Work streams outcome

03 August 2018

Disclaimer

This report contains recommendations on further improving the indicators for Security of Supply, SEW and storage assessment as part of the ENTSO-E Guideline for Cost-Benefit Analysis of Grid Development Projects, with the aim to improve the assessment of transmission and storage projects on a pan-European level (e.g. under TYNDP 2020).

It was developed in a cooperation between ENTSO-E and several external stakeholders.

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1. INTRODUCTION

The good experiences of including external stakeholders[1] in the process of improving the 2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects (further referred to as: "2nd CBA guideline"), on top of the legal requirement for a distinct public consultation phase, has encouraged ENTSO-E to start the drafting of the 3rd CBA guideline by including external stakeholders in the process. Therefore, ENTSO-E organised a public workshop on 7 December 2018. The main aims of this workshop were to publically inform stakeholders about the current ideas for improving the CBA guideline (mainly based on comments ENSTO-E received during the improvement process of the 2nd CBA guideline, i.e. the public consultation and direct communication with ACER and the European Commission) and to obtain input for future development of the CBA guideline. During this workshop, three main fields of improvements were identified:

- security of supply,
- assessment of storage projects, and
- the concept of Socio Economic Welfare.

External stakeholders were subsequently invited to participate in (one or multiple of) three work streams dealing with each of the topics, starting with a kick off meeting for each work stream on the 7 December 2017. Deadline for the work was April 2018.

Each of the work streams was organised by ENTSO-E and the work took place by physical meetings and web conferences. The work streams were set up to maximize external stakeholder input and reflect new ideas as much as possible, by having the content mainly drafted by the external stakeholders. In order to give all the work stream members the possibility to sufficiently contribute to the topics and comment on the status of the work, a 'way of working' was defined during the kick-off meeting for each work stream. This generally included a physical meeting date and weekly calls for each work stream.

After having achieved a sufficient maturity of the newly developed methodologies and ideas, each of the members within the work streams was given the opportunity to review the documents and comment on the outcome. At the end, ENTSO-E merged all reports from the different work streams into one document and performed a final review. The contents and views reflected in the reports were not altered during this final review.

The outcome of this process is given in this document starting with improvements on the security of supply (SoS) for which three main fields have been identified: SoS – Adequacy (Chapter 2), SoS – Stability (Chapter 3) and SoS – Ancillary services (Chapter 4). The ideas for future improvements on the Socio-Economic Welfare are given in Chapter 5. The outcome from the work stream on storage, which was closely linked to the other two streams as most

[1] all non-ENTSO-E stakeholders will be called "external" in this document

topics are applicable to both transmission as well as storage, is provide in Chapter 6. Chapter 7 provides an overview of all work stream participants. The authors of the different chapters are listed at the end of each chapter.

Please note that, as this document was drafted by several authors and aligned within three different groups (each working together in one of the work streams), it might happen that some aspects are discussed in more than one chapter.

2. SoS – Adequacy

2.1. Introduction and Scope

Among Security of Supply benefits of a new interconnector, adequacy represents a major topic. The adequacy depicts the capacity of the electric system to satisfy the consumer demand and the system's operational constraints at any time, including under extreme conditions (e.g. cold wave, low wind generation, unit or grid outages…). These extreme conditions could lead to loss of load events.A new interconnector could help to the adequacy by pooling the risk of facing loss of load and in the same time pooling the means (generation capacity) to face it. The interconnector can mitigate the adequacy risks among European countries and in particular the two linked by the interconnector. The less the stressed events of the countries are simultaneous, the higher is the adequacy benefit of a new interconnector. Indeed, non-simultaneous stressed events mean that when one country is facing adequacy risks, the other could provide power. Practically, the benefit can be seen in two ways:

- Decrease the need for generation capacity: for an equivalent SoS level (in terms of LOLE and EENS), an interconnector can decrease the peaking unit capacity needs.
- Decrease EENS volumes: when only one country is facing loss of load, a new interconnector can help to import more, hence reducing EENS.

More generally, the benefit could be a combination of the two effects (besides, this combination could evolve with time).

For a project's Cost Benefit Analysis, the adequacy benefit must be taken into account. It can be assessed through two approaches. On the one hand, the decrease in peaking unit investment needs (for the same SoS level) can be used. On the other hand, the reduction of EENS volume (installed capacity remaining constant) can be considered. Some implementation difficulties pushes to use an EENS based methodology. However a sanity check based on investment saving is proposed to make the assessment more robust.

TABLE 1 ADVANTAGES AND DISADVANTAGES OF ADEQUACY BENEFIT ASSESSEMENT METHODOLOGIES

	Investments savings	EENS reduction	EENS reduction with sanity check
Advantages	Physical underlying Result stability	Relatively easier to perform Benefit allocation between countries possible	Relatively easy to perform Benefit allocation between countries possible

			Physical underlying monitored through the sanity check
Disadvantages	Complex implementation (especially for meshed grid) Difficult benefit allocation between countries	Need for a VoLL Sensitivity to some parameters (initial LOLE, VoLL…)	Need for a VoLL

2.2. RECOMMENDATIONS TO IMPROVE THE SOS – ADEQUACY INDICATOR

2.2.1 PREREQUISITES

Loss of load is a very scarce phenomenon, resulting of the combination of extreme events. As a result, studying loss of load requires a refined model of the hazards that could affect the electric system. This refined model is essential to depict loss of load characteristics such as deepness and simultaneity. **Several hundreds of Monte Carlo years (MCY) are consequently necessary** (modelling climatic hazards, plant and even grid outages…).

Besides, studying adequacy requires that generation portfolios must be adequate. This means that loss of load expectancy (LOLE) should be reasonable. If it is not the case, it is proposed to adapt generation portfolios. This could be acceptable because scenarios might not be originally built to study adequacy. **Nevertheless, adequate scenarios (on several MCY) would be a great enhancement for TYNDP 2020, and would make the adaptation phase (as described below) unnecessary**. In this case the scenarios building phase should result in reasonable scenarios in terms of adequacy.

In the case of 'far away from adequate' scenarios an adaption of the adequacy is proposed with the aim to bringing the countries to a reasonable adequacy level[2]. This adaptation would consist in adding peaking units in countries where LOLE is too high and removing peaking units in countries where LOLE is too low. **Only peaking units should be concerned**: indeed modifying more deeply the generation assets could change the storyline of the energy policy of the scenario. Moreover, it might affect the consistency with other indicators, in particular the SEW[3]. As a result, some countries could stay over-adequate if there are lots of generation units with low marginal costs. .

[2] If a country has legal criteria, the latter would be use. If not, it is proposed to use loss of load expectancy of 3h/year.

[3] In general, only modifying peaking units portfolios will not have a large impact on the SEW.

2.2.2 METHODOLOGY

See example section for the detailed methodology application.

Step 1: adaptation
Adapt the peaking unit installed capacity in order to reach reasonable adequacy level in each country **without the current project**.

- For countries with too much LOLE, add peaking capacity until a reasonable target is reached. For the countries that have a legal standard, this value would be the target, for those without such kind of standard, a 3h LOLE could represents a good standard.
- For countries with too low LOLE, remove peaking capacity until reaching a reasonable value. Similarly, national legal standard, or if not 3h, would be the target. If removing peaking units is not sufficient to reach the target, the country would stay over-adequate. It is not recommended to remove more units with cheaper marginal costs. The current proposal is to only remove units from the categories 'light oil' and 'open-cycle gas turbine (old)' (ocgt_old), since these are the most expensive units in the system. If in a country there are no such units available, any change in the generation portfolio will also impact the SEW.

Note that this phase could be included at an earlier stage in the TYNDP process: during the Scenario Building phase.

If there is no LOLE in a country after adaptation, then the adequacy benefit for this country would be zero.

See part 2.3a discussion about the need of the adaptation.

Step 2: EENS saved
Perform a Monte Carlo simulation (with good hazards model) without the project and subsequently with the project, and assess the EENS reduction. Monetize the benefit by multiplying the EENS reduction by the Value of Lost Load[4].

Step 3: Individual sanity check
For each country impacted by the interconnector (e.g. each country whose EENS decrease by adding the interconnector), a cap in terms of peaking unit investment saving is assessed. This cap is assessed separately for each country. The idea behind the sanity check is that the adequacy benefit for a country cannot be higher than the cost of peaking units that would give the same adequacy benefit.

The process is as follows: start without the project, and add peak power plants in the country until the adequacy level (EENS and LOLE) is equivalent to (or very slighter better to) the setup with the project. This value gives a cap of the adequacy benefit brought by the interconnector to the country.

[4] If no national or ENTSO-E VOLL exists, values such as 10k€/MWh or 15 k€/MWh could be used.

The cap can be monetized using an agreed value of peaking unit capacity saved and compared to the EENS reduction calculated at step 2: if for a country the cap is lower than the EENS reduction, then the adequacy benefit adopted for this country is equal to the cap. At this stage, the global adequacy benefit is the sum for each country of all the minimum between EENS reduction value and the sanity check.

Note that the capacity of the interconnector gives an immediate cap: adding an X MW interconnector between two countries could not bring more adequacy benefit for each country than adding X MW of peaking units to its generation fleet.

Step 4: global sanity check
Perform a simulation without the project but with the capacities of the sanity check for the two countries linked by the interconnector. If the adequacy level is better for all the countries than the one reached when adding the interconnector[5], then a global cap in terms of investments savings is found. If the value of the global cap is lower than the adequacy benefit assessed at step 3, the adequacy benefit adopted is the value of this global cap.

The benefit could finally be allocated between each country proportionally to the benefit of each country adopted at step 3.

Note that for an X MW interconnector, a 2*X MW of peaking unit capacity is an immediate global cap.

2.2.3 INITIAL LOLE SENSITIVITY : WHY ADAPTATION IS NECESSARY

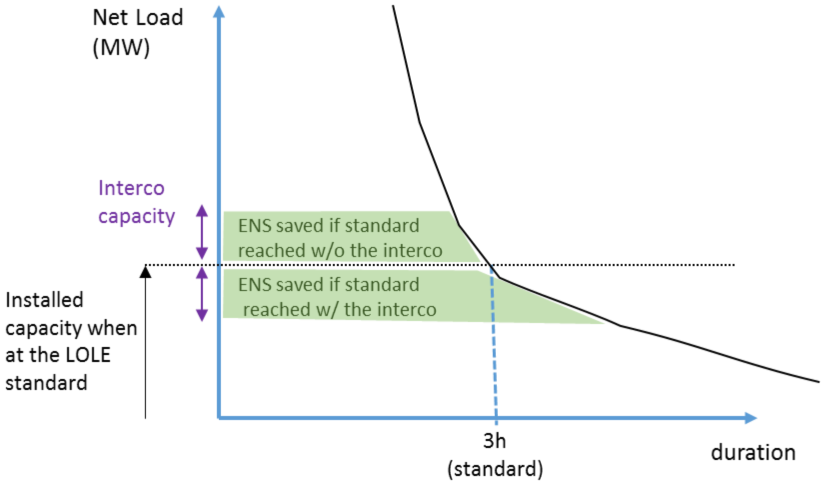
Adaptation is a change of scenarios. This change in scenarios only concerns peaking units and, in general, should thus not change the story line of the scenario.

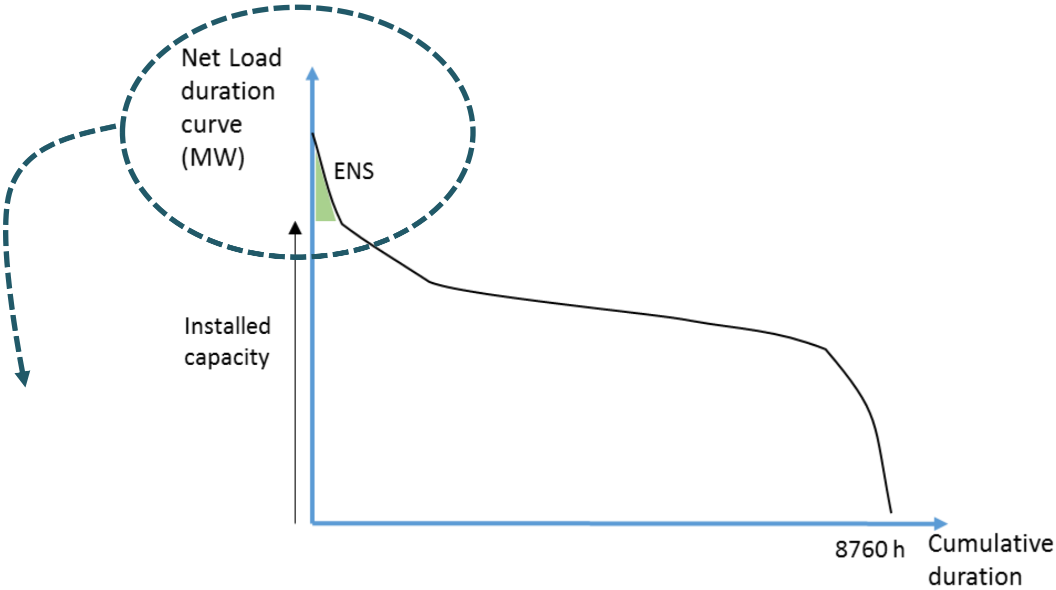
The graph hereunder illustrates the sensitivity of EENS reduction to the initial LOLE: the longer the initial LOLE is, the higher the EENS savings are. This observation makes the adaptation phase necessary to get relevant results in case the LOLE were not well calibrated.

The purpose of the adaptation is not to lead to an economical optimum. Indeed reaching an optimum is a deeper issue that could re-question the whole scenario. The aim is solely to approach reasonable LOLE (if no legal criteria, 3h/year seems to be a reasonable standard), as current scenarios have not been built at this purpose. Besides, in several countries some mechanism (e.g. capacity market) exists in order to reach this level.

Another question is whether to perform the adaptation with or without the project. Making the adaptation with the project is a way to be conservative and might describe better reality[6]. Moreover it avoids reaching significantly unreasonable LOLE when removing the interconnector.

[5] See example in section 2.3 if the level of adequacy does not improve.
[6] The interconnector is likely to be added to adequate countries


Net Load
(MW)
Interco
capacity
ENS saved if standard
reached w/o the interco
ENS saved if standard
reached w/ the interco
Installed
capacity when
at the LOLE
standard
3h
(standard)
duration


Net Load
duration
curve
(MW)
ENS
Installed
capacity
8760 h
Cumulative
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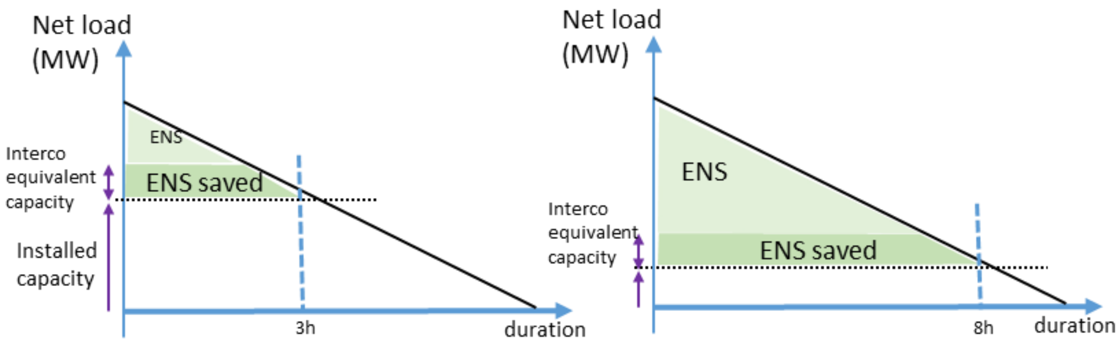
Net load
(MW)
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Interco
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Installed
capacity
3h
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Net load
(MW)
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capacity
ENS saved
8h
duration

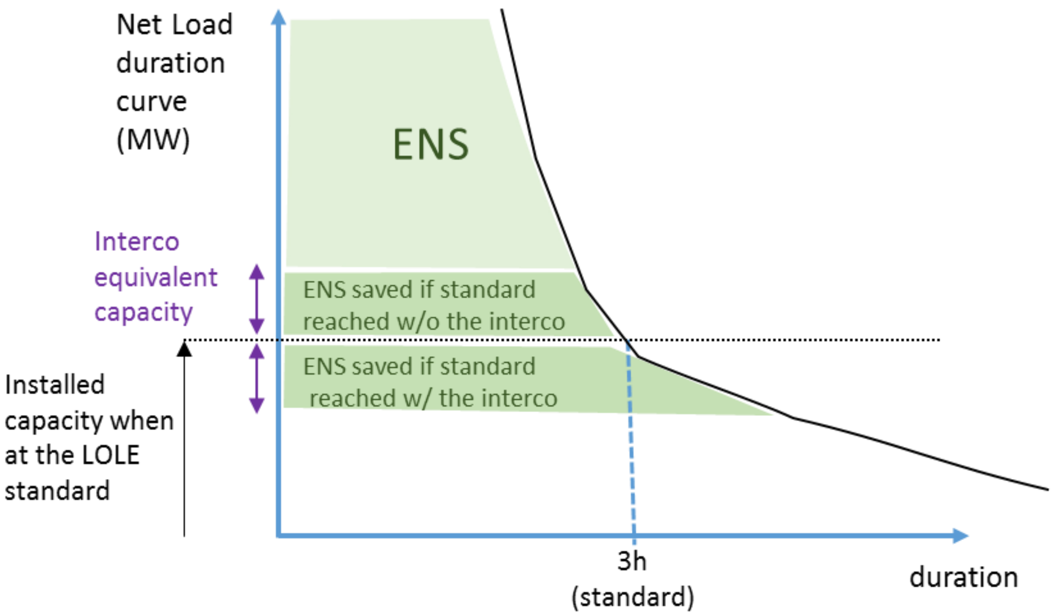

FIGURE 1 NET LOAD DURATION CURVE

As the adaptation would be performed without the project, one single one would be used for all PINT project, while for TOOT project a slight re-adaptation could be necessary.

To prove the necessity of this adaption, the method was tested for TYNDP18 and showed that in most scenarios of TYNDP 2018 only two countries would face LOLE (France and Ireland), in a significant amount. This would lead to unreasonable huge amount of benefits for interconnectors related to these 2 countries and 0 to all the other projects.

2.3. EXAMPLE

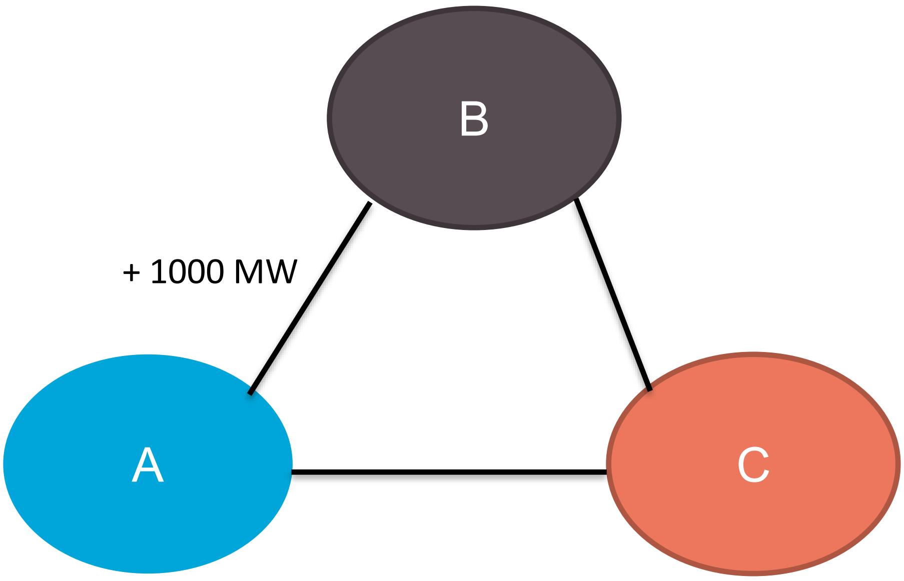

FIGURE 2 SITUATION STUDIED AS AN EXAMPLE

Let's consider the situation as shown in Figure 2 and study the adequacy benefit brought by an additional 1000MW interconnector project between A and B.

Step 1: adaptation

A and B are adapted to 3h without the new project. However, let's consider that it is not possible to adapt completely C by removing peaking units. The LOLE of C is 1h after adaptation.

Step 2: EENS saved

Situation	Interconnector presence	A – peak units (MW)	A - EENS (MWh)	A - LOLE (h)	B – peak units (MW)	B – EENS (MWh)	B – LOLE (h)	C – peak units (MW)	C - EENS (MWh)	C – LOLE (h)
Base (without interco)	without	1000	5000	3	700	4000	3	0	500	1
Add interco	**With**	1000	3000	2.7	700	2800	2.7	0	400	0.8

TABLE 2 STEP 2 : SECURITY OF SUPPLY OVERVIEW

A first benefit can now be assessed by monetizing EENS saved (here, just for the purpose of the example, VoLL = 10k€/MWh):

Country	A	B	C
EENS saved (M€/yr)	20	12	1
TOTAL (M€/yr)		**33**	

TABLE 3 STEP 2 : EENS SAVED AND VALORISATION

Step 3: individual sanity check

An individual sanity check is performed for each country independently: add peaking units in a country (from a situation without the interconnector) until reaching a slightly better or equal adequacy (in terms of LOLE and EENS). Perform it individually for each country mainly impacted:

Situation	Interconnector presence	A – peak units (MW)	A - EENS (MWh)	A - LOLE (h)	B – peak units (MW)	B – EENS (MWh)	B – LOLE (h)	C – peak units (MW)	C - EENS (MWh)	C – LOLE (h)
Base (w/o interco)	Without	1000	5000	3	700	4000	3	0	500	1
Add interco	**With**	1000	3000	2.7	700	2800	2.7	0	400	0.8
Sanity check A	Without	**1450**	2950	2.7	700	3900	2.9	0	450	0.9
Sanity check B	Without	1000	4900	2.9	**1100**	2750	2.7	0	450	0.9

Sanity check C	Without	1000	5000	3	700	4000	3	50	400	0.8

TABLE 4 STEP 3 : INDIVIDUAL SANITY CHECK

Let's now use the sanity check to cap the benefit per country (using a peaking unit cost of 40k€/MW/yr):

Country	A	B	C
EENS saved (M€/yr)	20	12	1
Sanity check value (M€/yr)	18	16	2
Adequacy benefit per country (M€/yr)	18	12	1
TOTAL (M€/yr)		**31**	

TABLE 5 STEP 3 : VALORISATION AFTER INDIVIDUAL SANITY CHECK

Step 4: Global sanity check

A global cap could be found as follow:

- Add the capacity of the sanity check of A and of B on the same situation
- If the adequacy is equal or better in all countries then a global cap is the value of the sum of the sanity check of A and B
- If not, keeping the capacity added in A and B, add some capacity in the country whose adequacy is still worse until reaching the one with the interconnector. A global cap is the value of the sum of those capacities

In the example here, adding the sanity check capacity in A and in B is not sufficient and 10MW should be added in C.

Situation	Interconnector presence	A – peak units (MW)	A - EENS (MWh)	A - LOLE (h)	B – peak units (MW)	B – EENS (MWh)	B – LOLE (h)	C – peak units (MW)	C - EENS (MWh)	C – LOLE (h)
Base (w/o interco)	Without	1000	5000	3	700	4000	3	0	500	1
Add interco	With	1000	3000	2.7	700	2800	2.7	0	400	0.8
Global sanity check A+B	Without	1450	2900	2.7	1100	2700	2.7	0	410	0.8
Global sanity check (A+B) + C	Without	1450	2900	2.7	1100	2700	2.7	10	400	0.8

TABLE 6 STEP 4 : GLOBAL SANITY CHECK

As a result, the global cap is the value of 450 + 400 + 10 = 860MW, which gives 34.4 M€/yr. The cap is higher than the value found at step 3 and the final benefit is equal to **31M€/yr**[7].

2.4. AUTHORS

Authors of this chapter include:

- Etienne Meyruey, RTE
- Nuno Martins, REN

3. SOS - SECURITY

3.1. INTRODUCTION

In the 2nd CBA guideline, the contribution of a project to the Security of Supply is estimated through three indicators, among which the "System stability" indicator. That methodology proposes to report the impact of a project on system stability only in a qualitative manner, generic per type of project related to its technology. Such a methodology does not provide meaningful insights about the way a specific project impacts the ability of the system to withstand disturbances. The purpose of this report is to analyze how the assessment of that impact could be improved.

However, before diving more in the ways to assess the impact of a project on system stability, it appears important to clarify definitions related to power system reliability. Indeed, from that clarification, it will be proposed to extend the assessment to the problem of power system security which includes (but is not limited to) power system stability.

For these reasons, this report is structured as follows. Definitions related to power system reliability are first clarified in section 3.2. Then, possible ways to assess projects' contribution to security are elaborated in section 3.3. Based on that, recommendations for the CBA 3.0 and possible future improvements are issued in section 3.4.

3.2. CLARIFICATION OF DEFINITIONS

The security of supply provided by a power system is related to its reliability. Traditionally, the reliability of a power system is decomposed into two fundamental aspects: adequacy and security. Adequacy relates to the existence of sufficient facilities (e.g. generation, transmission, distribution facilities) within the system to supply the consumer demand while

[7] If this cap had reduced the global benefit, a possible allocation would have been to keep the same ratio between countries than at step 3.

satisfying operational limits. Adequacy is therefore associated with static conditions which do not include system disturbances. Because adequacy has already a dedicated chapter in this report, it will not be further discussed in this section. On the other hand, security can be defined as the ability of the system to withstand disturbances arising from faults and unscheduled removal of equipment without further loss of facilities or cascading failures. Security is therefore associated with the response of the system to these disturbances.

Recently, the interest rose in the power engineering community for the concept of “resilience”. This concept is cited explicitly in criteria 2d of Annex IV and in criteria 6d of Annex V of the EU Regulation 347/2013. Resilience of a power system can be defined as its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event. Resilience encompasses adequacy and security aspects, but specifically for disruptive events (e.g. earthquake, hurricane), and includes considerations beyond traditional reliability analyses.

Finally, power system stability can be defined as the “ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact” [1]. To be secure, a power system must obviously be stable, but this criterion alone is not sufficient: electrical variables must stay within specific limits after the disturbance (e.g. no equipment overload, no voltage violation). The definition of security encompasses thus the definition of stability, but it is more general. Because stability and security issues are strongly interrelated (e.g. a transient stability problem can lead to the disconnection of one or several generators and could then entail voltage issues), it is proposed to extend the definition of the indicator to all security aspects, and to rename it thus into “SoS system security”.

3.3. ASSESSMENT OF PROJECTS’ CONTRIBUTION TO SECURITY

Transmission systems are usually planned and operated according to the N-1 security rule: the system must be able to withstand any single failure without stability problem and violation of operational limits. In the assessment of the SEW according to the 2nd CBA guideline, this N-1 security rule is already partly considered. Indeed, transfer capacities between areas are computed such that transmission elements are not overloaded in normal conditions and after any single contingency. It means that specific measures (e.g. installation of reactive power compensation devices) might have to be taken to allow the simulated dispatch to take place while maintaining a N-1 secure grid. A project might avoid such measures by contributing to security beyond thermal aspects. For example, a VSC-based HVDC system can contribute to reactive power compensation and voltage stability and could thus avoid the investment in capacitor/reactor banks (or other devices). This is the first category of benefits, avoided investments, discussed in section 0.

Even as the N-1 security rule is a standard to assess and manage a grid, the level of security of a grid goes beyond the behavior towards single contingencies. Indeed, contingencies not covered by the N-1 rule (e.g. busbar fault, tower failure) happen as well and can lead to demand loss. A project can improve the ability of the grid to withstand disturbances beyond single contingencies. This second category of benefits is discussed in section 0.

Finally, a project (e.g. HVDC link between two different synchronous areas) can impact the restoration. This is discussed in section 0.

3.3.1. AVOIDED INVESTMENTS

Because thermal aspects of the N-1 security rule are already considered in the SEW evaluation, the evaluation of avoided investments to respect the N-1 security rule thanks to a project must go beyond these aspects. The impact of a project on quasi-steady-state voltage issues (i.e. violation of voltage limits and voltage stability) can be estimated through a classical power flow study. However, it will only reveal the needs of capacitor/reactor banks that have a minor cost compared to the typical costs of transmission projects gathered in the TYNDP. Therefore, an estimation of the avoided investments based only on a power flow study is often (but not always) expected to have only a marginal impact on the CBA. The estimation of avoided costly investments (e.g. STATCOM, SVC) must rely on a dynamic study. In the context of the TYNDP, performing a detailed dynamic study for each project to estimate the avoided investments appears to be impracticable (data needs, computation time).

3.3.2. IMPROVEMENT OF SECURITY BEYOND N-1 EVENTS

The improvement of the system's security beyond N-1 events can be assessed in two ways: either through a deterministic approach, or through a probabilistic approach. In the first way, a pass/fail criterion can be used to assess the security of the system towards more extreme contingencies: either the system fulfills the security criteria, or it does not, similarly to N-1 assessment. Such a deterministic analysis is easy to perform but is difficult to interpret and there is no monetarization possible. Indeed, for example, if without the investment, 1000 out of 2000 N-2 contingencies are secure, and 1200 out of 2000 with the investment, what can we conclude except that the security level is higher? On the other hand, a probabilistic approach aims to estimate the average consequences of the lack of security in terms of meaningful metrics that can be converted into a monetary value (e.g. Expected Energy Not Supplied, similarly to adequacy assessments).

The main idea behind probabilistic security analyses is the following: if the system is not secure towards a specific set of contingencies, unacceptable conditions will occur (e.g. overloads, voltage problems, instabilities, etc.), these problems can end up in the loss of additional elements (cascading effect), and, in fine, loss of load can happen (e.g. localized loss of load at one or a couple of isolated buses, partial blackout, total blackout). The main aim of a probabilistic security assessment is to estimate the risk of loss of load. Various methodologies exist for that purpose, based on the simulation of cascading outages following unsecure contingencies. Similarly, to deterministic security assessment, methodologies can be clustered into two main groups: quasi-steady-state methodologies (i.e. power flow analysis) and dynamic methodologies. However, there is currently no standard methodology, and a recent benchmark revealed that there are major discrepancies between quasi-steady-state methodologies [2]. Therefore, this lack of robustness currently prevents the use of probabilistic security analyses in the framework of the TYNDP: conclusions can strongly depend on the specific methodology used. Further R&D work is needed to narrow down the range of results obtained from the different methodologies.

3.3.3. Impact on restoration (black-start services)

After the occurrence of a blackout (partial or total) in an area, the power system must be re-energized such that power plants can be restarted, and consumers resupplied. This is the restoration process. To initiate the restoration process, black-start services must be provided by generating units, storage units or HVDC links. In Europe, sourcing methods differ from one country to another: it can be an obligation for some units to deliver a black-start service, remunerated or not, or it can be organized as a market. In that context, projects analyzed in the TYNDP such as HVDC links between two different synchronous areas or storage units could improve the restoration process by reducing the time needed to resupply the customers or could reduce the costs related to the procurement of black-start services for a specific restoration performance target. However, the way the black-start services are managed in Europe is changing, and there is no uniformity between the different countries. Valuate the impact of a project on restoration time and the procurement costs of black-start services appears thus challenging in the framework of the TYNDP.

3.4. General recommendations

From the above discussions, it can be concluded that it is currently difficult to obtain a meaningful system security indicator for the CBA performed in the framework of the TYNDP. Indeed, beyond significant data needs and important computation times, methodologies leading to meaningful metrics are not yet standardized, contrarily to the adequacy assessment. In that context, it does not seem relevant to include a quantification of the SoS security indicator in the CBA 3.0 for the TYNDP2020.

Nevertheless, actions could be taken at the level of ENTSO-E to improve the situation. First, it must be understood to what extent a project such as an interconnector can impact the security, to estimate if it is worth to engage significant efforts in the systematic computation of security impacts of projects in the framework of the TYNDP. For that purpose, a “simple” case study should be investigated in the next two years to estimate the order of magnitude of security benefits. In this regard, Ireland could fit the needs, due to its islanded nature. Furthermore, standardization of probabilistic security assessment methodologies should be pursued, by encouraging the collaboration of utilities, consulting companies and academia on concrete problems. These actions could alleviate barriers currently hampering the quantification of the impact of a project on the power system security, such that a meaningful SoS security indicator could be derived for the future versions of the TYNDP.

3.5. References

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3.6. AUTHORS

Authors of this chapter include:

- Pierre Henneaux, Tractebel

4. SOS – ANCILLARY SERVICES

The ancillary services indicator shows net welfare savings through exchanging balancing energy and through imbalance netting. Balancing energy refers to products such as Replacement Reserve (RR), manual Frequency Regulation Reserve (mRR), automatic Frequency Regulation Reserve (aFRR). As we focus here on balancing energy (not capacity), the frequency containment reserve (also known as primary reserves) are currently out of scope, as no meaningful energy component exists for this product (primary reserve energy flows via the FRM).

Welfare benefits induced by exchanging balancing capacity (as defined in SOGL) which requires reserved cross zonal capacity, is currently out of scope for this indicator. Similarly, welfare benefits induced by sharing of balancing capacity (as defined in SOGL), which does not require reserved cross zonal capacity, is currently also out of scope for this indicator.

In general and in subsequent text, the current SoS indicator for ancillary services only focusses on welfare benefits induced by balancing energy exchanges – not focussing on the before mentioned potential welfare influence of a project on balancing capacity reservations. The latter remains to be further investigated for systematic inclusion for future CBA methodologies.

4.1. RECOMMENDATIONS TO IMPROVE THE SOS INDICATOR

New interconnectors (new pathways) and internal reinforcements (avoid congestions) can enable or improve the exchange of balancing energy within and between national balancing markets. For interconnectors this is the case where cross zonal capacity remains unused after latest market closure (day-ahead / intraday) in any of both directions (for upward- and downward activations). Exchanging balancing energy will enable cheaper bids from neighbouring markets to displace more expensive bids in the local balancing market, leading to cost savings and improvement in the net welfare. We acknowledge that this benefit can only be realised where platforms for exchanging balancing energy exist. For analysis in TYNDP framework, a realistic assumption can be made that in future the necessary EU platforms will be implemented and functioning properly for all balancing products (aFRR, mFRR, RR) – pursuant to the EBGL regulation.

To define a methodology for this indicator we have drawn upon studies carried out as part of the TERRE project. In the TERRE project, seven member states, France, Spain, Portugal, GB, Switzerland, Italy and Greece, trialled the exchange of RR balancing energy. Other relevant studies / cooperation exist that will provide useful insights, such as iGCC for the netting of balancing energy, PICASSO for the exchange of aFRR balancing energy and MARI for the exchange of mFRR balancing energy.

Methodology

The basic principle of this indicator is that increasing cross-border capacity could lead to a reduction in balancing energy costs. The scope of the methodology is to quantify this reduction in balancing cost. The expected outcome will eventually show an increase in the overall welfare of the system.

- **First Step – Common Platform**, we assume that in the future there will be platforms to exchange balancing energy such as IGCC (now "EU imbalance netting"), TERRE (RR), MARI (mFRR) , PICASSO (aFRR). The balancing platforms presuppose that the market pricing rules will be harmonised to marginal pricing across different markets, as required by EBGL, including the necessary settlement mechanism between TSOs and BSPs and amongst TSOs. The platform also presupposes that there will be standard balancing products to be exchanged. While this is already available for TERRE member states, we expect common balancing platforms to be rolled out as part of the balancing guidelines implementation. This assumption can be tested and adjusted for projects where common platform is not foreseeable.

- **Second Step- Balancing Need**: We assume that there is a system imbalance that needs to be resolved. The volume needed varies across member states and assumptions would be made about what this would be over the lifetime of the project being assessed. This need is not easy to forecast as generation and consumption mix are evolving. An option could be to use historical balancing needs making the assumption that they are representative for future assessments, as has been evaluated in TERRE study.. However, as the share of RES in the energy mix and the number of interconnectors is increasing, using historical data risks underestimating future balancing needs. It is strongly recommended to study the effects of this type of assumption.
  Furthermore, we acknowledge that a cross-border project or internal project with cross-border impact could itself increase the balancing needs across to bid areas but at the same time increase the means.

- **Third Step – Cross-border Exchange Capacity**: We will determine the available cross-border capacity after latest market closure, which can then be used to exchange balancing energy. This capacity in both directions (import/export) will be calculated as an output from the TYNDP market simulations. The simulation results will show the remaining cross-border capacity for every hour in the modelled years (including montecarlo/climatic years). It should be acknowledged that it's better to use latest market results including intraday and not only limiting to day-ahead, however it can give a first proxy.

- For each platform a dedicated model will be built and updated with spare capacity available with and without the project.
- Be aware that we should update the spare capacity taking into account what will be left after each platform simulation.

⇨ **Fourth Step – Opportunity for Imbalance Netting:** We will determine the opportunity for imbalance netting between control areas. Since imbalance netting can happen in both directions (import/export), fully congested cross-border capacity due to prior market flows still allows imbalance netting in the other direction.In situations where increased imbalance netting requires flows in the same direction as market flows, there is need for additional available cross-border capacity. The model should calculate the volume of imbalance netting that is possible.

⇨ **Fifth step – Balancing Bids and Offers:** The balancing bid price (or costs) stack for the different balancing markets should be established. There are currently four proposals to determine this with increasing levels of complexity

i) Determine a seasonal average balancing bid price using historical data

ii) Determine hourly national balancing bid price curves, ie price and volume offered, using historical data

iii) Determine historical balancing bid price savings exchanged through TERRE (or other such platform)

iv) Determine hourly national balancing bid price curve, ie costs and volume offered, using forecast data that reflects changes to generation mix (taking into account the technologies available for participating in the balancing market)

These options need to be further studied as we don't yet know what could be the best trade-off between sophistication and quality of the results.

⇨ **Sixth Step** - **Balancing Cost Savings.** For imbalance netting, the cost savings will be calculated as the difference of the balancing costs with and without the project.. **Merits and demerits of proposed methodologies**

Future market development: Capturing benefits relies on the availability of platforms to exchange balancing energy. However, as it is mandatory to be implemented by the EBGL regulation, this seems an acceptable hypothesis.

Data availability: It will be very difficult to access historical data to build bid price curves for different balancing markets. Further, data risk to be not harmonized yet since there are no standards products yet. On top of that these historical data might not be accurate for the future generation portfolios (demand response for balancing purposes only eventually included), fuel prices and CO_2 (to further study this aspect). In general, getting realistic estimates of both volumes and related costs/prices will be difficult and likely require high-level simplified approximations.

Complexity and timescales: There is a challenge around the choosing the right balance between complexity and feasibility of completing assessments within TYNDP timescales and resource level. For example, using the average balancing price difference may oversimplify the calculation and misrepresent the value of further cross-border capacity. On the other hand, producing full models for balancing markets may be too time consuming and not practical given existing commitments to deliver the SEW studies. The choice toward sophistication is highly dependent on the size of benefits that this indicator could catch. Higher benefits will justify higher efforts in terms of modelling and computation. We recommend performing a preliminary test to direct the next steps. In general there is the likely need to have 1 overall model that incorporates all control areas together, in order to avoid any double counting of benefits by having a fragmented implementation.

Flexibility: This methodology does not frame the benefits provided by avoided investment of flexible capacity for ancillary services nor the indirect benefits from improved exchanged of balancing capacity or sharing of balancing capacity, as stated in the introduction section.

Next Steps

1. Test the methodology to identify if the scale of the cost savings is significant and if more detailed quantitative analysis should be applied to this indicator. A first step could be to check the total welfare savings of individual platforms, in order to understand the potential benefits of these platforms and how individual TYNDP projects might contribute to the overall benefit increase.
2. Through this test, determine if links to particular markets will deliver significantly more benefits. And perhaps assess this indicator for links in these particular markets where there is high value from exchanging balancing energy. Another approach would be to unify and harmonize between the different markets, thereby simplifying the model in order to achieve short-term results. The latter approach could be interesting, as the final market design and interaction between different platforms and products have not yet been finally decided nor implemented.
3. Test the different historical methods to evaluate the increase in accuracy from employing more granular balancing bid price curves.
4. check for applicability in the TYNDP dependent on that decide on the implementation in the CBA 3.0.

4.2. Authors

Mayoma Onwochei, National Grid

Pieter-Jan Marsboom, Elia

5. Socio-Economic Welfare

During the finalization of the 2nd CBA guideline, feedback was received regarding the future considerations for the Socio-Economic Welfare (SEW) indicator.

Therefore, in preparation of the CBA 3.0, the feedback received was used to initiate further discussions with external partners from the (energy) industry regarding the modifications that industry participants would like to see addressed. To facilitate these discussions, a workshop was held on 7 November 2017 at the Leopold Hotel in Brussels.

Feedback during the workshop indicated a need to broaden the scope of the SEW indicator. Comments were also received from ACER and the European Commission asking for environmental and social costs (e.g. "true costs for society" of CO_2-emissions) to be reflected in the indicator.

The need for the broadening of the indicator was accompanied with comments calling for its sub-components to be measurable and quantifiable.

To address the comments received, a Socio-Economic Welfare (SEW) work stream was established, consisting of representatives of the ENTSO-E Drafting Team for Cost Benefit Analysis (DT CBA) mainly for organisation and from external stakeholders, who expressed an interest in becoming involved and who had relevant expertise. The list of the participants involved in the work stream is shown in the Author List below.

5.1. HOW WAS THIS CHAPTER DEVELOPED?

The chapter constitutes a report that was compiled based on the outcome of the initial stakeholder workshop and subsequent weekly conference calls to develop the topic.

The deliberations of each meeting were recorded and continued to be developed throughout the interactions, culminating in the preparation of this chapter.

How to use these recommendations?

Using the weekly discussions, each of the suggestions and comments received in respect of the SEW indicator was evaluated. The overall result was a recommendation for what changes to make to the indicator to address the comments received and to direct future work for ENTSO-E improving the CBA guideline.

5.2. SCOPE, NAMING AND COMPONENTS OF THE SOCIO-ECONOMIC WELFARE INDICATOR

The comments and recommendations received were evaluated, grouped into common themes and then collectively assessed to determine what specific actions were required. Tables containing this evaluation are contained in the Appendix A.

Based on the review undertaken, and described in the tables, the majority of the comments raised were either:

- Already addressed in the 2^{nd} CBA Guideline; or
- Scheduled to be addressed in CBA 3.0.

Consequently, no new topics were raised as a result of the process undertaken.

5.2.1. DEFINITION OF SEW

Expanding the commercially available cross-border transmission capacities between European countries (bidding areas) has a direct effect on the short-run economic surpluses of producers, consumers and TSOs. Availability of transmission capacity directly impacts on market prices and thereby affects the surpluses of different parties in different countries. This direct effect of transmission projects in altering economic surpluses of market parties is well understood and is measurable and quantifiable in simulations and has traditionally been regarded as 'the socio-economic welfare effect' of these projects.

Using the short-run economic surpluses as a measure of 'socio-economic welfare' is sometimes argued to be too narrow an interpretation, as stakeholders recognise effects of transmission projects on society beyond merely altering the short-run surpluses of parties involved in the electricity market. Expanding transmission capacities has direct impacts on society and its individuals, outside of the realm of their status as 'players' in the electricity market. Hence, transmission projects have a broader effect on total societal utility than just the short-run economic surpluses.

Measuring total societal utility would encompass a full assessment of all permanent (e.g., landscape effects, impact on sea level rise) and temporary (e.g., job creation during construction) effects of constructing transmission projects. The relationships between transmission projects and these impacts is not necessarily direct and well-defined and can play on a longer time horizon.

The scope of the TYNDP is to provide an overview of project benefits and costs for projects of pan-European significance. Assessing the full societal utility of transmission projects neither lies within its scope of abilities nor within the scope of the TYNDP. It is the role of politics rather than TSOs to optimize general economic or societal parameters. TSOs have clear-defined tasks in relation to expanding cross-border network capacity and the regulatory environment that is set up around TSOs' work, the parameters of which are set within the political sphere, should safeguard that short-term and long-term political objectives are met. However, the involvement of TSOs in this respect is highly limited and more of an operational nature.

The CBA work stream SEW therefore recommends that, in the context of the TYNDP project assessment, socio-economic welfare benefits of transmission projects should continue to be reported as the variation in economic surpluses, which is within the scope of TSO decision space. Nonetheless, the choice to limit the scope should be more explicitly elaborated in the CBA Guideline in order for users of ENTSO-E's CBA methodology to better understand this choice.

Furthermore, ENTSO-E should consider renaming the indicator 'B1 – Socio-economic welfare' in order to better reflect the scope of this indicator in relation to the more extensive concept of societal utility.

5.2.2. PROBABILISTIC ASSESSMENT

The TYNDP assesses the social economic welfare against a range of scenarios which have been developed following in-depth stakeholder engagement. These scenarios have been developed to provide a full range of credible outcomes of the future, with no weight been assigned to a given scenario. This allows the reader of the TYNDP to make his own judgement on what he believes is the most likely future scenarios and clearly identifies which scenarios a project provides a positive welfare benefit,

It has been suggested within the work stream that a probabilistic assessment would provide greater clarity on the social economic welfare benefits of an individual project. After further discussing this suggestion the team does not recommend this approach as it would require assigning probabilities and distribution curves to a wide range of variables which would be arbitrary and the effect of combing into a single probabilistic assessment would remove the ability of the stakeholder to clearly see the sceneries which drive the positive benefits.

Nevertheless, the working group does recognise that there would be benefit in undertake a more probabilistic approach for a given scenario and will recommend that this is given further consideration within the TYNDP.

5.2.3. BROAD DEFINITION OF CO2 EMISSIONS

The assessment of CO_2 emissions that is addressed within the 2nd CBA guidleine describes the amount of tons of CO_2 avoided as a result of a proposed reinforcementand the monetary value resulting from that are direct production cost savings that are already reflected within the SEW indicator.

Comments received have argued for the broader societal effects of CO_2 to be accounted for. These would include health effects, the impact on global warming and all the subsequent factors attached to that, for example. Although these effects are mentioned under the B4 indicator of the 2nd CBA guideline, more guidance is needed in order to evaluate these effects in a consistent manner.

Such a scope is broad and is relevant from a national, pan-European and global perspective, but would not be appropriate of feasible from a project perspective.

As a result, the proposal then is to more clearly define the scope and context of the CO_2 indicator with a more detailed discussion of the broader impact of the change in CO_2 levels.

5.2.4. ALIGNMENT WITH PCI PROCESS

The CBA guideline and the consequent CBA assessment on projects performed within the TYNDP framework represent an essential, although not unique, feed of the PCI selection process. In that perspective the stakeholders' (EC) request for a further alignment of the SEW indicator (and sub-indicators) with the assessment of needs for the PCI selection process would facilitate the process itself.

The work stream has however highlighted that the nature of the PCI selection process and needs assessment is the result of a regional trade-off and identification of priorities that goes beyond the methods and concepts expected within the CBA guideline.

This is in line with the overall view of the work stream for which ENTSO-E and thus its TSO members should keep playing the role of a pure technical body.

5.2.5. INCLUDING EXTERNALITIES

Reducing greenhouse gases is one of the directly measurable effects of transmission projects. The 2nd CBA Guideline presently mandates the reporting of the variation in CO_2 as a consequence of building a transmission project. A variation in the emission of greenhouse gases subsequently affects other societally relevant issues, such as sea level rise and public health. Hence, reducing emissions is not a goal, but rather a means to achieve an underlying goal. Reporting the variation in CO_2 emissions is thus a proxy for measuring the (generally harmful) climate effects of power generation – and the ability of transmission projects to reduce these emissions. A first step of showing the broader benefits of reducing CO_2 emissions was made in the 2nd CBA guideline by including the B4 – societal well-being indicator. However, further guidance should be given.

These deeper goals (or the cause-effect relation of emissions reduction and the goals) are often not (accurately) measurable, which makes it difficult to establish an adequate benefit indication of the transmission project. Furthermore, political goals are set at the level of the proxy (i.e., CO_2 emissions) and the CBA work stream SEW therefore recommends that the assessment of transmission project benefits is performed at the same level of measurement, so that transmission project contributions can be properly valued in comparison to achieving political targets.

5.3. RECOMMENDATIONS TO IMPROVE THE SOCIO-ECONOMIC WELFARE INDICATOR

After a series of weekly web conferences with intensive discussions on comments made and issues raised prior to the start of the work stream by various external stakeholders (the result of the deliberations is included in Appendix A), the CBA work stream SEW makes the following recommendations:

- Retain the current SEW definition;
- Include more formal and thorough explanations for the indicator;
- Include better discussions in which the context is better explained. For example, recognising that there is a very broad interpretation for Socio-Economic Welfare, but for practical reasons, and given the objective of the work being undertaken, the indicator is limited to changes in generation production.

- Ensure that each discussion throughout the indicator is well delimited and the scope is clearly defined, while recognising the broader context.

The recommendations are already addressed by the proposed work programme for the 3rd Guideline. Recommendations regarding the clearer scoping / delimiting of the indicator should be practical and straight-forward to implement.

5.4. Authors

Authors of this chapter include:

- *Maria Chiara Cavarretta, ENTSO-E*
- *Mario Duarte, EirGrid*
- *Andrew Hiorns, Smart Wires*
- *Martti van Blijswijk, TenneT TSO*

6. Assessment of Storage Projects

6.1. Introduction and Scope

Disclaimer: *this section is related to storage projects only. However, benefits that are described here might also apply for other types of projects.*

The transition of the European electricity system towards the EU climate and energy targets is progressing. Already in 2017, more than 33% of electricity consumption in the EU-28 was met by renewables (RES-E shares). Climate change requires that we consistently implement the energy transition. Future, longer-term targets may imply a RES-shares of more than 80%.

From an overall European perspective, an increase in the RES-E share will be primarily achieved through intermittent wind power and photovoltaics albeit local specificities will remain, like the focus on the use of hydropower resources in alpine regions. The evolution of the EU generation mix along this trend creates challenges and risks. Due to the intermittency of wind power and photovoltaics, from the short term to seasonal variations, there is an urgent need for sufficient highly efficient and economically viable flexibility solutions to complement transregional balancing efforts. Also system stability and security of supply require solutions to ensure regular grid operations in the long term. Failing to develop appropriate solutions creates in timely fashion leads to growing risks to security of supply. In the event of large-scale grid failure, for instance, the duration of split system operation has to be minimized and capability for stable island operations should be in place to reduce customer outages to a minimum.

Today, loads are mainly balanced thanks to the combination of hydro storage, pumped hydro storage (in alpine regions usually with the use of natural water inflow) and thermal power plants through the provision and activation of physical momentary reserve, ancillary services (primary, secondary, tertiary control reserves, voltage/reactive power control, black start capability and islanding operation, rotating mass, etc. …) as well as spot market products. In future, however, potential declines in available thermal capacity create a significant resource gap to be filled.

Storage technologies can improve RES-E integration and optimize thermal power plant operation economically and ecologically (significant CO_2 reduction) within the thermal phase-out scenario.

Energy Storage (ES) supports security of supply by contributing towards resource adequacy and system stability by providing capacity [MW] as well as energy [GWh].

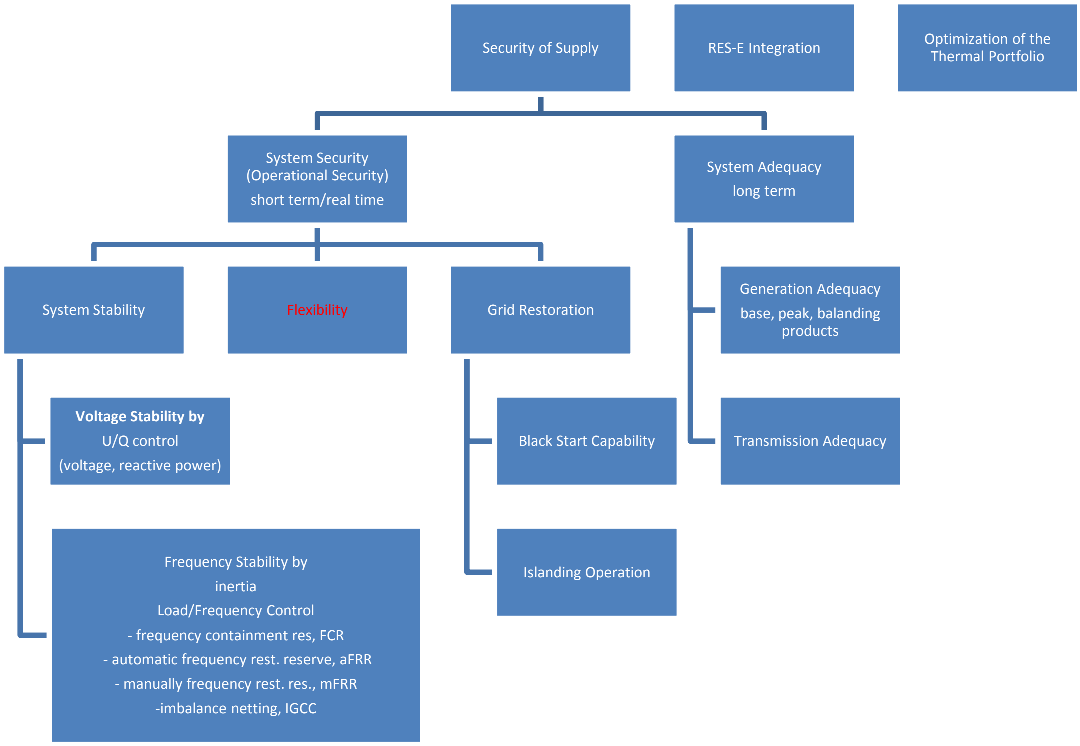

FIGURE 3:STORAGE BENEFITS.

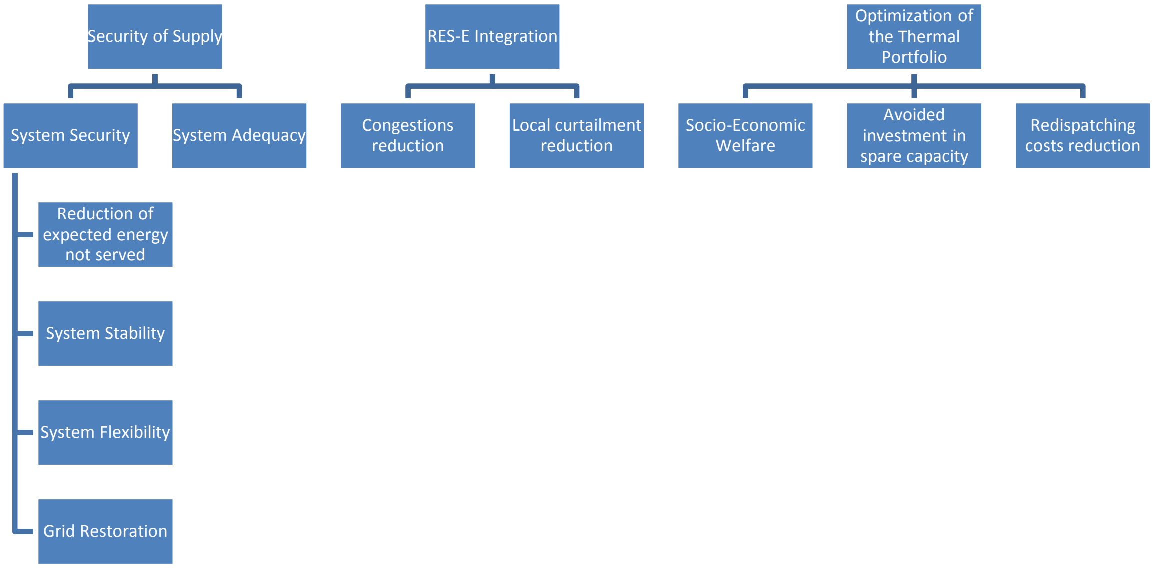

FIGURE 4: OVERVIEW OF STORAGE BENEFITS[8]

In the absence of a more refined methodology, CBA 3.0 can include a qualitative indicator depending on the ability of a project to provide synchronous inertia.

The scope of this section is not only to review all the potential benefits storage can provide but also to underline the peculiar aspects that need to be taken into account whenever needed.

According to the "2nd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects" adequacy is expressed using two sub-indicators, with the aim to capture security of supply issues as well as the contribution of projects to the efficiency of spare generation capacity: These are expected as energy not served (ENS) and as the reduction of required installed generation capacity (while maintaining the same level of ENS).

6.2. SECURITY OF SUPPLY

According to the Proposal for a Regulation of the European Parliament and of the Council on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC, COM(2016) 862 final of 30 November 2016, **'security of electricity supply'** means the ability of an electricity system to guarantee an uninterrupted supply of electricity to consumers with a clearly defined level of performance (quality criteria of grid operators). In addition, **'electricity**

[8] To be mentioned: these benefits can also be achieved by e.g. transmission projects.

crisis' means a situation of significant electricity shortage or impossibility to deliver electricity to end-consumers, either existent or imminent.

In the event of an electricity crisis as defined above, the Regulation also obliges EU Member States to support each other (engage in cross-border cooperation). Like the role played by pumped hydro and hydro storage plants in previous crises (e.g. ref. 2006 European Blackout, from Wikipedia, May 2017) also new storage technologies will be required to contribute in future.

From an overall perspective, security of electricity supply has a micro and a macroeconomic value that by far exceeds the pure market price of electricity. A stable and secure supply, in particular of electricity, is one of the fundamental preconditions for Europe's successful future as an economic powerhouse. As far as the local microeconomic consequences of ENS are concerned, plant downtimes (loss in profits, cost of delayed delivery, etc. …), possible damage to production facilities, food spoilt as result of lacking refrigeration, the cost of alternative or backup systems (emergency generator), are just a few examples of aspects to be taken into account. The macroeconomic costs of ENS are far more varied: not only they affect industry, trade and services, but also private life, social security and stability.

Consequently, it is necessary to consider the socio-economic structure to be able to carry out a macroeconomic ENS validation. The economic value of lost load should be estimated on a regional/national basis. Specific values published by NRA's are helpful for orientation.

During the transition phase from regular operation to a supply crisis, which may end in a blackout, storage devices avoid socio-economic damage for the following reasons:

a) They can play a major role in preventing grid splitting, customer outages and even widespread blackouts through the activation of ancillary services;
b) During the transition phase of operation as a result of frequency planning, they can effectively contribute to selected load shedding by rapidly modifying their energy absorption / discharge status (e.g. pumping / turbining in pump storage plants) in the event of frequency fall-off before consumers and other grid measures are affected.

Case b) is likely far more probable than case a) so the avoided socio-economic cost is expected to be far greater.

6.2.1. SYSTEM SECURITY

Storage, principally in the form of Pumped hydro, has been and will be so in future part of the generation portfolio of a number of member states for many decades, contributing to resource adequacy by supplying power at peak times and during supply balancing events.

In recent years additional technologies of grid scale ES have reached a commercial stage, positioning themselves as an attractive option to address growing flexibility needs. However, batteries, the most commercially advanced of these new storage resources, tend to be shorter in duration compared to pumped hydro thus able to contribute to manage system stress events differently.

Electricity systems with high shares of wind and photovoltaics will more and more suffer from the risk of not generating enough to meet demand, in particular during peak load in wintertime because of weather conditions (“Dunkelflaute”, free translation: 'dark flatness periods' referring to small or no availability of both solar and wind energy). It may be expected that these periods can last up to two to three weeks uninterruptedly (up to 500 hrs apiece) and may occur two or three times a year. This challenge calls for either large volumes of thermal backup reserves, or for highly efficient, long term/seasonal electricity storage.

Developing an adequate methodology to assess the contribution of storage to security of supply is needed to quantify this benefit in CBA 3.0. The assessment needs to consider factors such as storage capacity, duration cycling effects on duration/degradation and charge/discharge time. Considering the relative novelty of the capabilities and services to be provided, as well as the size of the potential in terms of volumes which could be deployed, and the assessment also needs fundamentally different modelling frameworks based on chronological analysis of network operations that incorporate generation and demand forecast accuracy.

Given the diverse nature of energy storage technologies it is important to properly represent in models the characteristics that impact ES contribution to security of supply. Some of these characteristics include among others, duration, state of charge estimation accuracy and storage plant availability.

6.2.1.1. Reduction of Expected Energy Not Served (EENS)

In case of low local network capacity or to support peak load, the ES can help to fully supply energy demand during all the period of the year avoiding risk of energy not served.

The reduction of expected energy not served can be calculated considering the comparison of i) risk of ENS without project with ii) risk of ENS with project by using the following formula:

$$\Delta ENS(MWh/y) = ENS_{with} - ENS_{without}$$

The same methodology can be applied to transmission projects that reduce the ENS, so further details can be identified in the chapter 0 of the document.

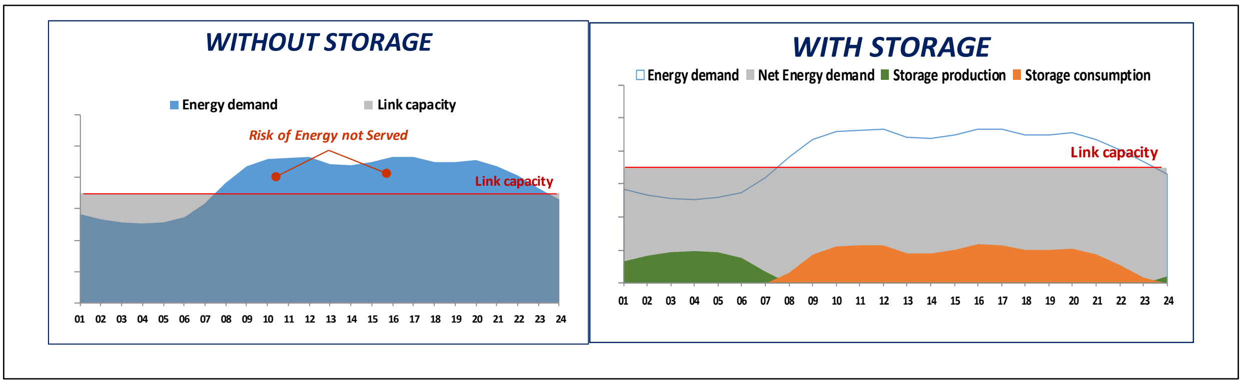

Figure 5: Example of Storage Benefits in terms of reduction of expected energy not served

6.2.1.2. System Stability

ES contributes also to **system stability** through the provision of system services enabled by its fast ramping nature. The provision of frequency response services requires keeping large thermal plant partially loaded. This results in sub-optimal operational conditions which may result in higher CO_2 emissions per kWh. On the other hand, voltage control management is highly locational and is handled by dispatching out of merit plant while curtailing in merit plant to serve voltage constraints. Energy storage will accrue benefits by allowing a more efficient market operation. This calls for the introduction of an indicator.

While these services traditionally have been provided by thermal plants, in the medium term, the operation of these synchronous generators will be significantly reduced: on the one hand, thermal plants could be decommissioned because of the progressive decarbonisation of power generation (unless CCS is successfully deployed). On the other, increasing shares of variable renewables will reduce the operation of plants with higher variable costs, specifically during low-demand hours. Some of the main challenges resulting from this condition are greater vulnerability to RoCoF (Rate of Change of Frequency) due to lower levels of system inertia and, lower Short Circuit Levels. Operating less resilient systems across Europe is likely to result in higher cost to end consumers and deploying the right infrastructure can help reduce these costs. It is therefore desirable to initiate the development of qualitative and quantitative analyses on the likely costs derived from operating less resilient systems across Europe. This should inform the value that different forms of flexibility create and should inform subsequent CBA version.

According to “ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects Generation, Draft for public consultation 25 April – 31 May”, “System stability is the ability of a power system to provide a secure supply of electricity under extraordinary conditions and to withstand and recover from extreme system conditions (exceptional contingencies)”

What could be currently defined as extraordinary condition will likely be the norm in the medium term, given the foreseeable increasing penetration of intermittent RES and a dramatic reduction of synchronous generation capacity due to frequent and acute ramping and the potential for decommissioning of large amounts of thermal capacity.

Some of the main challenges posed by these extraordinary conditions are greater vulnerability to RoCoF (Rate of Change of Frequency) due to lower levels of system inertia, lower Short Circuit Levels and reduced availability of black start plant.

Energy storage can create significant value by offering an effective means to tackle these problems. Some storage technologies can provide synchronous inertia and others can provide synthetic inertia due to a fast and accurate response. In addition, storage can also increase short circuit level, using indigenous energy, and be used to absorb or provide reactive power. Likewise, long duration assets can also be used for the provision of black start services.

An additional benefit of storage is that it provides system services (usually market based) without costs for fuel and ghg-emissions when the primary energy consumption originates from “green” energy sources, especially in a generation system with carbon-free generation that can be used to charge storage plants.

Energy storage provides frequency restoration services (primary, secondary, tertiary control reserve) as well as other (future) balancing products and generate value by opportunity cost savings (fuel, CO2, O&M, …) of thermal plants (capacity procurement and generation). Based on market oriented, optimization models the cost savings can be quantified. As these services may be different in control areas or regions of control areas, this estimation should be done on a restricted market area level.

Voltage control management is highly locational and is affected by power flows. Periods characterised by high RES generation are particularly challenging to manage for the amount of energy from these sources that needs to be accommodated. For this reason, system operators often resort to dispatching out of merit plant located where voltage constraints are while curtailing in merit plant not able to contribute to voltage constraint management. An appropriately-located energy storage could accrue benefits by allowing a more efficient market operation. This benefits should be monetised through the development of an adequate methodology, possibly looking at the avoided costs of such re-despatching operations.

As part of the work to comply with the new System Operation Guideline, ENTSO-E is developing a roadmap for inertia. This work could be complemented with analyses to include economic impact assessment of lower levels of inertia this could include the following:

- Estimating costs associated with the procurement of larger volumes of containment reserves as a result of low inertia levels;
- Assessing the comparative value between system services, e.g. if inertia could be procured this could reduce the cost to procure frequency containment reserves;
- Assessing the potential curtailment of RES as a result of low levels of inertia;
- Assessing black start costs and needs, as relying on thermal plant might result in relatively long lead times as these might have to be cold started;

In this context, it is of worth mentioning that storage performance are not in competition with synthetic inertia. In-fact, synthetic inertia does not have the quality for momentary reserves as it is for physical/synchronous inertia (ref. Dena studies on momentary reserves) so it can be simplified assuming that synthetic inertia provides the faster response to network oscillations while storages provides longer response to network oscillations.

In absence of a more refined methodology, CBA 3.0 could include a qualitative indicator capturing the ability of a project to reduce the need to procure expensive capacity to serve system services, even if it is not excluded that an expected quantitative stability margin increase can be estimated. Synchronous inertia is likely the most valuable among frequency services as this reduces the need to procure frequency response capacity including synthetic inertia and primary frequency. But it needs to be acknowledged that there is a need for minimum FCR requirement of 3000 MW required by system operation guidelines.

A second indicator could capture reactive power capabilities and a third indicator could capture black start capabilities.

Table 7 This table was taken from the 2nd CBA guideline and gives an example on how the KPIs can be treated. It will be updated with the next CBA guideline.

KPI	Score	Motivation

KPI	Score	Motivation
Response time – FCR[9]	0 = more than 30 s += less than 30 s ++= less than 1 s	30 s : ramp time of FCR 1 s : typical inertia time scale
Response time – including delay time of IT and control systems	0 = more than 200 s += less than 200 s ++= less than 30 s	200 s: FRR[10] ramp time 30 s: FCR ramp time
Duration at rated power – total time during which available power can be sustained	0 = less than 1 min += less than 15 min ++= 15 min or more	1 min : double the response time of FCR 15 min : Typical PTU[11] size
Available power – power that is continuously available within the activation time	0 = below 20 MW += 20 - 225 MW ++= 225 MW or higher	20 MW : 1-2% of a typical power plant is reserved for FCR and reachable from a project perspective 225 MW : PCI size

6.2.1.3. System Flexibility

The security of supply indicators for storage follow the same principles as for the transmission projects, covering the benefit to system adequacy to meet demand (B5) combined with the increase in system flexibility (B6).

With the exception of Flexibility (B6), the calculation of the benefit indicators is the same as for transmission. The B6 flexibility indicator is defined just related to increasing the capacity across a certain boundary. Therefore for storage a more storage specified method will be given below.

Energy storage may improve security of supply by smoothing the load pattern ("peak shaving"): increasing off-peak load (storing the energy during periods of low energy demand)

[9] FCR = frequency containment reserve
[10] FRR = frequency restoration reserve
[11] PTU = program time unit

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).

With regard to the benefits on the system flexibility of a storage project it is recommended to use a qualitative approach based on the table below, even if it is not excluded that an expected quantitative adequacy margin increase can be estimated. This assessment is to be based on the expert view considering the existing studies and technology information.

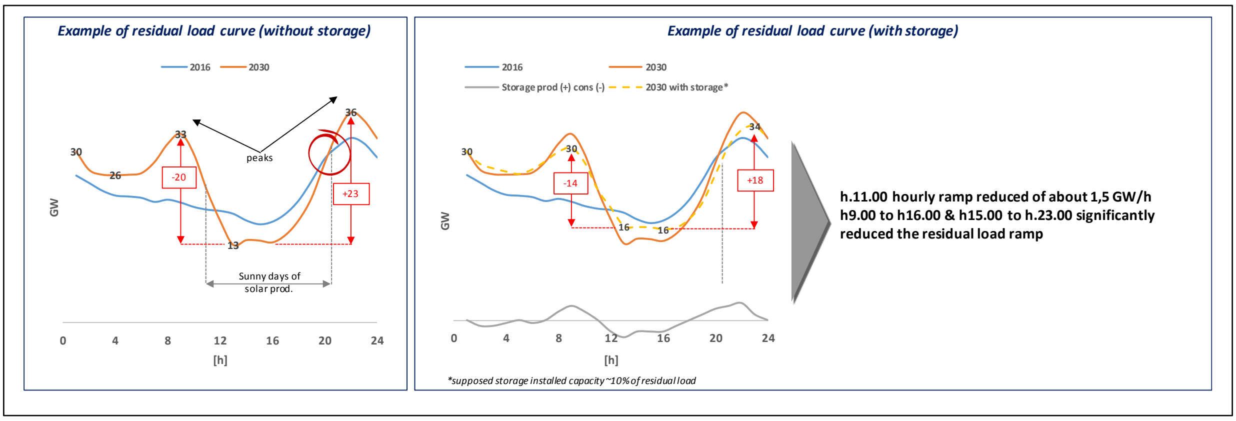

FIGURE 6: EXAMPLE OF STORAGE BENEFITS IN TERMS OF FLEXIBILITY INCREASE

6.2.1.4. FURTHER NETWORK SERVICES BENEFITS

ES can also provide black start capabilities. The challenge of valuating this service is that aspects such as safety & reliability, consumer satisfaction and economic efficiency are difficult to monetise. A way to evaluate this could be by taking reliability standards as a starting point and using LOLE or EENS as the basis to estimate the economic value based on VOLL. Additional elements to consider in assessing the value that a storage unit could create are specific location, duration, the impact that the provision of other services has on the plant's average state of charge.
An additional service that can be captured in this indicator is voltage control management. Contribution will depend on the energy storage technology. Some use conventional generators and others use inverters determining P - Q capability curves. An important factor to consider is service availability and the impact that the operation of the storage unit has in the balancing market. As can be seen from the chart below some plant are constrained so that MVARs at the right location are provided. This has a tangible cost that is set to increase as power flows are less predictable and as demand becomes less reactive.

There are no markets for voltage control or SCL. It therefore difficult to estimate the monetary value derived by a storage asset at the right location when this provides voltage control and SCL services. There is however evidence that cost to manage voltage control exist and that the energy transition is making them more expensive over the years.

In addition, the impact that this has on the operation of power (real power) markets is significant. If assets with the right characteristics (including synchronous compensators) and at the right location are installed these can accrue additional benefits that are currently not considered in the current CBA.

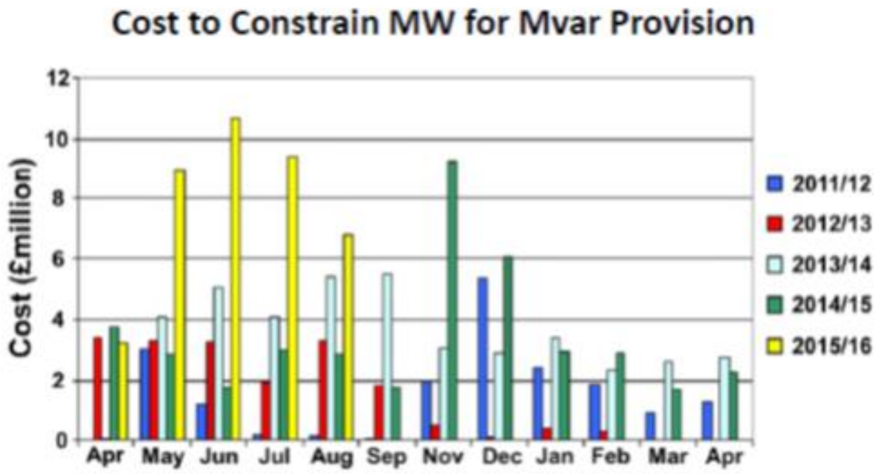

FIGURE 7: EXAMPLE OF STORAGE BENEFITS IN TERMS REDUCTION OF COST OF CONSTRAIN

6.2.2. SYSTEM ADEQUACY

Adequacy can be described as the ability of the electric system to ensure the safe and reliable operation of the grid through the provision of electrical energy to satisfy demand at any time. ES can contribute to resource adequacy by meeting demand in one area with generation from the same or another area produced previously. By increasing generation of certain plants and decreasing output of others, ES can modify the generation hourly mix even so no significant variation is expected. Thus ES has the potential to e.g. reduce the reliance on imported fuels, and to reduce the curtailment of low carbon indigenous generation. ES can also have other indirect impacts on the sizing of power system infrastructure, particularly if it helps reducing the system peak load: it may lead to reduced network investments otherwise required to cater for higher network peak load, or to avoided investments in marginal generation capacity needed to meet demand at peak. The development of adequate methodologies to assess the contribution of storage towards resource adequacy is ongoing and further work is needed to qualify and quantify these contributions.

The same methodology can be applied to transmission projects that increase adequacy, so further details can be identified in the chapter **Error! Reference source not found.** of the document.

Considering in the simulation a portfolio of generation in the scenario, the lack of adequacy can be quantified in terms of LOLE (MWh/y)

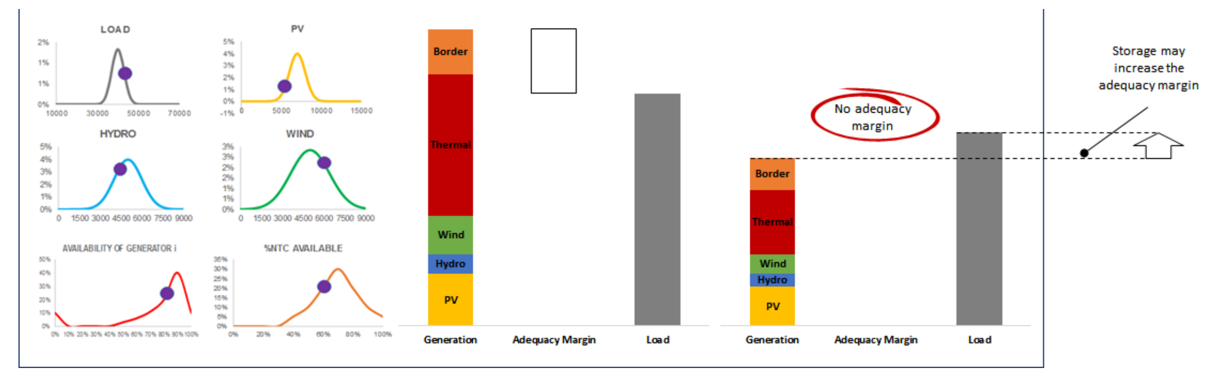

FIGURE 8: EXAMPLE OF STORAGE BENEFITS IN TERMS OF ADEQUACY INCREASE

6.2.3. MONETISATION OF SECURITY OF SUPPLY INCREASE

All the issues covered in the Security of Supply can be quantified (if no- qualitative indicators) in MWh/yr.

Therefore, if an approved value for the Value Of Lost Load is available, EENS due to security of supply can be monetized by multiplying the computed lost load during the year [MWh/yr] with the Value Of Lost Load (VOLL) [€/MWh]. The result is a value in [€/yr] which must be reported alongside the value in MWh. If there is no approved value, project promoters may also report a monetized value for EENS[12]. In this case, the VOLL that was used must be clearly displayed in the assessment table and project promoters must explain their choice.

6.3. RES INTEGRATION

6.3.1. CONGESTION REDUCTION

Energy storage facilitates the integration of growing shares of RES by

a) Absorbing energy at time of excess supply and releasing it at times when it is most needed. This capability can also be applied to reduce congestions in other parts of the grid reducing also transmission losses.
b) improve balance group management and ramping
c) providing mandatory frequency regulation service on behalf of RES plant. Once the RfG network code is enforced, large scale RES plant might have to reserve some primary energy for the provision of frequency response services. If energy storage

[12] without prejudice to different and justified assumption, a preliminary estimation of the VOLL could be the ratio between the National or European Gross Development Product (€) and the National or European Total Energy Demand.

provides this service on behalf of the plant, the RES plant would be able to convert 100% of available primary energy for injection to the grid if there was a derating factor for the RES plant needed to provide the frequency regulation.

The value that an energy storage plant can provide in this respect will depend on its duration. A proper methodology to assess the contribution to this indicator should be developed. In the meantime, qualitative indicators could be adopted based on available information. The qualitative indicator should adequately score ES while jointly considering the duration of ES and the challenge to be met. For instance, the indicator would provide a low score for systems with short durations (e.g. 4 hours or shorter) and a higher score to systems with longer duration for situation requiring the storage and discharge of large volumes of energy over long periods. Conversely, a shorter-duration ES could receive a high score whenever the challenge to meet is of short duration. In addition, the indicator should take into account ES-specific issues or costs linked to the type of ES operations (e.g. cycling information) like replacement costs and electrochemical degradation. Electrical Power and Research Institute (2010) published the table included below, showing technical requirements for the renewable integration. This could be potentially used as a basis.

TABLE 8 SOURCE: ELECTRIC POWER AND RESEARCH INSTITUTE, 2010.

Table 2-3
General Energy Storage Application Requirements [1]

Application	Description	Size	Duration	Cycles	Desired Lifetime
Wholesale Energy Services	Arbitrage	10-300 MW	2-10 hr	300-400/yr	15-20 yr
	Ancillary services [2]	See note 2	See Note 2	See Note 2	See Note 2
	Frequency regulation	1-100 MW	15 min	>8000/yr	15 yr
	Spinning reserve	10-100 MW	1-5 hr		20 yr
Renewables Integration	Wind integration: ramp & voltage support	1-10 MW distributed 100-400 MW centralized	15 min	5000/yr 10,000 full energy cycles	20 yr
	Wind integration: off-peak storage	100-400 MW	5-10 hr	300-500/yr	20 yr
	Photovoltaic Integration: time shift, voltage sag, rapid demand support	1-2 MW	15 min-4 hr	>4000	15 yr
Stationary T&D Support	Urban and rural T&D deferral. Also ISO congestion mgt.	10-100 MW	2-6 hr	300-500/yr	15-20 yr
Transportable T&D Support	Urban and rural T&D deferral. Also ISO congestion mgt.	1-10 MW	2-6 hr	300-500/yr	15-20 yr
Distributed Energy Storage Systems (DESS)	Utility-sponsored; on utility side of meter, feeder line, substation. 75-85% ac-ac efficient.	25-200 kW 1-phase 25-75 kW 3-phase Small footprint	2-4 hr	100-150/yr	10-15 yr
C&I Power Quality	Provide solutions to avoid voltage sags and momentary outages.	50-500 kW	<15 min	<50/yr	10 yr
		1000 kW	>15 min		
C&I Power Reliability	Provide UPS bridge to backup power, outage ride-through.	50-1000 kW	4-10 hr	<50/yr	10 yr
C&I Energy Management	Reduce energy costs, increase reliability. Size varies by market segment.	50-1000 kW Small footprint	3-4 hr	400-1500/yr	15 yr
		1 MW	4-6 hr		
Home Energy Management	Efficiency, cost-savings	2-5 kW Small footprint	2-4 hr	150-400/yr	10-15 yr
Home Backup	Reliability	2-5 kW Small footprint	2-4 hr	150-400/yr	10-15 yr

1. Size, duration, and cycle assumptions are based on EPRI's generalized performance specifications and requirements for each application, and are for the purposes of broad comparison only. Data may vary greatly based on specific situations, applications, site selection, business environment, etc.
2. Ancillary services encompass many market functions, such as black start capability and ramping services, that have a wide range of characteristics and requirements.

With regard to RES integration monetization due to ES, if not included in SEW or not double-counted in SEW, they have to be presented as additional information, in both cases in MWh.

The monetization would be to give these additional information in a simplified way by multiplying the annual avoided curtailed RES (in MWh) by the average market price (€/MWh) from market simulations output.

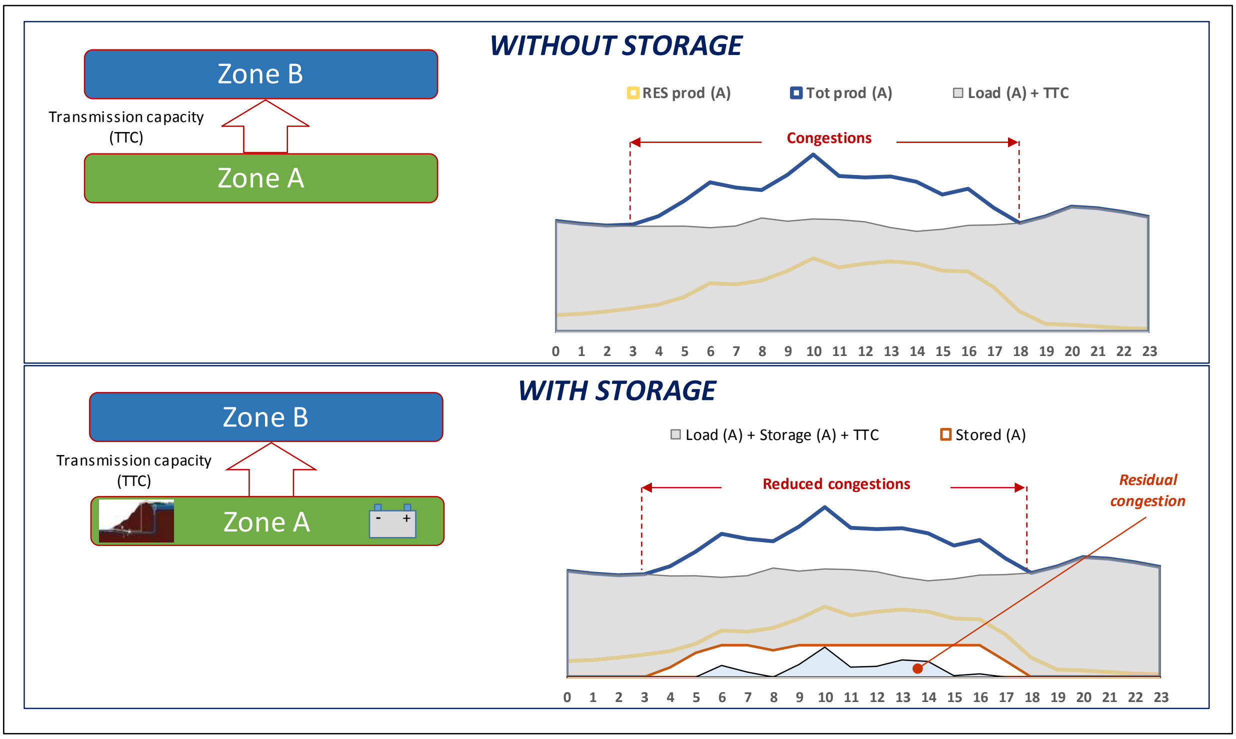

FIGURE 9: EXAMPLE OF STORAGE BENEFITS IN TERMS OF CONGESTION REDUCTION

6.3.2. LOCAL CURTAILMENT REDUCTION

In case of local lower capacity of the network to support peak generation, the ES can help to fully exploit renewable energy production during all the period of the year avoiding risk of energy not delivered/injected to the system.

The reduction of expected energy not delivered/injected can be calculated considering the comparison of i) risk of curtailment without project with ii) risk of curtailment with project.

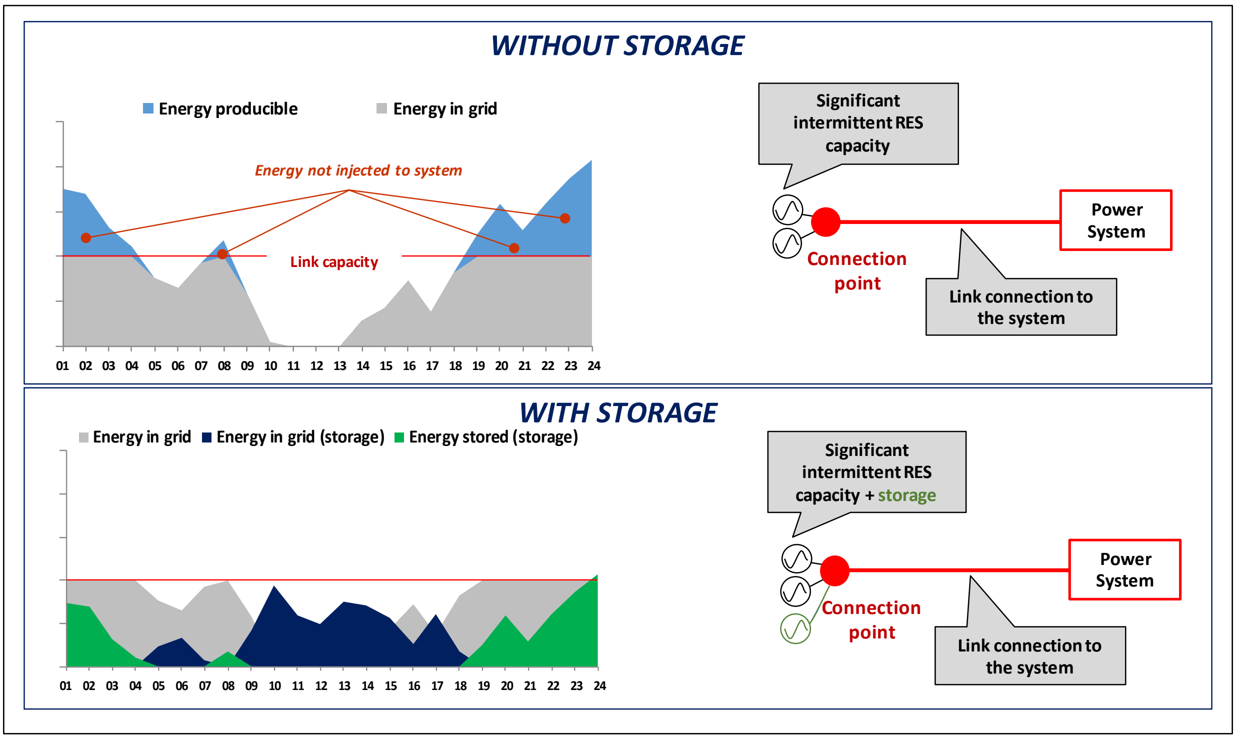

FIGURE 10: EXAMPLE OF STORAGE BENEFITS IN TERMS OF LOCAL CURTAILMENT REDUCTION

6.4. OPTIMIZATION OF THE THERMAL PORTFOLIO

6.4.1. SOCIO-ECONOMIC WELFARE

ES can increase socio-economic welfare by displacing high cost generation with low marginal cost, low carbon energy, specifically if that would have been otherwise curtailed like renewables in situation of system stress or excess supply. While this may be similar to some of the impacts of interconnectors, the fundamental difference is that whereas an interconnector can only benefit from price difference between zones, energy storage enables locational and temporal energy shift adding an important and valuable element to the analysis of GTC.

The proposed methodology to assess this is through a Production Cost Model (PCM), where costs resulting from commitment and dispatch of all resources on the system to meet the load at least cost are analysed while obeying all relevant constraints e.g. generation, operating reserve, an appropriate network model, etc. The proposed analysis should be carried out for selected representative years, e.g. 2020, 2025, 2030, 2035, 2040 to limit simulation time.

It is expected that with storage, results from PCM model show lower production costs. However, in real life the storage unit will participate in day ahead or balancing markets where prices will be set by the marginal device and these can be higher than those from the PCM model. In the long term if storage offers the best option it could displace other forms of more expensive generation resulting in real life and modelling results to converge.

Moreover, energy storage is an effective tool for peak shaving and it can be realized by shifting load to a later moment or by using onsite standby generation facilities during peak times.

The actions of storage in the system can be confined in two effects:

- due to higher electricity demand during daytime, ES can pump during the night and generate during the day;
- during days of higher RES production e.g. on sunny summer days because of high priority in-feeds of PV systems or if there is a lot of wind power production, ES are appropriate devices for reducing price fluctuations, due to the possibility of consuming and producing electricity.

ES can also be used to reduce network congestion by enhancing GTC (see chapter 6.3.1). The value of energy stored will depend on prevailing market conditions in either the wholesale market or in the balancing market depending on times where this energy is traded and the congestion management executed. Whereas this energy will be dispatched to maximise the economic benefit, and this is likely to be informed by the type of marginal units in the markets under consideration. The impact of storage efficiency on value created should be informed by modelling. Relevant factors to take into consideration are: storage duration, expected load profiles, timing and amount of excess energy.

6.4.2. AVOIDED INVESTMENT IN SPARE CONVENTIONAL CAPACITY

Energy storage is expected to allow lower investments in peaking generation capacity. This can be measured in MWs of spare capacity that does not need to be installed and can be monetised on the basis of investment costs of peaking units. The impact of ES on the generation mix should be calculated by considering the net reduction in the economic (i.e. inclusive of all externalities) cost of new generation, that is, the net economic cost difference between the additional generation required to charge the ES and the avoided generation during the discharge phase. A way to monetise the latter could be based on the operation of a peaking plant assuming the average operating point of this plants and its associated heat rate.

Nevertheless, it is relevant to avoid a double counting of the benefits of system adequacy.

Indeed, the 'Additional adequacy margin' can be measured in MW of spare capacity that does not need to be installed as a result of expanding transmission capacity or installing ES. It can be conservatively monetised on the basis of investment costs of peaking units only in case the following cases so the double counting is excluded:

- *according to the scenario under investigation, no benefit has been introduced in terms of system adequacy increase;*
- *further investment in spare conventional capacity is avoided over the capacity included into the scenario.*

Although this may not be appropriate if the share of the additional adequacy margin compared to the installed generation base is relatively large. In this case a specific analysis is required for the monetization of the additional adequacy margin.

In addition, storage is expected to reduce curtailment of low carbon indigenous electricity, thus potentially reducing the reliance of imported fuels to serve load.

6.4.3. Redispatching costs reduction

ES can also be used to reduce the redispatching cost as spread between higher cost generation units and lower generation cost storage unit assuming that renewable energy is stored.

The proposed methodology to assess this is through a Production Cost Model (PCM), where costs resulting from commitment and dispatch of all resources on the system to meet the load at least cost are analysed while obeying all relevant constraints e.g. generation, operating reserve, an appropriate network model, etc. The proposed analysis should be carried out for selected representative years, e.g. 2020, 2025, 2030, 2035, 2040 to limit simulation time.

It is expected that with storage, results from PCM model show lower redispatch costs. However, in real life the storage unit will participate in day ahead or balancing markets where prices will be set by the marginal device and these can be higher than those from the PCM model. In the long term if storage offers the best option it could displace other forms of more expensive generation resulting in real life and modelling results to converge.

In any case, a new qualitative approach/indicator is needed in order to avoid a double counting with SEW benefit.

6.5. Further benefits

6.5.1. Variation in losses in the transmission grid

Variation in losses in the transmission grid is the characterization of the evolution of thermal losses in the power system. It is an indicator of energy efficiency**.**

If located in the right place storage can improve load flow pattern reducing transmission losses when they decrease the distance between production and consumption. Location is a key element.

Losses reduction benefit can be evaluated and monetized using the same approach of CBA 2.0 for grid development projects.

6.5.2. Variation in CO2 emissions

To estimate the impact of storage on CO2 emissions a proper methodology should be developed.

We can use the recommendations presented in GRIDSTOR Recommended Practice (DNVGL-RP-0043) as the basis for the development of this methodology.

6.6. [APPENDIX: LITERATURE REVIEW OF THE RECENT PROPOSED METHODOLOGIES TO EVALUATE THE CONTRIBUTION OF STORAGE TO SECURITY OF SUPPLY

The methodology proposed was developed in the UK (National Grid, "Duration-Limited Storage De-Rating", November 2017)[13], but is not country specific as it is based on statistical analysis. The aim is to quantify the amount of perfectly reliable infinite duration firm capacity that can displaced by the deployment of finite duration capacity while maintaining a predetermined reliability level. The methodology is based on the statistical analysis of Equivalent Firm Capacity (EFC). EFC is a metric that can be used to normalise the security of supply contribution of non-conventional adequacy resources and has been designed to capture the effects of energy limited resources.

The methodology is the result of industry consultation and can be applied to other member states with country or regional data. The following table presents applicable results to the UK and show the relationship between duration and contribution to security of supply.

Table E1 – CM De-Rating Factors Proposed for Duration-Limited Storage Class in the 2018/19 T-1 and the 2021/22 T-4 Auctions

Final De-Ratings Per Duration in Hours	"2018/19"	"2021/22"
Storage Duration: 0.5h	21.34%	17.89%
Storage Duration: 1h	40.41%	36.44%
Storage Duration: 1.5h	55.95%	52.28%
Storage Duration: 2h	68.05%	64.79%
Storage Duration: 2.5h	77.27%	75.47%
Storage Duration: 3h	82.63%	82.03%
Storage Duration: 3.5h	85.74%	85.74%
Storage Duration: 4h +	96.11%	96.11%

FIGURE 11 SOURCE NATIONAL GRID(NATIONAL GRID, "DURATION-LIMITED STORAGE DE-RATING", NOVEMBER 2017

An additional methodology was presented by Imperial College and can be found in a document called "Analysis of Integrated Energy Storage Contribution to Security of Supply" here:http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Smarter-Network-Storage-(SNS)/

The methodology also assesses the contribution of storage on EENS and Equivalent Firm Capacity to estimate the contribution of storage to security of supply. An example of the results can be found here below.

13 https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/150/Duration%20Limited%20Storage%20De-Rating%20Factor%20Assessment%20-%20Final.pdf

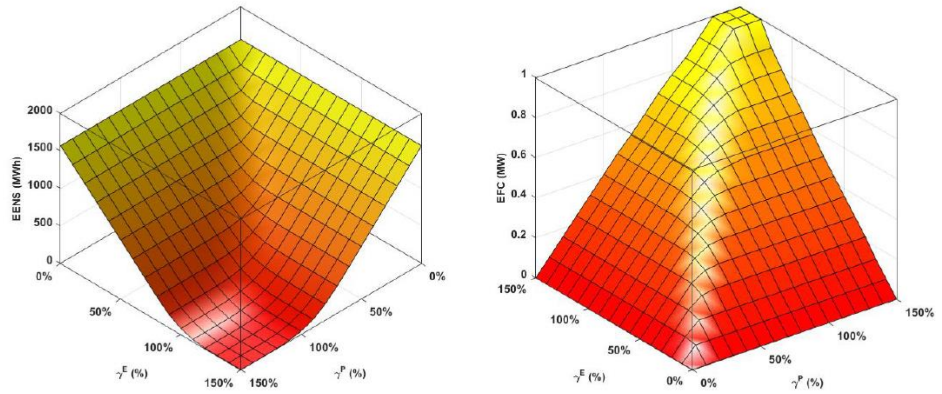

Figure 21: Sensitivity analysis of EENS and EFC as a function of power and energy allocation factors γ^P and γ^E under forecast errors $\sigma^P = 20\%$ and $\sigma^E = 20\%$.

Two examples of such methodologies are presented in “Analysis of Integrated Energy Storage Contribution to Security of Supply” by Imperial College and “Duration-Limited Storage De-Rating Factor Assessment – Final Report” by National Grid.

6.7. AUTHORS

Authors of this chapter include:

- Fernando Morales, Highview Power Storage
- Dr. Peter Bauhofer, TIWAG
- Michael Zoglauer, TIWAG

7. CONCLUSION

In the past years, ENTSO-E has almost continuously been developing its CBA methodologies in joint cooperation with ACER, EC, and other external stakeholders. External involvement in the drafting process is highly welcomed, as it supports ENTSO-E in developing state-of-the-art assessment methodologies that enables it to present relevant information to the public through, inter alia, its biennial Ten Year Network Development Plan.

The work streams that were set up and operated in the period December 2017 – April 2018 were considered as very valuable and ENTSO-E would like to thank all those that participated. An overview of participants who signed up for the various work streams is provided in the subsequent sections. Note that persons may have signed up for more than one work stream. Not all work stream participants are also authors of the respective chapters. The primary authors of the various segments of this document are therefore listed separately at the end of each chapter.

7.1. Participants of the SEW workstream

Affiliation	Name	Country
ACS Cobra	David Navidad Mencia	International
Amprion	Mario Bechmann	Germany
Baringa Partners	Ilesh Patel	United Kingdom
DNV GL	Martijn Duvoort	The Netherlands
EDF	Marie Petitet	France
EIB	Manuel Baritaud	Luxembourg
EirGrid	Mario Duarte	Ireland
ENTSO-E	Maria Chiara Cavarretta	Europe
Friends of the Supergrid	Pierre Bernard	Belgium
Smart Wires	Andrew Hiorns	United Kingdom
TenneT TSO	Martti van Blijswijk	The Netherlands

7.2. Participants of the SoS workstream

Affiliation	Name	Country
Abengoa	Juan Lazcano	Spain
ACS Cobra	David Navidad Mencia	International
RTE	Etienne Meyruey	France
DNV GL	Martijn Duvoort	The Netherlands
DNV GL	Pieter Van Der Wijk	The Netherlands
DNV GL	Carmen Wouters	The Netherlands
EDF	Cyril Gisbert	France
EIB	Manuel Baritaud	Luxembourg
Elia	Janus De Bondt	Belgium
ENTSO-E	Maria Chiara Cavarretta	Europe

Inabensa	Juan Santos	Spain
National Grid	Mayoma Onwochei	United Kingdom
Siemens Gamesa	Daniel Soto	Germany
Svenska kraftnät	Erik Hellström	Sweden
TenneT TSO	Dr. Nils Schindzielorz	Germany
TIWAG	Dr. Peter Bauhofer	Austria
Tractebel	Pierre Henneaux	Belgium

7.3. PARTICIPANTS OF THE STORAGE WORKSTREAM

Affiliation	**Name**	**Country**
ACS Cobra	David Navidad Mencia	International
AES Energy Storage	Taylor Sloane	USA
Baringa Partners	Ilesh Patel	UK
CENER	Raquel Garde	Spain
DEME	Frank Verschraegen	Belgium
DNV gl	Martijn Duvoort	The Netherlands
EASE	Marine Delhommeau	Belgium
EDF	Cyril Gisbert	France
Friends of the Supergrid	Pierre Bernard	Belgium
Highview Powre Storage	Fernando Morales	UK
IEB	Federico Ferrario	Luxembourg
Instalaciones Inabensa, S.A.	Pablo Infante Cossio	Spain
Siemens Gamesa	Daniel Soto	Germany

Terna	Corrado Gadaleta	Italy
TIWAG	Dr. Peter Bauhofer	Austria
TIWAG	Michael Zoglauer	Austria
Tractebel	Benjamin Dupont	Belgium
TransnetBW	Boris Gaillardon	Germany

APPENDIX A: SEW – REVIEW OF COMMENTS

Comment	Source	Status
Expand on Socio-Economic Welfare indicators to show additional value of, for e.g. RES integration, societal benefit of CO2 reduction etc. **SEW sub-components**	ACER, webconference in preparation of ACER Opinion on CBA 2.0	Addressed in 2^{nd} CBA Addressed in 2^{nd} CBA Partly addressed in 2^{nd} CBA Partly addressed in 2^{nd} CBA
Separately show monetized components of RES and CO2 in SEW indicator **SEW sub-components**	Official ACER Opinion on CBA 2.0, 08-2017	
Including the quantifiable benefits that fall under the term welfare which in general (will include the monetisation of RES integration and CO_2 mitigation) **SEW sub-components**	Unofficial draft European Commission Opinion, 12-2017	
covering more/all aspects that fall welfare (such as CO2 mitigation and RES integration) **SEW sub-components**	Unofficial draft European Commission Opinion, 12-2017	
Definition of SEW as “cross-border” or “internal” (references included for the calculation of indicators for SEW:cross-border and SEW:internal); **SEW sub-components**	ACER, webconference in preparation of ACER Opinion on CBA 2.0	Addressed in 2^{nd} CBA Addressed in TYNDP’18 Addressed in 2^{nd} CBA
Transparently display how the SEW has been calculated (only cross border impact, only internal impact or both together) **SEW sub-components**	Unofficial draft European Commission Opinion, 12-2017	
Contribution to savings in congestion managements **SEW sub-components**	ENTSO-E public stakeholder workshop, 7 November 2017	
To capture all the benefits **SEW sub-components**	ENTSO-E public stakeholder workshop, 7 November 2017	Open
Split SEW in a Socio and Economical Part **SEW sub-components**	ENTSO-E public stakeholder workshop, 7 November 2017	
defining a concept of welfare in general (of which SEW, as it is defined now, is a sub-indicator) **SEW sub-components** **SEW definition**	Unofficial draft European Commission Opinion, 12-2017	
Arbitrage benefits (related to storage?) **SEW sub-components**	ENTSO-E public stakeholder workshop, 7 November 2017	Unclear what is meant by this comment. Appears to be a concern, but it seems to be addressed by models presently.

Comment	Source	Status
CO_2 value – avoided damage in terms of climate impact / determining the actual impact of CO_2 (not only the monetary value as for CO_2 costs) / possible societal extra-value of RES integration and CO_2 variation **CO_2 emissions**	ENTSO-E public stakeholder workshop, 7 November 2017	Partly addressed in 2nd CBA
Improve CO_2 assessment (dispatched different power plants, reduce CCGT production) in the context of storage. **CO_2 emissions**	ENTSO-E public stakeholder workshop, 7 November 2017	Addressed in 2nd CBA
Displaced CO_2 in the context of storage **CO_2 emissions**	ENTSO-E public stakeholder workshop, 7 November 2017	Addressed in 2nd CBA
For monetising the „additional“ benefit of RES and CO_2 the outcome of already existing studies should be used **RES monetization** **CO_2 monetization**	ENTSO-E public stakeholder workshop, 7 November 2017	Consider in the context of performing sensitivities
giving a monetary value per ton CO_2 and/or per MW/MWh of included RES / Defining the (monetized) societal value of reducing CO_2 and integrating RES **RES monetization** **CO_2 monetization**	ENTSO-E public stakeholder workshop, 7 November 2017	
1. Define societal value of RES (shouldn't this be CO_2?) in €/tonne (e.g.: 200 €/tonne) 2. Then you have: a) CO_2 included in SEW through gen. costs (e.g.: 30€/t) b) Additional societal value:(200 – 30) * "avoided t of CO_2" **RES monetization** **CO_2 monetization**	ENTSO-E public stakeholder workshop, 7 November 2017	
Monetization of CO_2. important to know about the other sector. (we are focusing on electricity sector but how about CO_2 we saved if the quota is used by other sectors?) **externalities**	ENTSO-E public stakeholder workshop, 7 November 2017	Open

Comment	Source	Status
Reduced RES curtailment (in the context of storage) **RES integration**	ENTSO-E public stakeholder workshop, 7 November 2017	Addressed in 2nd CBA
RES allocation in long term – contribution of Storage and transmission in terms of time and geography **RES integration**	ENTSO-E public stakeholder workshop, 7 November 2017	Unclear what is meant by this comment.
giving a clear definition of what is meant under this indicator **SEW definition**	ENTSO-E public stakeholder workshop, 7 November 2017	Open
Renaming the indicator so that it reflects what is covered by it / Renaming SEW. Not reflecting the true meaning **SEW definition**	ENTSO-E public stakeholder workshop, 7 November 2017	Open
delivering a more clear definition and naming of this indicator **SEW definition**	Unofficial draft European Commission Opinion, 12-2017	Open
the term 'socio-economic welfare' (in its definition under the 1st and 2nd CBA guidelines) is misunderstood by some stakeholders, which expect the definition to encompass more than merely the change in yearly economic surpluses, and must be renamed; **SEW definition**	Unofficial draft European Commission Opinion, 12-2017	Open
Align SEW with PCI needs assessment indicators **PCI alignment**	Unofficial draft European Commission Opinion, 12-2017	Open
Consider the calculation of an SEW benefit indicator where probabilistic network studies are used to assess re-dispatch or generation curtailments beyond those captured by the market studies **sensitivities**	ACER, webconference in preparation of ACER Opinion on CBA 2.0	open

APPENDIX B: SEW – RECOMMENDATIONS

Category / topic	Brainstorm	Proposal (quantification)
Broad definition of SEW	**<u>YES:</u>** short-term variable cost; well-defined term in TSO world, but understood much broader by other stakheolders (e.g. creation of jobs); recognize that SEW is broad, explain our choice of 'narrow' definition; **<u>NO:</u>** broad definition in terms of all societal utility; uniformity is difficult to achieve if 'all utility' is (potentially) included; unable to assess indirect effects such as job creation; broadening the scope is the role of PCI process;	Keep economic definition, as understood in energy economics (short-run variable cost benefits). Acknowledge the broad context, but explain why we focus on the "narrow" definition → **make this decision more transparent!**
Probabilistic assessment of SEW	Falls outside the scope of indicator definition	Leave question to application of CBA (e.g. TYNDP)
Broad definition of CO2 emissions	Consider as externality. Difficult to quantify. Tonnes of CO2 emitted are clearly in. Health, mortality impact etc. cannot be properly assessed. Studies calculating the actual societal cost of carbon emissions (UK study). Governments should value the cost of carbon, not TSOs.	Determine carbon emission cost based on studies that compute the cost i.e. in €/tonne → reliability of source? Leave it to the politicians → we might do it for them, as we do with VOLL, but it should never be a TSO-produced figure.
Alignment with PCI needs assessment	This becomes a political issue, shouldn't get into this as TSOs ? Have project promoters align their plans for projects with the needs assessment (close the loop between iterations of TYNDPs).	PCI needs assessment deals with regional trade-offs and priorities. CBA should provide information to support this process, but not get into the political trade-offs itself.
Externalities		Acknowledge, but apply a clear limit of scope and include direct effects only