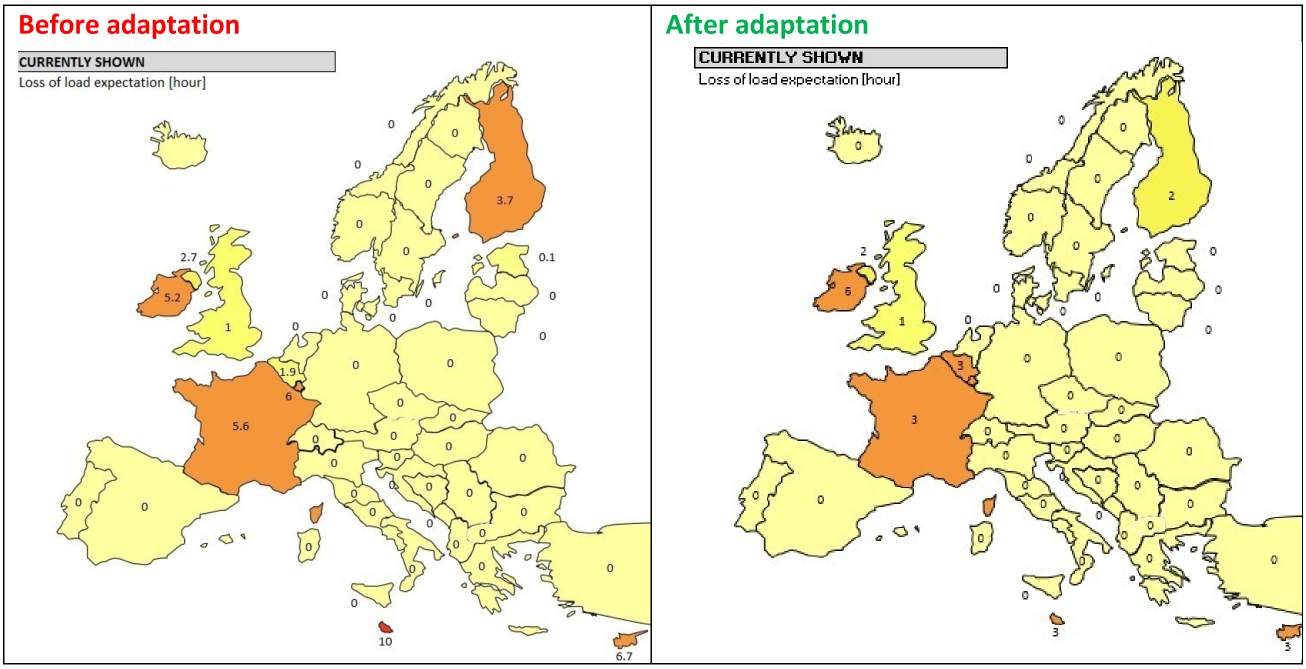

Figure 6: Effect of the adaptation on scenario Sustainable transition 2030

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 Loss Of Load Expectation 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 0 Loss of load Expectation, due for instance to large hydro capacities, limited sensitivity to climate conditions, or 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 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.

3.4 Monetization illustration:

The monetization of the detailed simulation results consists of 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 monetized 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 to 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 benefits just one country (Case 2):
  - o **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 a security of supply perspective the interconnector would effectively be as beneficial as the same level

of conventional generation installed in each of the two interconnected regions and this should act as a cap on the value.

- Sanity check cap = 2 × MW size of the Interconnector (MW) × 40,000 €/MW/Yr

o **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 monetized SoS benefit of the project is the minimum value of the monetized 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 monetization process, two simplified 3-region examples are given below. Both examples use a 1000 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 show benefit from the project and in that example the sanity check cap does not affect the final reported value. In Example 2 only two of the regions show benefit from the project and in that example the sanity check cap sets the final reported value.

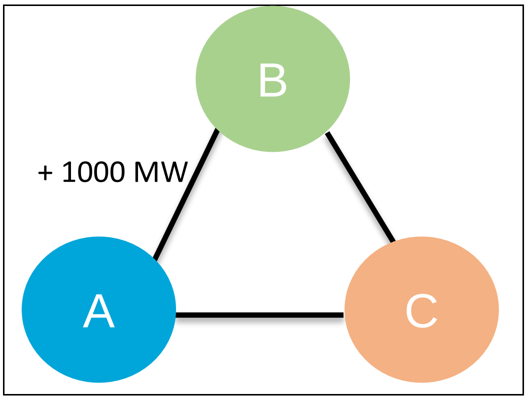

Figure 7: Simplified 3 region model used to illustrate the monetization approach.

Example 1 – all 3 regions show benefit from the project:

The table below gives the SoS levels (EENS and LOLE) before and after the inclusion of the 1000 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	5000	3	4000	3	500	1
WITH PROJECT	3000	2.7	2800	2.7	400	0.8
CHANGE IN EENS AND LOLE	2000	0.3	1200	0.3	100	0.2

Table 1: Security of supply overview

The benefit can now be monetized by multiplying the EENS saved by VoLL (10,000 €/MWh). The resulting value for each region and the total value is given in the following table.

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

Table 2: EENS saved monetization in millions of euro

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

$$2 \times 1000 \text{ MW} \times 40{,}000 \text{ €/MW/Yr} = 80 \text{ M'€/Yr.}$$ [13]

The final value reported would be the minimum of the monetized EENS and the sanity check cap, so this project would have a value of 33 M'€ reported.

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 1000 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: Security of supply overview

The benefit can now be monetized by multiplying the EENS saved by VoLL (10,000 €/MWh). The resulting value for each region and the total value is given in the following table.

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

Table 4: EENS saved monetization 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:

$$1 \times 1000 \text{ MW} \times 40{,}000 \text{ €/MW/Yr} = 40 \text{ M'€/Yr.}$$

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

3.5 Project assessment phase

Based on the adapted scenarios, projects contribution to SoS is obtained in most cases[14] by a single extra simulation. ENS savings are reported and monetized as proposed in section 2.2. Detailed benefits per scenario

[13] In more details, in each area, the ENS savings cannot exceed 40M€ (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 summed up with ENS saving where it is not active

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

per project can be found in the project sheet dedicated 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 manner storage or generation projects show benefits when located in a region with ENS or next to such regions.

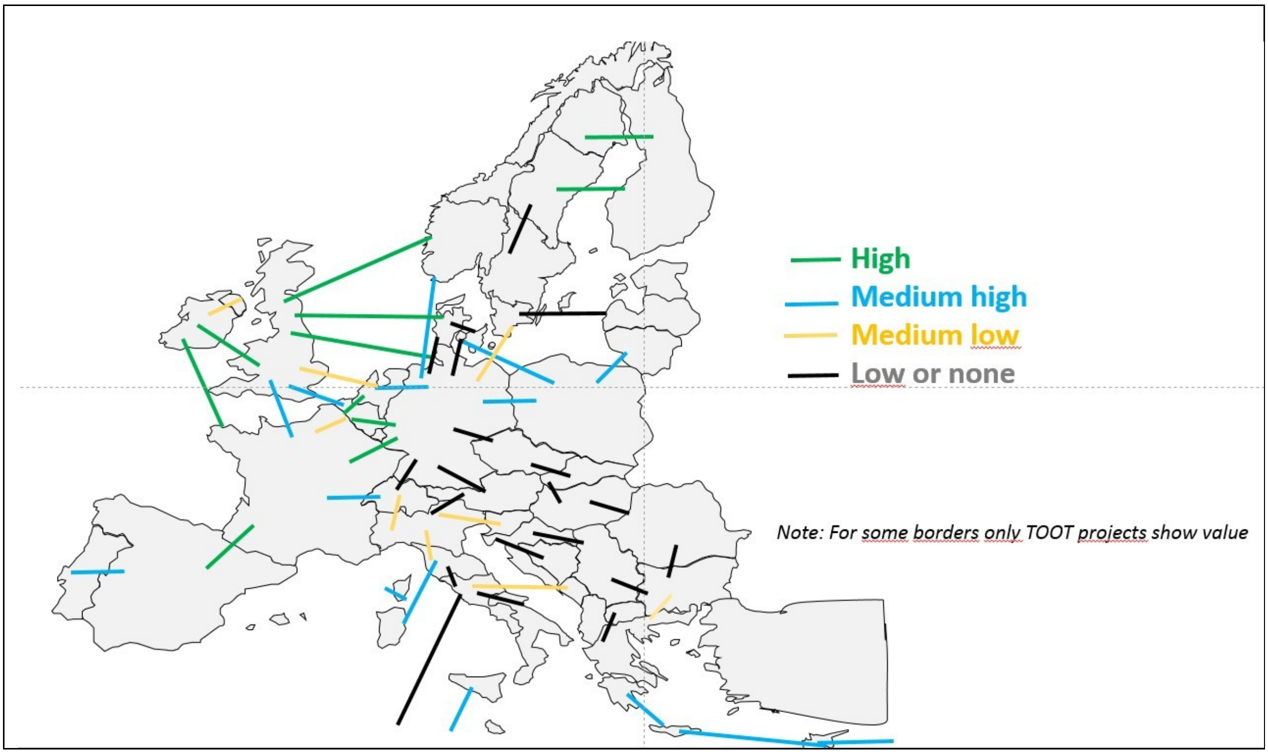

Figure 8: Overview of the results per border

4. Lessons learnt

The method has been successfully deployed within TYNDP2018, and it enhances the CBA analysis in the field of Security of Supply which was a key indicator expected from this edition. The use of an extended climate data base, 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 to better capture the phenomenon and align with ENTSO-E adequacy assessment (Mid Term Adequacy Forecast) standards.

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

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