Harmonised system-wide cost-benefit analysis for candidate electrolyser projects

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Abstract

This report presents the Cost-Benefit Analysis (CBA) methodology for candidate electrolyser projects developed in compliance with the requirements set in the Regulation (EU) 2022/869, notably Article 11.

1 Introduction and scope

Cost–benefit analysis (CBA) is a systematic evaluation tool aimed at determining whether an action/decision/investment is socio-economically desirable namely, if its prospective or potential system benefits (referred in the following as "benefits") outweigh its costs or to provide a base for comparing different actions/decisions/investments. A CBA methodology must describe the common principles for undertaking a CBA as well as clarifying the different steps a user must carry out to perform the exercise.

This CBA methodology for candidate electrolyser projects (in the following, "electrolysers CBA methodology") has been developed by the European Commission (the "Commission") in compliance with the requirements set in Article 11(8) of the revised Regulation (EU) 2022/869 (in the following, "TEN-E Regulation") [1].

The revised TEN-E Regulation, entered into force on 23 June 2022, lays down principles for the timely development and interoperability of the priority corridors and areas of trans-European energy infrastructure contributing at achieving EU climate and energy targets. An element of innovation of the revised TEN-E Regulation is represented by the inclusion of electrolysers are a new energy infrastructure category.

The electrolysers CBA methodology has been developed to ensure a harmonised energy system-wide cost-benefit analysis at Union level and it is compatible in terms of benefits and costs with the methodologies developed by the ENTSO for Electricity and the ENTSO for Gas pursuant to Article 11(1) of TEN-E Regulation[1].

This electrolysers CBA methodology has been developed in a transparent manner, including extensive consultation of Member States and all relevant stakeholders, in compliance with Article 11(8) of TEN-E Regulation.

1.1 The TEN-E Regulation

The Trans-European Networks for Energy (TEN-E) is a policy instrument focused on developing and linking the energy infrastructure of European Union (EU) Member States[2]. A well-planned and integrated energy infrastructure is essential to achieve such objectives: energy infrastructure is the part of the system that enables renewable energy to be incorporated into the grid, and then transmits and distributes energy across the EU from the supply source (whether imported or generated within the EU) to the end user, or stores energy until it is needed. Energy infrastructure provides for a reliable and secure energy system that helps to keep energy prices in check.

The revised TEN-E Regulation, which entered into force in June 2022, lays down guidelines for the timely development and interoperability of the priority corridors and areas of trans-European energy infrastructure contributing at mitigating climate change by supporting the achievement of the EU climate and energy 2030 targets and the EU climate neutrality objective by 2050 at the latest:, and to ensuring interconnections, energy security, market and system integration and competition that benefits all Member States, as well as affordability of energy prices. More specifically, the TEN-E Regulation:

- provides for the identification of projects on the Union list of projects of common interest (PCIs) and of projects of mutual interests (PMIs);
- facilitates the timely implementation of the Union list by streamlining, coordinating more closely and accelerating permit granting processes, and by enhancing transparency and public participation; and
- provides rules for the cross-border allocation of costs and risk-related incentives for projects on the Union list.

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(1) At the time of writing, this is the status of methodologies developed by the ENTSOs :
4th ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects: draft version 4.0 for public consultation (under public consultations since 20 December 2022); andENTSOG Single-Sector Cost-Benefit Analysis (CBA) Methodology – Preliminary draft (public consultation closed on 28 February 2023).

1.2 General criteria for candidate electrolyser projects

Project promoters of candidate electrolyser projects must ensure compliance with respect to the general criteria foreseen in Article 4(1) of TEN-E Regulation. In particular, the application for candidate projects shall clearly show that:

- the project is necessary for at least one priority corridor for hydrogen and, as described in Article 4(1)(a) of TEN-E Regulation;
- the potential overall benefits of the candidate project, assessed in accordance with the relevant specific criteria, outweigh its costs, including in the longer term, in line with the provisions set in Article 4(1)(b) of TEN-E Regulation.

Pursuant to Article 4(1)(c) of TEN-E Regulation, the candidate electrolyser project shall either:

i. involve at least two Member States by directly or indirectly, via interconnection with a third country, crossing the border of two or more Member States or
ii. be located in the territory of one Member State, either inland or offshore, including islands, and has a significant cross-border impact as set out in point (1)(f) of Annex IV to TEN-E Regulation: "*the project provides at least 50 MW installed capacity provided by a single electrolyser or by a set of electrolysers that form a single, coordinated project and brings benefits directly or indirectly to at least two Member States, and, specifically, as regards projects on islands and island systems, supports innovative and other solutions involving at least two Member States with a significant positive impact on the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective, and contributes significantly to the sustainability of the island energy system and that of the Union*".

According to the aforementioned options, the application shall clearly describe the level of benefits to different Member States, the direct and indirect benefits brought by the candidate project and, for islands and island systems, the significant positive impact on EU's 2030 climate target, the contribution to 2030 and 2050 EU's carbon neutrality objective and the significant contribution to the sustainability of the energy island and the EU as a whole.

In particular, project promoters must ensure that their applications are compliant with the following rules:

i. the proposed project includes a single electrolyser or a set of electrolysers forming a single, coordinated project with a capacity of at least 50 MW;
    a. hydrogen production must comply with the life cycle greenhouse gas emissions savings requirement of 70 % relative to a fossil fuel comparator of 94 g CO2eq/MJ as set out in Article 25(2) and Annex V to Directive (EU) 2018/2001. In addition;
    b. life cycle greenhouse gas emissions savings are calculated using the methodology referred to in Article 28(5) of Directive (EU) 2018/2001 or, alternatively, using ISO 14067 or ISO 14064-1;
    c. the life-cycle greenhouse gas emissions include indirect emissions;
    d. quantified life-cycle greenhouse gas emission savings are verified in line with Article 30 of Directive (EU) 2018/2001 where applicable, or by an independent third party
ii. the single electrolyser or the set of electrolysers forming a single, coordinated project must have a network-related function (on both hydrogen and electricity systems). In this respect, project promoters shall describe how their candidate projects contribute to overall system flexibility and overall system efficiency of electricity or hydrogen systems.
iii. when relevant, the proposed project can include related equipment, including pipeline connection to the network.

In order to allow the Commission to verify the compliance with general criteria, project promoters shall provide all the necessary underlying information and details, in line with the provision set in the project submission template for candidate electrolyser projects.

1.3 Specific criteria for candidate electrolyser projects

The contribution of the candidate projects to the specific criteria foreseen in Article 4(3) of TEN-E Regulation needs to be demonstrated.

Pursuant to Article 4(3)(e) of TEN-E Regulation, the application shall clearly show how the candidate project contributes significantly to all of the following specific criteria:

- sustainability, including by reducing greenhouse gas emissions and enhancing the deployment of renewable or low carbon hydrogen in particular from renewable sources, as well as synthetic fuels of those origins;
- security of supply, including by contributing to secure, efficient and reliable system operation, or by offering storage, flexibility solutions, or both, such as demand side response and balancing services; and
- enabling flexibility services such as demand response and storage by facilitating smart energy sector integration through the creation of links to other energy carriers and sectors.

2 General approach

In line with the provisions set in Article 11 of TEN-E Regulation and similarly to the methodological approach developed earlier for candidate electricity transmission projects [2] and gas infrastructure projects [3], the assessment of candidate electrolyser projects shall take into consideration pertinent assumptions concerning future scenarios, the definition of the reference network used to assess the impact of the project as well as the techniques to be used in calculating costs and benefits for the candidate project.

Scenarios are a description of contrasted yet plausible futures that can be characterised by a combination of demand and supply assumptions. With reference to the assessment of candidate electrolyser projects, such scenarios shall consider possible development for the electricity, gas and hydrogen systems, energy exchanges within the modelled system (according to the different level of detail, it can encompass the geographical area immediately affected by the project or a wider area) and with the modelled systems. These different future developments can be used as input parameter sets for subsequent simulations and analyses.

This methodology is based on the multi-criteria approach, which allows to consider and combine monetised, quantified and qualitative benefits. This approach is also consistent with the methodologies developed by the ENTSOs.

The steps for applying the electrolysers CBA methodology to be carried out by project promoters are described below:

- clear identification of input information for the consistent assessment of candidate electrolyser projects, taking into consideration general indications on common scenarios and assumptions, the latest TYNDP scenarios developed by the ENTSOs and other complementary information (see section 2.1);
- description of relevant modelling frameworks[2] used for the evaluation of benefits (see section 3.1) and description of the impact of any simplified assumption on the pertinent calculations;
- calculation of benefits (see section 3.1) within the study horizon in both “with” and “without” cases
- calculation of costs (see section 3.2) within the study horizon; and
- calculation of the Economic Net Present Value and benefit-cost ratio.

2.1 Scenarios, assumptions and sensitivities

A list of common parameters and assumptions ensures consistency across all candidate electrolyser projects. Some information is provided in the templates for candidate PCI projects; other assumptions and input parameters should be aligned as much as possible with the latest joint TYNDP scenarios. Project promoters can introduce complementary assumptions, in line with the scope of the candidate electrolyser project: any choice of parameters and assumption from project promoters deviating from values described in joint TYNDP scenarios shall be clearly described and justified.

Below a list of key parameters and assumptions for candidate electrolyser projects is provided:

- duration of the study horizon. As a general assumption, the duration of the study horizon should be the minimum between a) the longest technical lifetime of any equipment and b) the maximum reference period for energy projects as referred to in Article 15(2) and Annex I to Commission Delegated Regulation (EU) No 480/2014[3] [7]. The duration of the study horizon shall not be in any case higher than the study horizon of the harmonised energy system-wide cost-benefit analysis methodology for projects on the Union list falling under the energy infrastructure categories set out in point (1)(a), (b), (d) and (f) and point (3) of Annex II to TEN-E Regulation. The study horizon shall start the year after the commissioning year.
- hydrogen demand: for each Member State and for each year within the study horizon. Hydrogen demand should be netted by the amount of hydrogen not affecting the hydrogen grid infrastructure (for instance

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(2) While project promoters are free to select any modelling tool for the assessment of the benefits of their candidate electrolyser projects, it is recommended, when possible and relevant, the use of an open source tool (for instance, PyPSA [4]) to foster transparency.

(3) 25 years.

when hydrogen transport is covered via freight transport, trucks, etc.) Simplification related to the geographical scope are allowed, consistently with the geographical scope of the project;

- natural gas demand: for each Member State and for each year within the study horizon. Simplification related to the geographical scope are allowed, consistently with the geographical scope of the project;
- other fuel demands for each Member State and for each year within the study horizon. Simplification related to the geographical scope are allowed, consistently with the geographical scope of the project;
- hydrogen price: for each Member State, for each hydrogen production technology and for each year within the study horizon. This assumption should be consistent with the most updated TYNDP scenarios and, if available, the latest Commission data, where relevant;
- natural gas price: for each Member State and for each year within the study horizon. This assumption should be consistent with the most updated TYNDP scenarios and, if available, the latest Commission data, where relevant;
- other fuel prices for each Member State and for each year within the study horizon. This assumption should be consistent with the most updated TYNDP scenarios and, if available, the latest Commission data, where relevant;
- shadow or social cost of carbon for each year within the study horizon. As a general assumption, values for the shadow cost of carbon within the study horizon should be aligned, where applicable, to the most updated ones[4];
- emission and monetisation factors for non GHG emissions: for each Member State and for each year within the study horizon. This assumption should be consistent with the most updated TYNDP scenarios. Examples of reference monetisation values for select pollutants as found in [8] are reported here below:

Table 1. Reference monetisation values for select pollutants

€2015/kg	NOx	NH3	SO2	PM2.5	PM10	VOC
low	24.10	19.70	17.70	56.80	31.80	1.61
middle	34.70	30.50	24.90	79.50	44.60	2.10
high	53.70	48.80	38.70	122.00	69.10	3.15

Source: [8]

- discount rate. As a general assumption, a 4% social discount rate should be assumed, in agreement with the current value assumed for other PCI energy infrastructure categories. The discount rate should in any case be compatible with the same value defined in the harmonised energy system-wide cost-benefit analysis methodology for projects on the Union list falling under the energy infrastructure categories set out in point (1)(a), (b), (d) and (f) and point (3) of Annex II to TEN-E Regulation;
- if a legislative and regulatory frameworks would allow the establishment of an EU hydrogen security of supply policy, suitable values for Cost of Disruption of Hydrogen Supply (CODH) for each Member State and for each year within the CBA horizon; and
- monetization factors for RES curtailment for each Member State and for each year within the CBA horizon.

To increase the validity of CBA results, sensitivity analyses can be carried out to evaluate the impact that the variation of parameters has on the socio-economic desirability of candidate electrolyser projects. It is

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(4) In particular Tables 5 and 6 of Commission Notice 2021/C 373/01 [7], in line with the most updated EIB estimates. A review of the current values for shadow cost of carbon is expected in a future EIB Group Climate Bank Roadmap progress report [5].

important to note that the aim of such sensitivity analyses is not to introduce complete and different scenarios but to understand the resilience of the CBA evaluation with respect to few changes in critical parameters.

The parameters listed below, although not exhaustive, can be subjected to sensitivity analyses for electrolyser projects:

- fuel and CO_2 prices;
- climate year: different climatic years result in different temperatures and, consequently, different values demand values;
- natural gas and hydrogen demand, as result of different techno-socio-economic conditions;
- commissioning date of projects: delays in any phase of the realisation of a project might its impact socio-economic desirability. A sensitivity analysis on the commissioning date increases the robustness of the CBA assessment;
- CAPEX and OPEX; and
- discount rate.

2.2 Project implementation status

In order to support the process for establishing the regional list of projects pursuant to Annex III to the TEN-E Regulation, project promoters for candidate PCI process shall declare in their applications the level of maturity of the relevant projects, in line with the following stages, consistent with PCI monitoring reports developed by ACER[5]:

- projects "Under consideration"
- projects "Planned but not yet in permitting";
- projects "Permitting"; and
- projects "Under construction"

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[5] *PCI monitoring* | www.acer.europa.eu. (2023). https://www.acer.europa.eu/gas/infrastructure/ten-e/pci-monitoring.

3 Project CBA for candidate PCIs

The assessment of candidate electrolyser project shall be carried out considering the social perspective: Candidate projects would be considered sustainable from a social perspective if, in line with the provisions set in Article 4(1) to TEN-E Regulation, their potential overall benefits, assessed in accordance with the relevant specific criteria, outweigh their costs.

Benefits of a candidate electrolyser project must be calculated taking into consideration two configurations:

- "with case", where the candidate project is realised, it is inserted in the system and, if socio-economically desirable, realizes during its lifetime system benefits that are larger than total costs; and
- "without case" where the candidate project is not realised.

As said above, the calculation of the difference of indicators between the "with" and the "without" cases allow to calculate benefits. For instance, the variation of greenhouse gas (GHG) emissions achievable thanks to the realisation of candidate electrolyser projects is equal to the difference in the "with" case (i.e. the electrolyser project is built) and the "without case" (i.e. the electrolyser project is not built).

In some cases, the calculation of benefits does not need a complex modelling exercise representing the whole system, while in others extensive modelling activities are required. In some cases, simplifications might be introduced to reduce the modelling complexity, although there is trade-off between modelling complexity and accuracy of the assumption.

Benefits and non-capital costs are calculated for each year of operation of the project throughout the duration of the study horizon of the equipment and installation constituting a candidate electrolyser project. Consequently, to compare the total benefits generated by the candidate project during its corresponding study horizon with the related total costs, this electrolysers CBA methodology requires the use of the discounted cash-flow method for the calculation of the *Economic New Present Value* (ENPV) of the candidate electrolyser project: in particular, annual cash flows considering costs and benefits for the system in nominal terms shall be discounted using the discount rate as defined in section 2.1 of this electrolysers CBA methodology.

3.1 Benefits

While the calculation of each benefit should preferably aim for a monetary value, the lack of a fully operational EU hydrogen market, data and models may impede the full monetization of some benefits Such monetization may be feasible in future assessments. Where monetization is not possible, the quantitative/qualitative assessments of the benefits are to be considered. In general, the indicators can be:

- **Monetised:** they are expressed in monetary terms.
- **(Non-monetised) quantified:** they are quantified but not expressed in monetary terms
- **Qualitative:** they are expressed in qualitative terms (for instance, "++", "+", "0", etc.).

Table 1. Summary of benefits considered in the electrolyser CBA methodology

Benefit [unit]	Specific criterion - Article TEN-E
B1- Variation of GHG emissions [€/a]	Sustainability - Article 4(3)(e)(i)
B2 – Variation of non-GHG emissions [€/a]	Sustainability - Article 4(3)(e)(i)
B3 – Variation of renewable and/or hydrogen production – Fuel cost savings [€/a]	Sustainability - Article 4(3)(e)(i)
B4 - Variation of synthetic fuel production– Fuel cost savings [€/a]	Sustainability - Article 4(3)(e)(i)

B5 – Reduction of curtailed hydrogen demand [€/a]	Security of supply - Article 4(3)(e)(ii)
B6 – Variation of electricity RES curtailment [€/a]	Security of supply - Article 4(3)(e)(ii)
B7 – Variation of socio-economic welfare in electricity markets [€/a]	Smart energy sector integration - Article 4(3)(e)(iii)
B8 – Cross sectoral cost savings [€/a]	Smart energy sector integration - Article 4(3)(e)(iii)

Source: Own elaboration.

The following sections describe how benefit indicators must be calculated in line with the specific criteria set in Article 4(3) of TEN-E Regulation.

Member States impacted by the benefits achievable thanks to the candidate electrolyser project should be identified, and disaggregated benefits at Member State level should be provided.

All the benefits should be calculated in the way to avoid double counting. In this respect, project promoters shall clearly describe how this in ensured in the calculation of each benefit.

3.1.1 B1 - Variation of GHG emissions

Benefit Definition:

- Definition: economic valorisation of the variation of greenhouse gas emissions achievable thanks to the candidate electrolyser project.
- Relevance: electrolysers are key infrastructural projects for producing low carbon and particularly renewable hydrogen, for replacing the use of non-renewable hydrogen, natural gas and, under the proper socio-economic and technological conditions, it can enable a cost-efficient solution to store energy (directly via compressed or liquefied hydrogen or indirectly via other mediums such as ammonia, methanol, solid-state systems, etc.).

Benefit Calculation:

- Modelling needs: modelling requirements for the calculation of the benefit must be compliant with the provisions set in point (4)(a)(ii) of Annex II to TEN-E Regulation.
- Data needs: data requirements for the calculation of the benefit must be compliant with the provisions set in point (4)(a)(ii) of Annex II to TEN-E Regulation.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as tons of equivalent carbon emission savings. Then, the benefit is finally expressed in monetary terms when the tons of CO_2 emission savings are multiplied by the shadow cost of carbon. As a simplification in the absence of widely available and undisputed cost data, applying the shadow cost of carbon to all GHG emissions is in line with Commission Notice 2021/C 373/01.

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(e)(i) TEN-E Regulation

EU energy policy aims at reducing greenhouse gases (GHG) emissions by achieving intermediate targets towards Union's carbon neutrality by 2050. In this respect, infrastructural projects such as electrolysers are key in achieving potential GHG emission reductions and in lowering the EU carbon footprint, according to the carbon footprint of the electricity used to feed the electrolyser. In particular, electrolysers allow the production of low-carbon and renewable gases[6] and reduce GHG emissions due to substitution effects enabled by the reduction of the use of fossil fuels.

Calculation process

1. Pursuant to the provisions set in point (4)(a)(ii) of Annex II to TEN-E Regulation, project promoters must calculate life cycle greenhouse gas emissions savings using one of the following three approaches:
   a. methodology referred to in Article 28(5) of Directive (EU) 2018/2001 [11][7];
   b. the standard ISO 14067 "Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification"[8]; and
   c. the standard ISO 14064-1 "Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals"[9].

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(6) At the time of writing, the definition of low-carbon and renewable gases in this methodology are to be intended consistent with the Hydrogen and decarbonised gas market package, proposed by the European Commission in December 2021 and currently being negotiated by the co-legislators. After the entry into force of the Hydrogen and decarbonised market package, the official definitions will apply.

(7) On February 2023 the Commission proposed the GHG delegated act to calculate GHG emissions savings from renewable fuels of non-biological origin (RFNBO) and recycled carbon fuels.

(8) https://www.iso.org/standard/71206.html

(9) https://www.iso.org/standard/66453.html

2. GHG emission savings achievable thanks to the candidate electrolyser project are evaluated by comparing two situations:
    - GHG emissions in the “with case”, $emission|_{with}$, and
    - GHG emissions in the “without case”, $emission|_{without}$

3. The variation of GHG emissions achievable thanks to the candidate project, expressed in CO_2 equivalent emissions, are converted in monetary terms by using the shadow cost of carbon:

$$B_1 = \sum \left[emission_{CO_{2\,equiv}}\Big|_{without} - emission_{CO_{2\,equiv}}\Big|_{with} \right] \cdot ShCost_{CO_2}$$

4. The economic present value of the variation of GHG emissions achievable thanks to the project is calculated within the study horizon using the discounted cash-flow approach.

<u>Main elements to consider</u>

- carbon footprint electricity feeding the candidate electrolyser project;
- operational data of the candidate electrolyser project: efficiency, technical constraints, etc.
- specific information required as input information for the alternative approaches described in point 1 above.
- CO_2 price is an input to the calculation and it might be subject to sensitivity analysis (see section 2.1)

3.1.2 B2 - Variation of non-GHG emissions

Benefit Definition:

- Definition: economic valorisation of the variation of non-greenhouse gases emission achievable thanks to the project.
- Relevance: electrolysers are key infrastructural assets for the production of renewable and low-carbon hydrogen. By reducing the usage of polluting fuels, they can reduce the system environmental footprint by reducing non greenhouse gases emissions.

Benefit Calculation:

- Modelling needs: accurate assessment would require a detailed modelling exercise simulating a larger portion of the hydrogen system (both transmission and distribution levels) beyond the project and, if any, of the systems (e.g. electricity and gas) involved in the production and integration of low carbon and renewable gases resulting in the reduction of non-GHG emissions. An alternative solution without significant modelling requirements would be based on project assumptions and relative calculations, using reputable methodologies.
- Data needs: if detailed modelling is introduced, extensive data to simulate a sufficiently large portion of the hydrogen system and, if any, of the systems involved in the production of renewable gases, are needed. In absence of extensive modelling, the benefit can be calculated but using operative data about the estimated amount of equivalent reduced greenhouse gases emissions.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as tons of non-GHG emission savings. Then, the benefit is finally expressed in monetary terms when the tons of non-GHG emission savings are multiplied by the relevant monetisation values (see reference values in Table 1).

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(d) of TEN-E Regulation.

Further benefits from electrolysers can be realised thanks to the reduction of non-GHG emissions that also contribute to climate change. Non-GHG emissions include direct emissions like particulate matter, or indirect methods that trigger chemical reactions leading to pollution, such as acid rain, also increase pollution levels. To ensure that eventual mitigation effects introduced by candidate electrolyser projects are accurately evaluated, special attention must be paid to these non-CO2 emissions. This should involve at least addressing the primary emission types of CO, NO_2 (including NO that forms NO_2 in the atmosphere), SO_2, and various particulates (such as PM_2, PM_5, and PM_{10}).

By optimising the use of fossil fuels, electrolysers can reduce such emissions. As elaborated below, effects of potential differences in the assumed social costs of pollutants should be investigated through sensitivity analyses.

Calculation process

1. Evaluation of the amount of non-GHG emissions avoided thanks to the candidate electrolyser project is based on the following approach:
    a. a detailed modelling exercise is carried out by project promoters, based on the emission factors per pollutant of the various technologies displaced, in which the amount of polluting generation is evaluated in both the “with” and “without” cases. Given the objective function of the optimisation algorithm and the combination of the active constraints of the problem, the model provides as output the variation in non-GHG emissions achievable thanks to the project.
    b. If detailed modelling is not feasible, the approach with simplified assumptions should be followed: project promoters calculates the emission factor difference based on the most granular emission intensity data available, and the amount of polluting generation displaced based on their knowledge of the operational capability of the project. Prospective emission

intensities can be imputed by interacting such data with installed generation capacities in the scenarios considered, as compliant with TYNDP scenarios.

2. The variation of emissions for the *g*-th non-GHG pollutant achievable in the *z*-th zone of the modelled/represented system thanks to the candidate electrolyser project is converted into monetary terms by using the social cost of the pertinent emissions provided in the information set accompanying the project submission template.

$$B_2 = \sum\nolimits_g \left[emission_{g,z}\big|_{without} - emission_{g,z}\big|_{with} \right] \cdot emission\_cost_g$$

3. The economic present value of indicator B_2 is calculated within the CBA horizon using the discounted cash-flow approach.

Sensitivity analyses shall be run to check the monetary values of benefits from avoided non-GHG emissions under different assumptions about their social costs (see Annex V(2) of the TEN-E Regulation).

3.1.3 B3 – Variation of renewable and/or low-carbon gases integrated into the gas network – Fuel cost savings

Benefit Definition:

- Definition: Fuel cost savings achievable thanks to the replacement with low carbon and particularly renewable hydrogen.
- Relevance: low carbon and particularly renewable hydrogen produced via electrolysis can reduce extra-EU fuel dependency (for instance, by reducing the consumption of imported natural gas converted in hydrogen via SMR) increasing security of supply and foster cross-sectoral flexibility.

Benefit Calculation:

- Modelling needs: accurate assessment would require a detailed modelling exercise simulating a larger portion of the electricity-hydrogen system beyond the project (i.e. up to the European level). An alternative solution without significant modelling requirements would be based on project assumptions and relative calculations.
- Data needs: if detailed modelling is introduced, extensive data requirement to simulate the whole electricity-gas-hydrogen system (i.e. simulations up to the European level would require data requirements similar to the ones for ENTSOs TYNDPs). In absence of extensive modelling, the benefit can be calculated but using operative data about the estimated amount of low carbon and particularly renewable hydrogen produced, hypotheses on the amount of fuel replaced and the related fuel cost prices.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as the replaced amount of hydrogen. Then, the benefit is finally expressed in monetary terms when the replaced amount of hydrogen amount is multiplied by the hydrogen price differential.
- The analysis should provide a breakdown in low-carbon and renewable hydrogen integrated in the system thanks to candidate electrolysers projects.

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(e)(i) TEN-E Regulation.

A candidate electrolyser project can bring benefits stemming from the substitution of other fuels low carbon and particularly renewable hydrogen. This happens, for instance, when low carbon and particularly renewable hydrogen replace fossil-fuel based hydrogen produced via Steam Methane Reforming (SMR) for industrial uses. While they might not be currently cost-competitive compared to hydrogen produced via SMR, learning curve effects, economy of scale and massive RES installed capacity is expected to gradually make them cheaper than a fossil fuel based one. Low carbon and particularly renewable hydrogen produced as fuel substitute can be either consumed locally (for instance, if the electrolyser facility is close to an industrial facility), stored and shipped from production to the consumption point in different forms or, when dedicated transmission infrastructure will be available, injected into the hydrogen grid. This benefit is conceptually similar to the benefit “Fuel cost savings” considered in the ENTSOG methodology [3].

It is important to highlight that this benefit shall not include the economic impact of the variation of the related GHG emissions as the latter is already internalised in the indicator “B1 - Variation of GHG emissions [€/a]”. In addition, this benefit shall not include any benefits already included in the indicator “B4 – Variation of synthetic fuel production– Fuel cost savings”.

Calculation process

1. Evaluate how the hydrogen production mix shifts thanks to the candidate electrolyser project, differentiating between renewable hydrogen, low carbon hydrogen and hydrogen produced with other technologies (for instance, SMR):
    a. In case a detailed modelling exercise is carried out, it must evaluate the operation of the modelled electricity, gas and hydrogen system in both “with” and “without” cases. Given the

objective function of the optimisation algorithm and the combination of the active constraints of the problem, the model provides the variation in the hydrogen production mix achievable thanks to the candidate project as well as the related costs.

b. In case of simplified assumptions, the assessment it must calculate the input data required to calculate the indicator using assumptions based on knowledge of the operational capability of the project as well as of general assumptions about the relevant portion of the EU electricity and hydrogen system concerned by the candidate electrolyser project. All the assumptions must be duly justified and referenced.

2. The fuel price savings of hydrogen replaced by low carbon and particularly renewable hydrogen achievable thanks to the candidate project converted are calculated as follows.

$$Cost_{H2} = QH2_{RENEW} \cdot P_{RENEW\ H2} + QH2_{LC} \cdot P_{LC\ H2} + \sum_t QH2_{other,t} \cdot P_{other\ H2,t}$$

$$B_3 = Cost_{H2}|_{without} - Cost_{H2}|_{with}$$

Where:

- $QH2_{RENEW}$, $QH2_{LC}$ are the quantities of renewable and low carbon hydrogen integrated in the system;
- $QH2_{other,t}$ is the quantity of non-renewable and non-low carbon hydrogen produced with the t-th hydrogen production technology integrated in the system (no GHG emission costs included); and
- $P_{RENEW\ H2}$, P_{LC} and $P_{other\ H2,t}$ are the prices corresponding to renewable, low carbon and the t-th other hydrogen production technologies

3. The economic present value of the indicator B_3 is calculated within the CBA horizon using the discounted cash-flow approach.

Main elements to consider

- Increased production of renewable and/or low-carbon hydrogen:
  - data requirement and data granularity are comparable to the ones concerning ENTSOs TYNDPs, if quantities are evaluated as output of a detailed modelling exercise of the electricity-hydrogen EU system. Specific data requirement might differ according to the different modelling formulation;
  - no extensive data requirements if project promoters use assumptions on the operation of the electricity and hydrogen system achieved thanks to the candidate electrolyser project.
- Hydrogen prices are input to the calculation and they might be subject to sensitivity analysis.

3.1.4 B4 – Variation of synthetic fuel production– Fuel cost savings

Benefit Definition:

- Definition: Fuel cost savings achievable thanks to the replacement of one of more fuels with one or more synthetic fuels (i.e. methane, gasoline, diesel, kerosene, etc.) produced starting from low carbon and particularly renewable hydrogen.
- Relevance: Power-to-X (P2X) is a process that incorporates electrolysis to produce hydrogen as an intermediate product, which is then used in another chemical process downstream to produce different fuels. Such fuels can then be locally used, stored or, when possible, injected in the gas system. While the multiple energy conversion reduces the round-trip efficiency of the whole P2X cycle, the process can be justifiable from an economic perspective if synthetic fuels are produced low carbon and particularly renewable hydrogen with low marginal costs of production. Increased availability of synthetic fuels can reduce extra-EU fuel dependency, increasing security of supply and foster cross-sectoral flexibility.

Benefit Calculation:

- Modelling needs: an accurate assessment would require a detailed modelling exercise simulating a larger portion of the electricity-gas-hydrogen system beyond the project (i.e. up to the European level). An alternative solution without significant modelling requirements would be based on project assumptions and relative calculations.
- Data needs: if detailed modelling is introduced, extensive data requirement to simulate the whole energy system (i.e. simulations up to the European level would require data requirements similar when not exceeding the ones for ENTSOs TYNDPs). In absence of extensive modelling, the benefit can be calculated but using operative data about the estimated amount of synthetic fuels that can be produced starting from hydrogen, hypotheses on the amount of fuels replaced and the related fuel cost prices.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as the replaced quantities of fossil fuels replaced by synthetic fuels. Then, the benefit is finally expressed in monetary terms when replaced quantities of fuel are multiplied by fuel price differential.
- The analysis should provide a breakdown in low-carbon and renewable gases

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(e)(i) TEN-E Regulation

Notes

- Economic effect of GHG reduction is not included to avoid double counting with B1.

Similarly for the case of benefit B_3, a candidate electrolyser project can create value for the system by supporting the production of synthetic fuels, developed from electrolysed hydrogen, able to substitute other fuels such as methane, gasoline, diesel, kerosene, etc. Synthetic fuels produced as fuel substitutes can be either consumed locally (for instance, if the electrolyser facility is close to an industrial facility), stored and shipped from production to the consumption point in different forms or, if quality standard allow it and if in gaseous form, injected into gas grid. This benefit is conceptually similar to the benefit “Fuel cost savings” considered in the ENTSOG methodology [3].

It is important to highlight that this benefit shall not include the economic impact of the variation of the related GHG emissions as the latter is already internalised in the indicator “B1 - Variation of GHG emissions [€/a]”. In addition, this benefit shall not include any benefits already included in the indicator “B3 – Variation of renewable and/or low-carbon gases integrated into the gas network – Fuel cost savings [€/a]”.

Calculation process

1. Evaluate the fuels production mix shifts thanks to the candidate electrolyser project:

   a. In case a detailed modelling exercise is carried out, it must evaluate the operation of the modelled energy system in both “with” and “without” cases. Given the objective function of the optimisation algorithm and the combination of the active constraints of the problem, the model provides the variation in the fuel generation production mix achievable thanks to the candidate project as well as the related costs.
   b. In case of simplified assumptions, the assessment must calculate the input data required to calculate the indicator using assumptions based on knowledge of the operational capability of the project as well as of general assumptions about the relevant portion of the EU energy system concerned by the candidate electrolyser project. All the assumptions must be duly justified and referenced.

2. The price savings of fossil fuels displaced by alternatives synthetized starting from hydrogen produced by the candidate electrolyser project is calculated as follows.

$$B_4 = \sum\nolimits_t Q_{fuel,t}\big|_{withouth} \cdot P_{fuel,t}\big|_{withouth} - Q_{fuel,t}\big|_{with} \cdot P_{fuel,t}\big|_{with}$$

Where:

- $Q_{fuel,t}\big|_{withouth}$ is the quantity of the t-th fuel in the system in the “without” case;
- $P_{fuel,t}\big|_{withouth}$ is the price to the t-th fuel in the system in the “without” case;
- $Q_{fuel,t}\big|_{with}$ is the quantity of the t-th fuel in the system in the “with” case, synthesised from hydrogen produced thanks to the candidate electrolyser project;;
- $P_{fuel,t}\big|_{with}$ is the price of the t-th fuel in the system in the “with” case, synthesised from hydrogen produced thanks to the candidate electrolyser project;;

3. The economic present value of the indicator B_3 is calculated within the CBA horizon using the discounted cash-flow approach.

Main elements to consider

- Increased production of renewable and/or low-carbon hydrogen:
  - data requirement and data granularity are comparable to the ones concerning ENTSOs TYNDPs, if quantities are evaluated as output of a detailed modelling exercise of the EU energy system. Specific data requirement might differ according to the different modelling formulation;
  - no extensive data requirements if one uses assumptions on the operation of the EU energy system achieved thanks to the candidate electrolyser project.
- Fuel prices are input to the calculation and they might be subject to sensitivity analysis.

3.1.5 B5 – Reduction of curtailed hydrogen demand

Benefit Definition:

- Definition: reduction of curtailed hydrogen demand that cannot be satisfied in a given area.
- Relevance: when an internal EU market for hydrogen will be established, the higher integration of hydrogen stemming from candidate electrolyser projects could mitigate the risk of curtailment of hydrogen demand that could occur in moments when the demand of hydrogen is higher than the supply, when storages are insufficient and/or when there is not enough hydrogen production capacity in the hydrogen system. In this respect, the integration of hydrogen production infrastructure such as electrolysers devoted to reduce curtailed hydrogen demand can increase security of energy supply in the Union.

Benefit Calculation:

- Modelling needs: an accurate assessment would require a detailed modelling exercise simulating a larger portion of the electricity, gas (distribution and/or transmission levels) and hydrogen systems affected by the candidate electrolyser project, potentially up to the European level. Simplified approaches might be allowed considering the scale of the candidate electrolyser project.
- Data needs: extensive data requirement to simulate a significant portion of the electricity, gas and hydrogen systems is required in case of an accurate modelling exercise. In absence of extensive modelling, the benefit can be calculated by using operative data about additional amount of hydrogen unlocked by the candidate electrolyser project, the timing and the location of unserved hydrogen demand and/or benefits from the ability to optimise electrolyser operations.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as avoided hydrogen demand curtailment (expressed in tons/a or in GWh/a) achievable thanks to the candidate electrolyser project. Then, the benefit is finally expressed in monetary terms when avoided hydrogen demand curtailment is multiplied with values of Cost of Disruption of Hydrogen Supply (*CODH*) for each Member State, when available.

Link with specific criteria TEN-E Regulation

- Security of supply: Article 4(3)(e)(ii) TEN-E Regulation.

Notes

- A prerequisite for the calculation of this indicator is the establishment of an internal hydrogen market, legislation concerning hydrogen security of supply and the availability of suitable values for CODH.

Hydrogen security of supply can be considered by looking at whether there are countries in EU that risk any hydrogen demand curtailment: in this respect, candidate electrolyser project may play a role in increasing security of supply by mitigating such occurrences thanks to their production.

Calculation process

Provided that the proper regulatory, legislative and market frameworks are established, the benefit B_5, conceptually similar to the benefit "Avoided curtailment demand" considered in the ENTSOG methodology [3], can be calculated as follows:

1. Evaluate the operation of the modelled electricity and hydrogen system in both "with" and "without" cases. Given the objective function of the optimisation algorithm and the balance hydrogen demand constraints, the model provides as output the level of unserved, then curtailed, hydrogen demand, in each modelled zone.
2. The monetized benefit related to the reduction of hydrogen demand curtailment in each Member State achievable thanks to the candidate electrolyser project can be calculated as follows.

$$B_5 = \sum_z (Demand\_curtailment_z|_{without} - Demand\_curtailment_z|_{with}) \cdot CODH_z$$

3. The economic present value of the indicator B_5 is calculated within the CBA horizon using the discounted cash-flow approach.

<u>Main elements to consider</u>

- Reduction of curtailed hydrogen demand:
    - the accurate evaluation of unserved hydrogen demand on the relevant portion of the hydrogen system affected by the candidate electrolyser project requires running a hydraulic model simulation;
    - the use of the probabilistic approaches to calculate hydrogen demand curtailment in different demand situations, also significant of different climatic stress conditions. For the calculation of B_5, is recommended to use the average value of demand curtailment calculated as value in each demand situation multiplied by probability of occurrence of situation;
    - using assumptions on the operation of the hydrogen system achieved thanks to the candidate electrolyser project eases the need of running a modelling exercise but it decreases accuracy of the assessment.

3.1.6 B6 – Reduction of RES curtailment

Indicator Definition:

- Definition: reduction of RES curtailment in the electricity system achievable thanks to the candidate electrolyser project.
- Relevance: reduction of RES curtailment by using the RES surplus to feed electrolysers connected to the electricity network increases security of supply of the Union.

Indicator Calculation:

- Modelling needs: if the project is connected to the electricity network and not to a dedicated and exclusive RES infeed, the accurate assessment would require a detailed modelling exercise simulating a larger portion of the electricity system beyond the project (i.e. up to the European level). An alternative solution without significant modelling requirements would be based on project and system assumptions and relative calculations.
- Data needs: extensive data requirement to simulate the whole electricity system (i.e. simulations up to the European level would require data requirements similar to the ones for ENTSOs TYNDPs). In absence of extensive modelling, the benefit can be calculated by using operative data about the estimated amount of additional RES that can be used to produce renewable hydrogen thanks to the candidate electrolyser project as well as about the amount of avoided RES curtailment.
- How the benefit is expressed: first, the benefit is expressed in quantitative terms as avoided RES curtailment (expressed in GWh/a) achievable thanks to the candidate electrolyser project. Then the benefit can be expressed in monetary terms by multiplying the avoided RES curtailment for the monetisation factors for RES curtailment.

Link with specific criteria TEN-E Regulation

- Security of supply: Article 4(3)(e)(ii) TEN-E Regulation

Notes

- Economic effect of the related GHG reduction is not included to avoid double counting with B1.

RES curtailment arises in the electricity system when the instantaneous production of renewable energy sources exceeds the instantaneous electricity demand, taking also in consideration inflexibility of certain component of the electricity system (for instance, minimum up time and downwards ramp constraints of dispatchable thermal power plants). In this occurrence, if the electricity system is not able to store or transmit such surplus in other areas of the system, system operators might force RES to reduce their output to ensure system security: consequently, the system is not exploiting cheap and clean energy output.

While electrolysers might have technical operational constraints, they can still provide additional flexibility to the energy system as a whole, increasing their energy intake in RES surplus moments to produce renewable hydrogen. This capability can be beneficial under different perspectives:

- by reducing the curtailment of renewable energy that it is instead stored in hydrogen to be used on a second stage, candidate electrolyser projects can enable additional decarbonisation of end-uses increasing the sustainability of the whole energy system;
- the reduction of curtailment for RES generation contributes at increasing the safety and the stability of network operation, enhancing security of supply; and
- the flexibility provided by candidate electrolyser projects can be seen as a measure of demand response in the electricity system enabling energy storage: consequently, candidate electrolysers contributing at reducing RES curtailment facilitate smart energy sector integration by reinforcing links among energy carriers (i.e. electricity and hydrogen) and sectors (i.e. electricity, hydrogen, industry, transport, etc.), ultimately unlocking cost savings for the Union.

Calculation process

The benefit B_6, conceptually similar to part of the benefit B3 “RES Integration Benefit” considered in the ENTSO-E methodology [2], can be calculated as follows:

1. Evaluatethe reduction of RES curtailment following one of the two approaches below:
    a. in case a detailed modelling exercise is carried out, the assessment must evaluate the operation of the modelled electricity system in both “with” and “without” cases. Given the objective function of the optimisation algorithm and the balance demand constraints, the model provides as output the level of curtailed RES generation, in each modelled zone;
    b. in case of simplified assumptions, one shall calculate the estimated amount of RES curtailment that can be avoided by redirecting such infeed to the candidate electrolyser project. All the assumptions must be duly justified and referenced.
2. The monetized benefit related to the reduction of avoided RES curtailment in the z-th zone of the modelled electricity system can be calculated by multiplying avoided RES curtailment for proper monetisation factors for RES curtailment (expressed in €/MWh).

$$B_5 = \sum_z (RES\_curtailment_z|_{without} - RES\_curtailment_z|_{with}) \cdot K_{RES\_curtailment_z}$$

3. The economic present value of the indicator B_5 is calculated within the CBA horizon using the discounted cash-flow approach.

Main elements to consider

- Avoided RES curtailment
    - running a full EU electricity model to calculate avoided RES curtailment might correspond to data requirement and data granularity comparable to the ones concerning ENTSO-E TYNDP.
    - no extensive data requirements might be needed if one uses the estimation about the amount of avoided RES curtailment that can be avoided thanks to the candidate electrolyser project.
- Monetisation factors for RES curtailment: such factors (in theory different for each EU Member State) could be subject to sensitivity analysis.

3.1.7 B7 – Variation of socio-economic welfare in electricity markets

Benefit Definition:

- Definition: variation of Social Economic Welfare (SEW) in electricity markets achievable thanks to the candidate electrolyser project.
- Relevance: candidate electrolyser projects can enhance flexibility and efficiency of electricity markets, resulting in an increase of SEW for the Union.

Benefit Calculation:

- Modelling needs: if the project is connected to the electricity network and not to a dedicated and exclusive RES infeed, the accurate assessment would require a detailed modelling exercise simulating a larger portion of the electricity system beyond the project (i.e. up to the European level). The modelling shall be able to capture different phases of electricity markets, in particular closer to the real-time (for instance, balancing markets and ancillary services markets), giving the flexibility capability and related benefits that a candidate electrolyser projects can offer to such markets: for instance, modelling of balancing markets would require higher temporal granularity (i.e. intra-hour modelling.
- Data needs: extensive data requirement to simulate the whole electricity system (i.e. simulations up to the European level would require data requirements similar to the ones for ENTSOs TYNDPs) with a level of detail sufficient enough to represent market session close to the real time. Level of detail of data should be consistent and compatible with the modelling exercise.
- How the benefit is expressed: the benefit is expressed in monetary terms either by using the generation cost approach or the total surplus approach.

Link with specific criteria TEN-E Regulation

- Smart energy sector integration: Article 4(3)(e)(i) TEN-E Regulation.

Notes

- Economic effect of the related GHG reduction is not included to avoid double counting with B1.

Socio-economic welfare (SEW) is defined in economics via the concept of utility, i.e. the value that different actors in the market associate to a particular good or service. Individuals tend to maximize their utility through their actions and consumption choices and the interactions of buyers/consumers and sellers/producers through the laws of supply and demand in competitive markets yield to consumer and producer surplus. A natural equilibrium point is achieved when the highest overall (social) level of satisfaction is created among the different actors.

In power system economics, SEW is often defined as the short-run economic surpluses of electricity consumers, producers and, given the nature of the transportation problem, transmission operators (collecting congestion rents). Any infrastructural project inserted in the system affects either the generation or the consumption mix or the transmission capacity, resulting into a variation and/or redistribution of SEW within the modelled system (between different actors and/or among different modelled zones).

Current EU electricity market design offer the following opportunities to electrolysers [16]:

- participating in day-ahead electricity market, acting as implicit (price-based) demand response. In this respect, electrolyser can vary their consumption according to price signal: for instance, they can quickly ramp–up their consumption at times where there is RES surplus (reducing RES curtailment, see benefit B_5) and especially in hours where operational constraints on inflexible generation might result in negative prices, increasing SEW for EU society;
- participating in intraday electricity market: electrolyser might adjust their consumption profile in continuous trading, matching buy or sell orders in order to balance positions: in this respect, electrolysers might act as additional flexibility resource in intraday electricity markets, contributing at increasing SEW for EU society;

- participating in electricity balancing markets: in this respect and whether allowed by the pertinent regulatory framework, electrolysers could be controlled to quickly ramp-up or ramp-down their consumption participating either individually (if sufficiently large) or through aggregators in electricity balancing markets by providing, for instance, Frequency Containment Reserve (FCR) and/or automatic/manual Frequency Restoration Reserve (aFRR/mFRR). If such services are remunerated in the zone where the electrolyser is connected, a cost-efficient flexibility service provided by the electrolyser would result in an increase of SEW for the system.
- participation in other (non-frequency) ancillary services markets: ancillary services are defined as "those services necessary to support the transmission of electric power from seller to purchaser, given the obligations of control areas and transmitting utilities within those control areas, to maintain reliable operations of the interconnected transmission system". Given the fact that electrolysers act as loads in the electricity markets, they can provide the following ancillary services:
    - reactive power and voltage control: electrolysers exploit AC/DC converters that can be used as STATCOMs, providing reactive power and voltage control [17].
    - scheduling and dispatch: given their flexibility, electrolysers might increase efficiency of scheduling (i.e. change status of a generation unit) and dispatch (i.e. change output of a scheduled generation unit) carried out by system operator with the aim of maintaining adequate levels of security for the system while increase the SEW of the system.
- participating in the market based procurement of congestion management

Calculation process

The benefit B_7, whose part of it is conceptually similar to the benefit B1 "SEW benefit" considered in the ENTSO-E methodology [2], can be calculated as follows:

1. If the candidate electrolyser is connected to the power system, the assessment evaluates the increase of SEW following one of the two approaches below:
    a. generation approach, where the benefit for the system is calculated by assessing the difference between total operating cost of the power system in both "without" and "with" cases;
    b. total surplus approach: where the benefit for the system is calculated by assessing the difference between total SEW (sum of consumer and producer surpluses and congestion rent) of the power system in both "with" and "without" cases;
2. In case a detailed modelling exercise is carried out, given the objective function of the optimisation algorithm representing the different phases of the electricity market the assessment can calculate the benefit as sum of the difference of total costs in each modelled market m (i.e. day-ahead, intraday, balancing, other ancillary services markets);

$$B_7 = \sum\nolimits_m (Total\ cost\ ele_m|_{without} - Total\ cost\ ele_m|_{with})$$

or

$$\begin{aligned} B_7 = \sum\nolimits_m & (Consumer\ surplus_m|_{with} - Consumer\ surplus_m|_{without}) \\ & + (Producer\ surplus_m|_{with} - Producer\ surplus_m|_{without}) \\ & + (Congestion\ rent_m|_{with} - Congestion\ rent_m|_{without}) \end{aligned}$$

    a. in case of simplified assumptions, the assessment shall calculate the estimated amount of RES curtailment that can be avoided by redirecting such infeed to the candidate electrolyser project. All the assumptions must be duly justified and referenced.
3. In case of simplified assumptions, the assessment shall calculate the estimated amount of increase of SEW that can be achieved in each step of the electricity market thanks to the market efficiency brought by the candidate electrolyser project. All the assumptions must be duly justified and referenced.

4. The economic present value of the indicator B_6 is calculated within the CBA horizon using the discounted cash-flow approach.

Main elements to consider

- An accurate characterization of the different steps of EU electricity markets would require extensive modelling and data requirement, both in terms of temporal granularity (e.g. intra-hour modelling for electricity balancing markets), spatial granularity (e.g. nodal formulation to account re-dispatch) and problem formulation (e.g. AC modelling to account participation to voltage control and ancillary services markets). Consequently, modelling and corresponding data requirements could significantly vary according to the level of accuracy and detail chosen.

3.1.8 B8 – Cross sectoral cost savings

Benefit Definition:

- Definition: cost savings enabled by electrolysers by enabling cross-sectoral flexibility.
- Relevance: by enabling services such as demand response and energy storage, candidate electrolyser projects can realize total savings (both capital and operative savings), creating synergies and benefits for the Union.

Benefit Calculation:

- Modelling needs: in order to fully capture the cost savings enabled by candidate electrolyser projects, a detailed modelling exercise encompassing several other relevant sectors (for instance but not limited to, power, gas, hydrogen, heat, transport and industry) is necessary. The level of representation shall be consistent with the specific characteristics of the project as well as the necessary temporal and spatial granularity and the cross-sectoral interactions among the sectors. Different modelling approaches are possible taking into consideration with the alternatives in terms of interaction among the different dimensions of the energy system, leading to different trade-off levels between complexity and accuracy.
- Data needs: extensive data requirement to allow the simulation of the operation of the integrated energy system, with a level of detail, in principle, considerably higher than the one necessary for the simulations of electricity and gas sectors alone.
- How the benefit is expressed: the benefit is expressed in monetary terms as difference between total costs in “without” case and the “with” case.

Link with specific criteria TEN-E Regulation

- Smart energy sector integration: Article 4(3)(e)(iii) TEN-E Regulation

Notes

- Double counting with other indicators shall be avoided.

To ensure a cost-efficient, fair and inclusive energy transition, it is necessary that all relevant sectors, such as gas, electricity, industry, transport, and heat are considered in a more integrated perspective: the transition to a more integrated, holistic and optimised system can be achieved only if the role of assets able to act along different dimensions of the one energy systems is emphasized, creating opportunities for cross-sectoral cost efficiencies arising by stressing the “energy efficiency first” principle.

In this respect, electrolysers play a key role in unlocking such efficiencies, by enabling flexibility services facilitating links among the different energy carriers and sectors: trivially, electrolysers use electricity to create hydrogen, which is a key resource for certain industries and that can be potentially used as a fuel for both transport and heating system. Cost savings can also arise in terms of reduction of capital expenses in several sectors enabled by candidate electrolyser projects.

A proper characterisation of cost savings cannot neglect the required level of detail of needed modelling exercises and data gatherings, which can increase more than linearly with the number of sectors represented and potentially be more extended and cumbersome than the one related to the integrated model as referred in Article 11(10) of TEN-E Regulation. In this respect, the level of detail shall reflect the level of implementation of the best practice developed by the ENTSOs with respect the implementation of the integrated (electricity, gas and hydrogen) energy model.

It is important to highlight that double accounting with any benefit considered in the previous indicators shall be avoided: in this respect, the assessment shall clearly describe how this aspect is ensured.

Calculation process

For each year within the CBA horizon, the assessment shall evaluate the cross-sectoral cost savings achievable thanks to candidate projects as follows:

1. In case of complete integrated model, the assessment of candidate projects shall calculate the benefit as variation of annual total costs (both operational and capital, if the model can also be used for investment decision) that can be achieved thanks to the candidate electrolyser project in all the s sectors which is directly calculate by the integrated model from both "without" and "with" simulations of the integrated model;

$$B_8 = \sum \; [Total\ cost(s)|_{without} - Total\ cost(s)|_{with}]$$

2. In case of separate simulation of different systems, the assessment of candidate electrolyser projects shall identify proper values for boundary conditions necessary to ensure consistency between the results calculate by the separate models: such values might come as output of a simplified integrated model from separate studies or assumptions: in case of separate studies or assumptions, exogenous information must be duly justified and referenced. If the assessment is following this approach, the benefit is calculated as the estimated variation of annual total costs (both operational and capital, if the models can also be used for investment decision) of the used models that can be achieved thanks to the candidate electrolyser project in all the sectors

$$B_8 = \sum_s [Total\ cost_s|_{without} - Total\ cost_s|_{with}]$$

3. If no simulations are carried out, the assessment of candidate electrolyser projects may estimate cost the benefit as the estimated variation of annual total costs (both operational and capital, if the models can also be used for investment decision) of the used models that can be achieved thanks to the candidate electrolyser project in all the sectors. Exogenous information must be duly justified and referenced.
4. $B_8 = \sum_s [Total\ cost_s|_{without} - Total\ cost_s|_{with}]$

5. The economic present value of the indicator B_8 is calculated within the CBA horizon using the discounted cash-flow approach.

Given the fact that this indicator can, in principle, encompass all the others, it is important that no double counting with the latter exists: in this case, the assessment should clearly identify these risks and remove the share of the indicator which is already accounted in another one.

Main elements to consider

An accurate characterization of this indicator would require extensive modelling and data requirement, similar if not exceeding the requirements set for the integrated model pursuant to Article 11(10) of TEN-E Regulation. Consequently, modelling and corresponding data requirements could significantly vary according to the level of accuracy and detail chosen.

3.2 Costs

Project promoters shall provide relevant costs for each year analysed in the study horizon accompanied with assumptions on the duration of authorisation, construction time and decommissioning phases. In particular, project promoters shall take into account the following cost elements:

- capital expenditure costs;
- operational and maintenance expenditure costs;
- costs induced for the related system over the technical lifecycle of the project;
- decommissioning and waste management costs; and
- other external costs.

Project promoters shall clearly describe what cost elements are incurring within the study horizon, taking into consideration the specificities of equipment and installations constituting the pertinent candidate electrolyser project.

Costs occurred before the study horizon shall be actualised at using as reference year the year after the adoption of the relevant Union list of PCIs and PMIs (e.g. 2024 is the reference year for the first Union list of PCIs and PMIs under the revised TEN-E Regulation, see section 3.4).

Member States impacted by the costs related to a candidate electrolyser project should be identified and disaggregated costs at Member State level should be provided.

Information shall be provided in a format allowing the Commission to check and verify the impact of the assumptions and the relevant calculations (e.g., Excel spreadsheet). Confidentiality of sensitive information must be ensured in line with the provisions of TEN-E Regulation.

3.3 Residual impacts

When dealing with the potential adverse impacts of a project, the primary approach is to prevent such impacts from occurring in the first place, for instance by optimising the routing and the location of the project. When this is not possible, mitigation measures can be put in place and, in certain cases, compensatory measures may be legally mandated. When the project planning has advanced enough, the expenses associated with these measures can be accurately estimated and are included in the overall project costs (see section 3.2). When the required information for such cost internalisation is not available yet, however, residual impact can be evaluated, in line with the approaches developed by the ENTSOs in their respective methodologies (see footnote 1). In particular, project promoters for candidate electrolyser projects shall evaluate, when relevant:

- S1 (Residual Environmental Impact);
- S2 (Residual Social Impact); and
- S3 (Other Impacts).

3.3.1 S1 – Residual Environmental Impact

In line with the approach developed by ENTSO-E in its CBA methodology (see footnote 1), the residual environmental impact of a candidate electrolyser project shall be evaluated by identifying:

- stage of the candidate project, in line with the project implementation status, see section 2.2;
- potential impact, i.e. to what extent the candidate electrolyser project impacts on nature and biodiversity (length and surface area of infrastructure located within an environmental sensitive area); and
- type of sensitivity, i.e. rationale on why the area is considered sensitive (e.g. biodiversity, habitat, etc.).

For candidate electrolyser projects in the “permitting” or “under construction”, the elements listed should be reported based on the current data of the project promoter, also referencing the environmental impact assessment performed to identify those elements. When a project is not sufficiently mature ("planned, but not yet in permitting"' or "under consideration") and when the aforementioned elements are not available the project promoter shall clearly state that an environmental assessment is not yet available due to the low degree of maturity of the candidate project and that the actual routing of the project is not defined yet.

3.3.2 S2 – Residual Social Impact

Similarly to what described in section 3.3.1 and in line with the approach developed by ENTSO-E in its CBA methodology (see footnote 1), the residual social impact of a candidate electrolyser project shall be evaluated by identifying:

- stage of the candidate project, in line with the project implementation status, see section 2.2;
- potential impact, i.e. to what extent the candidate electrolyser project impacts on densely populated areas or protected areas (length and surface area of infrastructure located within an socially sensitive area); and
- type of sensitivity, i.e. rationale on why the area is considered sensitive (i.e. population density, landscape, etc.)

For candidate electrolyser projects in the "permitting" or "under construction", the elements listed should be reported based on the current data of the project promoter, also referencing a social impact assessment performed to identify those elements, when required by the legislative framework. When a project is not sufficiently mature ("planned, but not yet in permitting"' or "under consideration") and when the aforementioned elements are not available, the application shall clearly state that a social assessment is not yet available due to the low degree of maturity of the candidate project and that the actual routing of the project is not defined yet.

3.3.3 S3 – Other impacts

Any other impact (positive or negative) not covered in S1 and S2 shall be included in S3. Any impact already accounted in S1 and S2 shall not be considered in this indicator.

3.4 Project value – NPV and B/C – calculation

The Economic Net Present Value (ENPV) represents the difference between the present value of all monetised benefits and the present value of all costs, discounted using the discount rate.

$$ENPV = \sum_{y=0}^{T} \frac{TotB_{mon,y} - TotC_{,y}}{(1+r)^{y}}$$

where:

- T is the study horizon;
- y represent the year within the study horizon when benefits and costs occur;
- $TotB_{mon,y}$ is the sum of monetized benefits for the y-th year;
- $TotC_{y}$ is the sum of total costs for the y-th year;
- r is the discount rate;

Another indicator to be calculated is the benefit-cost ratio (BCR), which is the ratio between the present value of all monetised benefits divided by the present value of all costs[10]

$$BCR = \left. \sum_{y=0}^{T} \frac{TotB_{mon,y}}{(1+r)^y} \middle/ \sum_{y=0}^{T} \frac{C_y}{(1+r)^y} \right.$$

Benefits and costs shall be actualised at using as reference year the year after the adoption of the relevant Union list of PCIs and PMIs (e.g. 2024 is the reference year for the first Union list of PCIs and PMIs under the revised TEN-E Regulation).

3.5 Transparency and confidentiality

In submitting their application project promoters for candidate electrolyser projects must provide all the necessary information with the appropriate level of transparency, also taking into consideration the provisions of the TEN-E Regulation, to allow the Commission to be able to rebuild the NPV and BCR calculations.

Confidentiality of sensitive information is ensured in line with the provisions of the TEN-E Regulation.

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(10) More detailed information on the project value calculation can be found in the latest CBA methodology developed by the ENTSOs [2], [3].

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List of abbreviations and definitions

ACER	European Union Agency for the Co-operation of Energy Regulators
BCR	benefit-cost ratio
CBA	Cost Benefit Analysis
EIB	European Investment Bank
ENPV	Economic Net Present Value
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
GHG	Greenhouse gases
JRC	Joint Research Centre
PCI	Project of Common Interest
SMR	Steam Methane Reforming

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Annex 1. Modification of the methodology due to the contributions received from the public consultation.

1. Introduction

The consultation on the draft electrolyser CBA methodology is part of the process for development of methodologies for a harmonised energy system-wide cost-benefit analysis at Union level pursuant to Article 11(8) of the revised TEN-E Regulation. Concerning the electrolyser CBA methodology, the consultation started on 7 October 2022 and ended on 6 January 2023. The consultation has been carried out through EUSurvey[11], the European Commission's official survey management tool.

The objective of this consultation was to seek input from stakeholders on the draft electrolyser CBA methodology published on 7 October 2022, who were invited to answer questions for the overall approach of the methodology as well as questions for each individual indicator of the methodology.

The public was consulted on the following general question:

- *In your view, to what extent does the draft methodology allow for a harmonised energy system-wide cost-benefits analysis at Union level?*
- *Do you have any feedback regarding the assumptions considered in the draft methodology? (Section 2.1)?*

Concerning the specific indicators proposed, the public was consulted on the following questions for each individual indicator, respectively:

- *In your view, is the benefit well described in line with the legal base?*
- *Do you have suggestions for data sources which could be used for the calculation of this benefit?*
- *Suggestions for data sources which could be used for the calculation of this benefit?*

2. Consultation results

Three participants responded to the consultation via EUSurvey. Replies came Denmark, Italy and Sweden. In terms of categories, the replies from two transmission system operators from academia.

One reply has been received to the Commission via email: the reply came from an international industry association.

A joint ACER-NRAs document was been submitted to the Commission via email in response to the public consultation on horizontal consistency of CBA methodology developed pursuant to Article 11(8) of the revised TEN-E Regulation.

3. Summary of changes due to input received from the public consultation

Number Comment	Respondents' comments	Outcome
A1	An approach for residual value to account the benefit of a project beyond the study horizon shall be introduced. Alternatively, the duration of the study horizon could be extended to account the full technical lifetime of assets part of a candidate hydrogen project (several respondents).	In order to be aligned with other best practices in EU energy infrastructure development we will not introduce any residual value in the hydrogen CBA methodology.

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(11) https://ec.europa.eu/eusurvey/home/about

Number Comment	Respondents’ comments	Outcome
A2	The methodology should monetize indicators as much as possible, even in the absence of fully operational EU hydrogen market, to introduce provisional monetisation factors.	All the benefit indicators presented in the electrolyser CBA methodology are monetised. The maturity of the EU hydrogen market and security of supply framework currently hinders the capability to monetize indicators when applying this methodology in a specific PCI/PMI process. At the same time, this methodology has been developed pursuant to Art. 11(8) of the revised TEN-E Regulation and, consequently, with no specific link to a specific PCI/PMI process.
A3	In absence of supply costs the hydrogen production cost (LCOH) could be calculated, for each Member State and for each year within the study horizon, as the total cost expenditure required for the development of the infrastructure respect to the volumes that it would allow to transport and to be applied as monetisation factors for indicators “Variation of the share of renewable and low-carbon hydrogen integrated into the system” and “Increased deployment and integration of synthetic fuels”. Furthermore, the application of different LCOH should be envisaged in consideration of the characteristics of the assessed projects (e.g. scale, localization, etc.).	We acknowledge that the TYNDP scenarios are sometimes not fully aligned with the most recent energy policy or technological development, due to the timeline differences. However, the TYNDP scenarios represent a key source of information to ensure consistency among all energy infrastructure projects. This being said, when justified, different hypotheses can be used by project promoters to run their analyses as well as their sensitivities: for specific PCI/PMI process, additional information are to be provided in project submission templates.
A3	The methodology should be more clear on where project promoters can find input and assumptions for their analyses	Improved the text by further clarifying the sources of information for project promoters.
A4	The CBA methodology should be able to quantify the reduction of other non-CO2 negative externalities (e.g. NOx, SOx, PM, etc.) stemming from the project, that would be monetise according to the social cost of the pollutant (“Pj” expressed in €/ton), coherently with CBAs proposed for other infrastructure categories (i.e. energy storage).	Improved the text by adding the benefit “Variation of non-GHG emissions”.
A5	The text of the methodology shall stress that no double counting is accepted.	Improved the text accordingly.
A6	Pending the definition of an EU hydrogen security of supply policy for the definition of a Cost of Disrupted Hydrogen (CODH), as a conservative proxy values adopted for the CODG should be used, allowing project promoters to provide evidence of higher values to be used in the evaluation.	Such monetization shall be introduced when a clear framework about hydrogen security of supply will introduced in EU energy policy framework. We take note of the suggestion to use CODG (Cost of Disrupted Gas) as proxy value for CODH but it believes the former is not an appropriate proxy for the latter.
A7	Ideally project promoters model the difference in	We agree with the comment received and

Number Comment	Respondents’ comments	Outcome
	expected unsupplied demand (energy and valuation) in Monte-Carlo varied scenarios & for extreme cases (extreme weather, infrastructure disruptions,...) Acknowledging the difficulty to assess this criterion absent the capacity for detailed modelling and without corresponding data, it seems insufficient to leave this to project developers’ basic estimation.	improved the text in the description of the indicator (see “Main elements to consider”).
A8	On reduction of RES curtailment: as detailed in part two of the document to fully capture and evaluate with a cross-sectorial assessment the benefits that project would determine for electricity system it would be essential to include elements that would allow for a monetisation. For this aim it may be used, in absence of a reference factor, the average electricity market price (€/MWh) extracted from market simulations tools.	We take note of the comment received but we believe that such assumption would distort the evaluation of other benefits (e.g. B7 in this methodology). The Commission observes that, if used, the monetisation factor for RES curtailment will be provided in the project submission template.
A9	On reduction of RES curtailment: the benefit has poor support from a theoretical point of view. RES integration is in general made in a project level optimal fashion, i.e. optimizing cost/income (SEW) with regards to possible spillage. To later reduce RES spillage has no special benefit other than a slight impact on electricity market prices and SEW. This impact should be measured as power market SEW, and ONLY that. The assumption of increased Security of Supply thanks to less RES curtailment is a real stretch. Generally, the extra, "stored" RES, will probably have little effect on the occasions when SoS problems arise.	To a certain extent, we agree with the comment received. The reduction of RES curtailment has an impact on SEW and, in this respect, this element shall not be double counted as in general for the whole CBA methodology. At the same time, if national/European energy policy frameworks introduce a penalisation of RES curtailment per se, i.e. not connected to the market dimension, this element would not be considered in the SEW. We observe that, if introduced, monetization factors for RES curtailment outside the market dimensions will be provided in the project submission template, consistently with national and European energy policy frameworks. We observe that the inclusion of this indicator under the security of supply generic criterion is consistent with the text in Annex IV(7)(b) to revised TEN-E Regulation.
A10	The description of benefit “Cross sectoral cost savings” is considered too vague.	From a conceptual point of view, we agree and therefore improved the text calling for sufficient clarity from the project promoters in identifying and explaining all possible sources and impact of cross-sectoral cost savings. At the same time the broad impact that candidate electrolyser projects can have on the entire energy system represents a limitation in being specific without risking to be too limitative. Being this the first methodological proposal for the evaluation of candidate electrolyser projects it is

Number Comment	Respondents' comments	Outcome
		important to ensure to project promoters the possibility to highlight any possible benefit resulting from the realization of their projects, provided that such description is duly explained, motivated and verifiable. The Commission may be more specific concerning this indicator in possible future versions of this methodology, in case robust practices arise from the application in PCI processes.
A11	Cross sectoral cost savings can also include SEW. To avoid double counting the methodology could clearly separate which cost reductions are accounted.	Improved the text but it believes that the text of benefit B7 in this methodology is specific enough.
A12	Cost savings can also arise in terms of reduction of capital expenses in other sectors enabled by candidate electrolyser projects (e.g. electricity transmission development costs, electric storage costs, etc.).	We take note of the comment received but it observes that any consideration in this respect shall be accompanied by a clear and unambiguous indication that such avoided costs are directly linked to the specific candidate electrolyser project.

Table 4. Result of the public consultation – ACER-NRAs document

Number Comment	Respondent's comment	Outcomes
B1	All project promoters should use same "common" assumptions, best if clearly specified in the methodology the values or reference which should be used in the calculations.	The assumptions should either come from TYNDP scenarios or from information provided in the template for the project submission. At the same time, the project promoters shall be entitled to introduce complementary assumptions and use pertinent calculations approaches, in line with the scope of the candidate hydrogen project, provided that such deviations and modelling/simplification assumptions are clearly described and justified.
B2	Clear rules on the study horizon and discount rate: 25 years from the start of the operation of the project and 4%. Recommendable to give guideline on how to treat years before the start of operation of the project (in particular concerning already incurred costs).	The methodology already mentions the use of the values 25 years and 4%. The benefits shall be accounted from the year after the commissioning year (first full year of system benefits). Included guidance on how to actualise costs occurring before the start of operation of the project.
B3	Improve terminology: a. refer to "socio-economically desirable" rather than "profitable", as later is more	Improved the text accordingly.

Number Comment	Respondent's comment	Outcomes
	a term used in business analysis b. refer to Economic Net Present Value (ENPV) as CBA is an economic analysis of a project and not a financial analysis	
B4	For qualitative indicators no methodology is proposed to apply an "appreciation scale" making impossible to compare different projects.	The qualitative indicators are expressed as percentage, which inherently allows an appreciation to compare different projects.
B5	Where possible, the cost distribution and socioeconomic impacts per Member State should be provided. The impacted Member States should be identified.	Improved the text accordingly.
B6	Avoiding double counting is mentioned in the proposed methodology, anyhow description of the verification process for double counting seems to be missing.	The verification process of non-double counting shall be carried out in line with the provisions set in point (2) of Annex III to the revised TEN-E Regulation.
B7	There are no definitions nor references of low carbon gases (reference to REDII / REDIII Delegated acts)	Improved the text accordingly, via footnote in section 3.1.1.
B8	With respect to the benefit "Reduction of curtailed hydrogen demand", the methodology should define in which demand situation this indicator should be computed (e.g. yearly demand vs peak day with 1/20 years probability) and, possibly, also in which import disruption condition(s). When calculating demand curtailment, we believe approach taken in ENTSOG 2nd CBA methodology should be followed in respect to the climatic stress conditions analysis.. 5.	The text already align the proposed indicator with ENTSOG's 2nd CBA Gas Methodology. In addition, the text has been improved in "Main elements to consider" to explicit the use probabilistic approaches to calculate gas demand curtailment in different demand situations, also resulting in different climatic stress conditions.
B15	The definition of Costs is aligned with Regulation 2022/869, Annex V, also to ensure a harmonised approach among all the CBA methodologies.	Improved the text accordingly in section 3.2.
B16	The formula of the Economic Benefit/Cost ratio is missing.	Improved the text accordingly in section 3.4.
B17	As a CBA Methodology is a guidance document for the assessment of projects, expected to be valid for more than one cycle of assessment (e.g. for several TYNDPs), it is not practical to include implementation details of the methodologies, parameters, or specific assumptions for the calculation of each benefit, which may vary for each cycle of assessment. Therefore, each CBA Methodology needs to be complemented by "Implementation Guidelines",	We note that the consistency in the implementation of a CBA methodology is important to ensure that the results of practical application are comparable. It is also necessary to provide clarity to the project promoters on what assumptions, criteria, models should be used to calculate costs and benefits for each Union list cycle. Thus, we amended the text to reflect that that project promoters should by default use the ENTSOs scenarios as primary data

Number Comment	Respondent’s comment	Outcomes
	which shall include additional detailed information to be published in each assessment cycle, including how the simulations are to be performed, and specifying which method is to be used (in case the CBA Methodology allows for more than one possibility), the values of the parameters and the assumptions used	sources to make the calculations of costs and benefits. CBA methodologies should also contain information that in case the Commission prescribe the use other parameters than the ones being used by ENTSOs, which will be specified in the template for PCI/PMI candidate submissions at the beginning of specific PCI cycle. These data sources and assumptions shall be harmonised to the extent possible across the CBAs.
B18	The CBA methodology shall reflect interdependencies and clustering of projects	Such comment might not be relevant to the assessment of candidate electrolyser projects.
B19	In order to ensure comparability in term of project maturity, all CBA Methodologies should consider the same project implementation stages. In its PCI Monitoring Reports , ACER considers the following ones: (1) Under consideration, (2) Planned but not yet in permitting, (3) Permitting, (4) Under construction.	Improved the text accordingly.
B20	A common methodological framework for the assessment of the societal and environmental impacts of the projects, should be described in all CBA methodologies.	Improved the text accordingly.
B21	Given the uncertainty involved in the future projections of the CBA results, all CBA methodologies should include sensitivity analysis on critical parameters, and a framework for identifying these critical parameters. The approach to the use of sensitivity analysis on the application of CBA should be aligned in all CBA methodologies. These sensitivities should also be aligned with Regulation (EU) 2022/869, Annex V(2).	Improved the text accordingly.

Table 5. Result of the public consultation – Email received

Number Comment	Respondent’s comment	Outcomes
C1	Point ii mentions that the electrolyser/s must have a network related function. We suggest clarifying whether such function is related to gas or electricity networks.	Improved the text accordingly.
C2	Specific criteria for candidate electrolyser projects: We suggest clarifying the wording ‘low-carbon hydrogen in particular from renewable	The wording comes from Art. 4(3)€ of the revised TEN-E Regulation.

Number Comment	Respondent's comment	Outcomes
	sources'.	
C3	In addition, one of the key criteria is the capability of projects to offer storage and flexibility. What are then the boundaries between electrolysers projects and energy storage projects?	The nature of the asset involved in any energy infrastructure category is provided in Annex II to revised TEN-E Regulation.
C4	Because certain elements of projects, e.g. underground storage facilities, will usually have economic lifetimes which greatly exceed the time horizons suggested in the guidelines, we suggest that the project promoters should be given the possibility to at least include long lifetime assets in the projects residual value (if extending the time horizon of the analysis is not possible).	See the answer above.
C5	For the hydrogen price and ETS carbon price parameters, we suggest clarifying who would be the data supplier.	See the answer above.
C6	Please include more detailed information about monetization factor and Cost of Disruption of Hydrogen Supply for each MS calculation.	When available, such values will be provided in the template for the project submission.
C7	The monetized benefit related to the reduction of avoided RES curtailment can be calculated by project promoters by multiplying avoided RES curtailment by proper monetisation factors for RES curtailment (expressed in €/MWh). We suggest clarifying what this includes (e.g. RES LCOE? Some avoided compensations paid to RES operators in case of curtailment? Other?)	Such monetisation factor shall consider penalisation of RES curtailment introduced, if relevant, in national/European energy policy frameworks.

4. Summary of changes due to input received from the public consultation

Table 6 provides a summary of the modification to the draft electrolyser CBA methodology in line with the comments received and described in Tables 3 and 4, respectively.

Table 6. Summary of the impact of the public consultation to the text of the electrolyser CBA methodology

A1	Improvement request.	Not accepted.
A2	Improvement request.	No action needed.
A3	Improvement request.	No action needed.
A3	Clarification request.	Text clarified.
A4	Improvement request.	Accepted.

A5	Clarification request.	Text clarified.
A6	Improvement request.	Not accepted.
A7	Improvement request.	Accepted.
A8	Improvement request.	No action needed.
A9	Clarification request.	No action needed.
A10	Clarification request.	No action needed.
A11	Clarification request.	Text clarified.
A12	Improvement request.	No action needed.
B1	Improvement request.	Accepted.
B2	Improvement request.	No action needed.
B3	Clarification request.	Text clarified.
B4	Improvement request.	Accepted.
B5	Improvement request.	No action needed.
B6	Clarification request.	Text clarified.
B7	Improvement request.	Accepted.
B8	Improvement request.	Accepted.
B9	Improvement request.	Accepted.
B10	Improvement request.	No action needed
B11	Improvement request.	No action needed
B12	Improvement request.	Accepted.
B13	Improvement request.	Accepted.
B14	Improvement request.	Accepted.
C1	Improvement request.	Accepted.
C2	Improvement request.	No action needed.
C3	Improvement request.	No action needed.
C4	Improvement request.	No action needed.
C5	Improvement request.	No action needed.
C6	Improvement request.	No action needed.

C7	Improvement request.	No action needed.

5. Other important changes

This section briefly describes important changes implemented by the Commission to the text of SGG CBA methodology, compared to the version submitted for public consultation. These changes have been introduced to increase consistency with other TEN-E methodologies, in line with the provisions of Article 11(8) of the Regulation;

- introduction of the benefit “B2 - Variation of non-GHG emissions”;
- improvement of the benefits “B3 – Variation of renewable and/or hydrogen production – Fuel cost savings” and “B4 - Variation of synthetic fuel production– Fuel cost savings”; and
- introduction of approaches for the evaluation of residual impacts (see section 3.3).

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