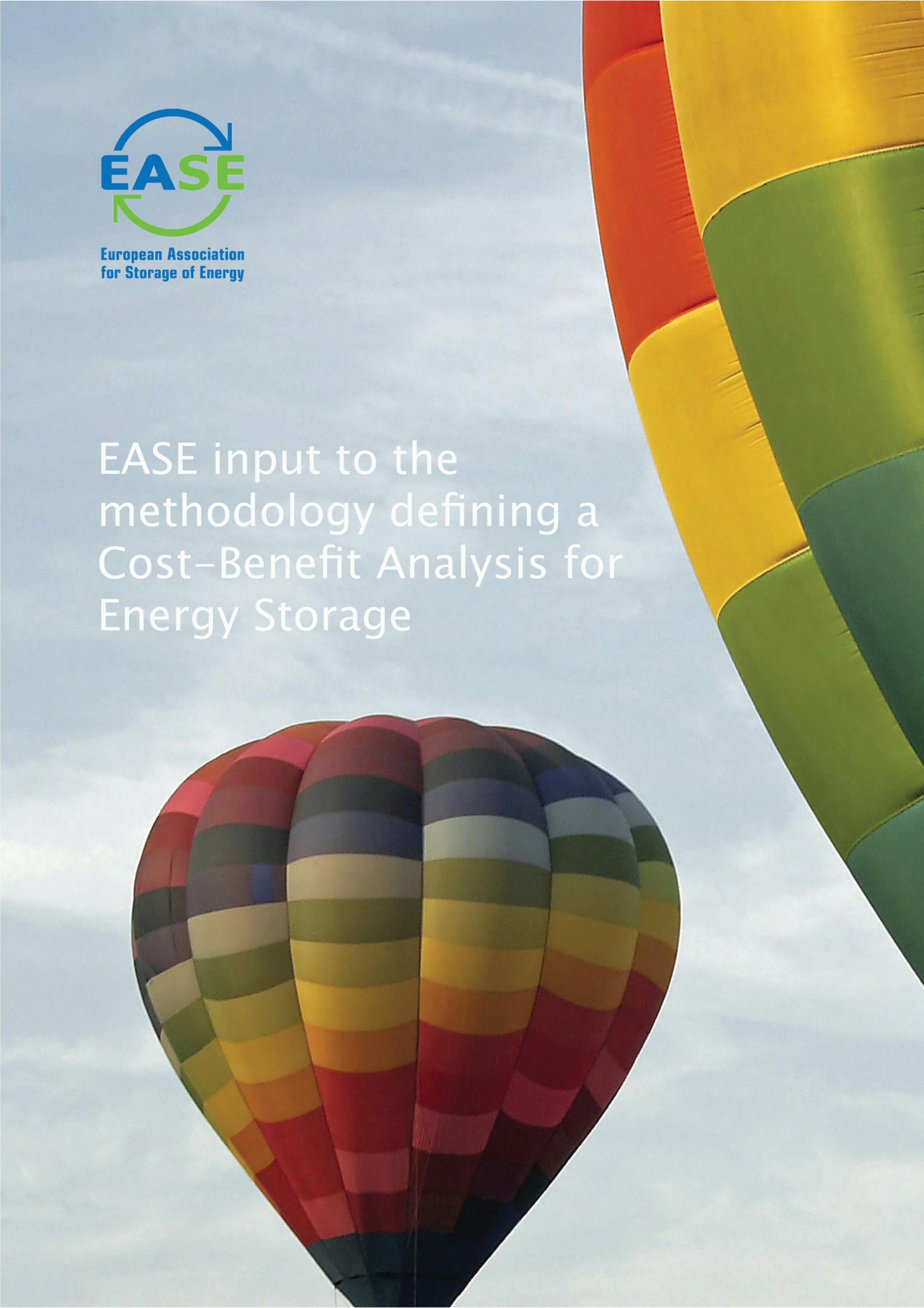
European Association
for Storage of Energy

EASE input to the methodology defining a Cost-Benefit Analysis for Energy Storage



This document was elaborated by the EASE Technology & Strategy Committee's Task Force on CBA methodology

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Content

1. Context and objectives of the document

1.1. Context

ENTSO-E is preparing the future Ten-Year Network Development Plan (TYNDP) in view of the entering into force of the new European Regulation on guidelines for the implementation of European energy infrastructure priorities in 2013.

ENTSO-E has to deliver a Cost Benefit Analysis (CBA) methodology in order to:

- Produce a system-wide CBA, allowing the assessment of all TYNDP projects in a homogeneous way;
- Assess all the electricity projects of common interest (PCIs);
- If required, provide information for cost allocation and incentive/grants for the PCIs process.

ENTSO-E has asked EASE to provide insights on a CBA for storage projects in order to be able to integrate storage projects next to transmission projects in the CBA of the TYNDP. Therefore, the focus will only be on energy storage projects that are reaching the threshold size of 225 MW[1]. Any electricity storage connected at the distribution level and medium-sized electricity storage connected at the transmission level is thus excluded from the scope of this document.

1.2. EASE Objective

EASE wishes to give a reply to ENTSO-E request on the following aspects:

- Comment the validity and suitableness of applying the proposed indicators for energy storage projects;
- Develop an environmental indicator "social and environmental sensibility" since it is technology-specific (S1).

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:EN:PDF: annex IV, 1b

2. Introduction: what is a Cost Benefits Analysis

CBAs[2] are characterised by a set of common features:

1. **Based on scenarios**: hypotheses are made on commodities prices, demand, CO_2 prices, non-dispatchable production (RES[3], run of river), energy mix (nuclear, fossil fuel power plants) and interconnections.

2. **Use of models and simulations**: a CBA aims at providing quantitative elements – it therefore implies the use of adapted tools. The models used can have different features and specificities regarding e.g. the modelling of hydraulic power and intermittency arising from solar and wind generation, to the deterministic or stochastic approach, to the possibility to modify and adapt the fossil fuel production park. Two main types of tools are used :

   a. **Market models**: these models use a simplified representation with cooper plate zones linked to each other through interconnections. They allow simulating the demand-production adequacy on an hourly basis through many years, with a detailed representation of hydro power and interconnections. They cannot be used to study precisely internal congestions.

   b. **Network models**: these models provide a vision of power flows through the system. They are based on Kirchoff laws, and on a detailed representation of the system (lines, nodes, consumption, transformers, etc.). Security constraints are also generally taken into account. Due to important calculation time and to the very high number of data needed, only a few hours can be simulated, which is the main limit of these models.

3. **Planning**: the two kinds of models are used jointly to provide a realistic view of a project. Market models are used to assess the benefits of a project, whereas network models are used to determine the network reinforcements needed to realise the project. Therefore, one project is generally a cluster of sub projects (reinforcements, transformers, etc.)

4. **Criteria evaluation**: the tools are used to calculate criteria. These are generally based on production costs, flows, installed capacity, LOLE[4], CO_2 emissions, etc.

5. **Criteria prioritisation**: the criteria need to be categorised and given different levels of importance in order to help assessing the interest of a project.

6. **Comparison of "two worlds"**: criteria are often not expressed in absolute value, but as relative values, which allows comparing the system with and without the project.

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[2] In this context, CBA is, among others, an input in the Projects of Common Interest (PCI) selection process.

[3] Renewable Energy Sources

[4] Loss Of Load Expectation

3. ENTSO-E proposed criteria and perimeter

3.1. Perimeter: evaluation of Projects of Common Interest (PCI)

All the PCIs (storage, electricity transmission, gas & smart grids) shall meet the following general criteria[5]:

- The project is necessary for at least one of the energy infrastructure priority corridors and areas,
- The potential overall benefits of the project, assessed according to the CBA, outweigh its costs, including in the longer term,
- The project meets any of the following criteria:
    - Involves at least two Member States by directly crossing the border of two or more Member States,
    - Located on the territory of one Member State and has a significant cross-border impact,
    - Crosses the border of at least one Member State and a European Economic Area[6] country.

Concerning the storage projects (as well as electricity transmission) they should contribute significantly to at least one of the following specific criteria[7]:

- Market integration, inter alia through alleviating the isolation of at least one Member State and reducing energy infrastructure bottlenecks; competition and system flexibility,
- Sustainability, inter alia through the integration of renewable energy into the grid and the transmission of renewable generation to major consumption centres and storage sites,
- Security of supply, inter alia through interoperability, appropriate connections and secure and reliable system operation;

For electricity storage, the project provides at least 225 MW installed capacity and has a storage capacity that allows a net annual electricity generation of 250 GWh/year[8].
It must be "directly connected to high-voltage transmission lines designed for a voltage of 110 kV or more[9]".

[5] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:EN:PDF - see article 4.1.

[6] The European Economic Area (EEA) comprises the countries of the European Union (EU), plus Iceland, Liechtenstein and Norway.

[7] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:EN:PDF - see article 4.2.

[8] Ibid - see annex IV, 1b

[9] Ibid - see annex II, 1c

3.2. Criteria proposed by ENTSO-E

The CBA of storage will use the same boundary conditions, parameters, overall assessment and sensitivity analysis techniques as the CBA for transmission. In particular, the TOOT[10] methodology implies that the assessment will be carried out including all storage projects of the TYNDP, taking out one storage project at the time in order to assess its benefits.

The Benefit categories are defined as follows:

- **Security of supply** (B1): Energy storage may smooth the load pattern ("peak shaving"), by increasing off peak load, hence alleviating network constraints and insulating/protect consumers from energy price spikes (replacing expensive peaking units). Network studies will be able to assess this service in regional networks, whereas market studies will account for the value provided at the level of a European Region. Both will be measured as variations in EENS[11] or LOLE.

  This criterion is evaluated in MWh/year.

- **Socio-economic welfare** (B2): Impact of storage on socio-economic welfare (generation portfolio optimisation) is generally known as arbitrage value. It is the main claimed benefit of large scale storage. Indeed, storage can take advantage of the differences in hourly peak and off peak electricity prices by storing electricity at times when prices are low, offering it back to the system when the price of energy is higher, hence increasing socio-economic welfare. This socio-economic welfare indicator integrates the increase of welfare related to the decrease of re-dispatching costs required to relieve transmission congestions. Market studies will be able to assess this value based on an hourly resolution, which is consistent with current market models. This criterion also includes the value creation related to RES integration (decrease of RES curtailment will in turn decrease the generation operational cost), security of supply (through the VOLL[12]) and variations in CO_2 emissions (through the cost of CO_2).

  This criterion is evaluated in €/year.

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

  This criterion is evaluated in MWh/year.

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

  This criterion is evaluated in MWh/year.

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[10] Take Out One at the Time (TOOT) methodology consists of excluding investment items or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement

[11] Expected Energy Not Supplied

[12] Value of lost load (VOLL)

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

  This criterion is evaluated in tCO_2/year.

- **Technical resilience/system safety** (B6): Electricity storage systems can be employed to control power fluctuations and to improve management of large incidents occurring on power transmission structures, providing voltage support or frequency regulation.

  This criterion is a KPI[13].

- **Total project expenditure of storage** (C1) includes investment costs, costs of operation and maintenance during the project lifecycle as well as environmental costs (compensations, dismantling costs etc...). The project expenditure cost of storage also includes the costs of equipment to connect the storage device to the transmission grid.

  This criterion is evaluated in €/year.

- **Social and environmental sensibility** (S1): The social and environmental impact of a storage project is very different from transmission, and highly dependent on the used technology.

  This criterion is a KPI.

[13] Key Performance Indicator (KPI)

4. EASE comments

4.1. General comments on Energy Storage issues

The Energy Storage (ES) need is mainly based on the urgent request for grid flexibility and grid stability in order to enable the complete "Electrical Systems" to cope with the increased peak demand on one hand and the increased level of variable energy generation on other hand.

ES can be located at all places along the Electricity Value Chain (Generation, Transmission, Distribution and Customer) and can provide simultaneously specific value to the different stakeholders. In particular, ES can provide ancillary services that need to be taken into account in the CBA analysis.

Presenting Energy Storage in the frame of the TYNDP of ENTSO-E does not at all imply that EASE considers that ES should be on the regulated side of the market.

4.2. General comments on the CBA methodology

EASE recognises the usefulness of elaborating a CBA method in order to assess the interest of storage for the electrical system, within the PCI framework. EASE is also in favour of a CBA method for storage as close as possible to the CBA method for interconnections. Indeed, these two technical solutions can either be complementary or in competition.

EASE, in line with the opinion expressed by the Florence School of Regulation[14], insists that the CBA should concentrate on a reduced list of indicators. The main indicator should be the **net** socio-economic welfare (equal to: gross socio-economic welfare minus capital expenditures). See Figure 1.

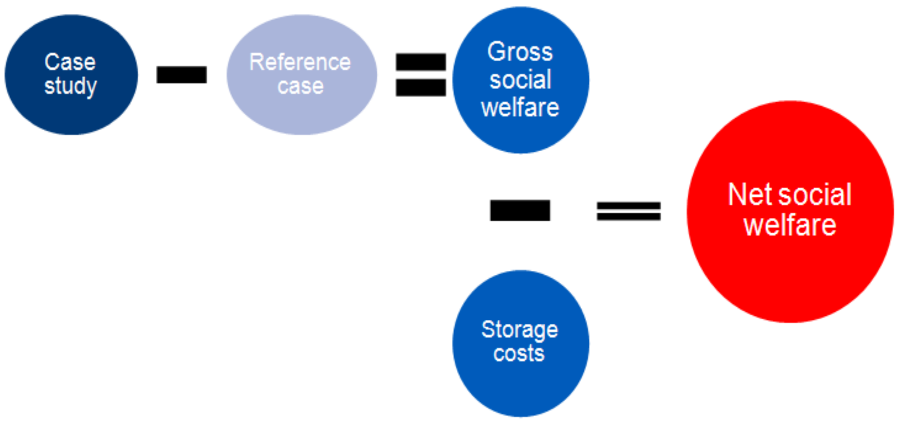

Figure 1: CBA's main indicator according to EASE: **net** socio-economic welfare

Furthermore, EASE favours, also in-line with the Florence School of Regulation recommendations, both the TOOT approach (removing one project at a time) and the

[14] THINK report, Topic 10, « *Cost Benefit Analysis in the Context of the Energy Infrastructure Package* », Final Report, January 2013

incremental approach (adding one project at a time) in order to provide confidence in the robustness of the indicators.

In the CBA different WACCs[15] should be considered in a sensitivity analysis: infrastructure projects generally require a lower WACC (long term social planner view) while production means are generally assessed at a higher WACC (private investment horizon).

The net socio-economic welfare indicator already includes the value related to many other indicators (such as RES integration, CO_2 emissions, security of supply). Other indicators are useful and needed, but of secondary importance. They can indicate other qualitative insights (quantitative aspects are already be accounted for in a net socio-economic welfare indicator) and their relevance should be taken into account by attributing specific weighting factors.

EASE underlines that this CBA only concerns the projects eligible in the PCI selection process (Capacity exceeding 225 MW, connected to the 110 kV network and a net annual electricity generation of 250 GWh/year). The applications related to distribution networks (investment deferral, power quality, etc.), retail (self-consumption), hydrogen uses other than electricity (mobility, power to gas, etc.), and the corresponding technologies are therefore not considered here. Concerning the net electricity generation of 250 GWh/year, a storage device will always consume more energy than it will produce. This point needs to be clarified.

Lastly, as storage can generate value for all the stakeholders of the electricity value chain (regulated as well as deregulated), EASE thinks that the work on a CBA methodology for storage should be a process involving both regulated and deregulated actors.

This consultation is a first step in that direction. However, the final document should also be written jointly by ENTSO-E and main deregulated stakeholders. This process could lead to the elaboration of a specific CBA methodology for storage, separated from the interconnection CBA.

4.3. Comments on tools and method

EASE is well aware that modelling storage in market and network models can be challenging – the modelling assumptions made can have a strong impact on the results. In particular, the results obtained from a deterministic approach can be very different than those obtained from a stochastic approach. This should therefore be taken into account when modelling storage – the models used to perform the CBA should be described in detail, in order to allow stakeholders to understand the results.

It is also important that whatever methodology is applied when calculating the economic benefits of storage, a distinction is made according to the player (producer, TSO, DSO, etc.) using it.

Storage can provide more services than interconnections. In particular, services linked to ancillary services and power quality should be taken into account in the CBA approach – there again, the associated features in the models should be described in detail.

[15] Weighted Average Cost of Capital

4.4. Detailed comments per criteria proposed by ENTSO-E

- **Security of supply**

Concerning the security of supply linked to the production/consumption adequacy, EASE considers that all projects should be compared with the same level of security of supply (i.e. same values of EENS or LOLE). This means that when studying a project, the thermal power generation fleet should be readapted, in order to reach the same values of LOLE or EENS.
. The security of supply should indeed be an evaluated criterion when it is linked to the network.

- **Socio-economic welfare**

This indicator currently only calculates the gross value generated by storage: the storage fixed costs are not taken into account (CAPEX[16]). Instead of a gross socio-economic welfare, we recommend the use of another indicator: the "net socio-economic welfare". This indicator is the difference between the socio-economic welfare and the investment costs of the project.

Moreover, the indicator "socio-economic welfare" proposed does not include the system cost diminutions linked to the avoided fixed costs in generation. Indeed, when comparing a new scenario to a reference scenario, the criteria "security of supply" should be the same in the two cases (same LOLE, and same associated price), as expressed previously – this means that in the new scenario, the required thermal generation should be readapted. Some generation capacity should therefore be taken in or out, which translates into more or less fixed costs (generation CAPEX) for the system. Regarding storage, we believe that its development would reduce the need for thermal back up – hence, could be an important part of the value created and should be taken into account in the assessment.

The proposed indicator "gross socio-economic welfare" (taking into account the previous remark) can still be of interest, but only to compare two situations where the net socio-economic welfares are similar, but where the gross welfare/gross storage expenditure are very different.

- **RES integration**

As mentioned by ENTSO-E, integrating more RES into the system already has an impact on the socio-economic welfare criteria (production from RES displaces production from thermal power, thus saving both variable and fixed costs). Additionally to better deal with the intermittent characteristic of RES generation sources, Energy Storage allows the decrease of RES curtailment due to congestions in the transmission grid.

Therefore, this indicator should be considered as secondary, as part of it is already monetised in another criterion.

- **Variation in losses**

Concerning losses in the transmission system, the impact of a new interconnection can be well assessed, and can be an important indicator. For storage, the impact would probably be of much less significance and this criterion should only be considered as a complement.
This indicator should provide a net economic value: a storage device can, at peak times, reduce congestions, and therefore losses when electricity is expensive – but it will increase

[16] Capital Expenditure

the losses while charging (but with a lower electricity price). The indicator should then be a comparison of the cost of losses with and without the storage device. For the storage case technology specific storage losses must be considered.
Furthermore, we note that while potentially diminishing the cost of losses, the storage would also improve the utilisation rate of the line and thus improve its dimensioning. This could be monetised and taken into account.

- **Variation in CO_2 emissions**

A better RES integration (B3) should decrease the CO_2 emissions. As mentioned by ENTSO-E, CO_2 costs are internalised in the socio-economic welfare criterion. Therefore, this indicator should be considered as secondary, similar to the "RES integration" criterion.

- **Technical resilience/system safety**

EASE agrees that this criterion is important - in particular, storage can be used to provide black start services or to limit blackouts.

- **Total project expenditure of storage (C1)**

As mentioned above, this criterion should already be included in a "net socio-economic welfare" criterion (**Figure 1**).

As for the "gross socio-economic welfare" indicator, the "total project expenditure of storage" criterion can still be of interest, but only to compare two situations where the net socio-economic welfares are similar, but the gross welfare/gross storage expenditure are very different.

4.5. Criterion "Social and environmental sensibility"

ENTSO-E mentions that "The social and environmental impact of a storage project is very different from transmission, and highly dependent on technology", and has asked EASE's opinion on the matter.
According to ENTSO-E, "the social and environmental sensibility characterises the project impact as perceived by the local population and assessed through preliminary studies, and as such gives a measure of the social and environmental sensibility associated with the project".

- In the PCI framework, only bulk storage seems to be concerned by this CBA criterion: Pumped Hydro Storage, CAES and hydrogen (if the hydrogen is produced with an electrolyser, and re-used to produce electricity, the locations for electrolysis a re-electrification may be different). Therefore, the "social and environmental sensibility" indicator described here only focuses on these three technologies but should also take into consideration electrochemical energy storage.

EASE considers that the indicators used for interconnections projects are also suitable for storage. EASE stresses that the underneath stated examples solely serve to give a better internal understanding of the matter and should be suppressed in the final publication:

- Environmental sensibility: impact on the project's feasibility, and/or on the delivery date of the project (delays) and impact on human activity.
- Impact on nature (e.g. biodiversity)
- Compensation costs: compensation might be needed for public acceptance. Those

should be internalised in the calculation of the “net socio-economic welfare”.

Regarding technologies:

- Pumped Hydro Storage: compensations related to the use of water for non-energy generation purposes can be important (compensation towards tourism, agriculture, fisheries, etc.), but vary a lot from one country to another.
- CAES storage: geological concern, safety, etc.
- Hydrogen storage, less data is available to estimate its acceptability - this is subject for further research.

Electrochemical storage systems should also be taken into consideration. Additionally, the impact of the transmission line in order to link the new storage facility to the closest HV network substation should be encompassed in the studied project.
When compared to conventional grid deployment, energy storage systems can also have a faster implementation period, with potentially lower environmental impact and shorter permitting processes since there are fewer territories involved.

5. Other remarks

In demonstrators or studies, other criteria can be used to assess the interest of storage projects. Among them, the "industrial and job creation impacts" are often mentioned.
In the framework of the PCI selection process, the industrial and job impacts should be one of the inputs, as the CBA, to fully assess the interest of projects. It should not be integrated in the CBA itself.

Finally, it is essential that the PCI list consists of robust projects that have a realistic probability of being built within a reasonable period of their planned commissioning dates. The CBA should include a formal process to assess the likelihood of a project realisation or failure, whether due to environmental, technical, technology or other constraints. This will mitigate the risk of unachievable projects occupying the PCI list, albeit for a limited period, at the expense of achievable projects. This may require a qualitative assessment but it is an essential step in ensuring a robust and achievable list of projects.

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Disclaimer:
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