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JRC TECHNICAL REPORT

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

[DRAFT FOR PUBLIC CONSULTATION]

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Joint Research Centre

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Abstract

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

1 Introduction and scope

Cost–benefit analysis (CBA) is a systematic evaluation tool aimed at determining whether an action/decision/investment is profitable (namely, if its 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 hydrogen projects (in the following, "hydrogen CBA methodology") has been developed by the JRC, the European Commission's (the "Commission") science and knowledge service, in compliance with the requirements set in Article 11 to Regulation (EU) 2022/869 (in the following, "TEN-E Regulation") [1]. In particular, the hydrogen 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 to TEN-E Regulation.

Article 11 of the TEN-E Regulation mandates ENTSOG to develop a draft CBA hydrogen methodology by April 2023, followed by Member States' and ACER opinion and finally the Commission approval, resulting in a final hydrogen CBA methodology no earlier than end of 2023. This requirement does not meet the timeline of the 1st PCI/PMI process under the revised TEN-E Regulation, which should end in the adoption of the first Union list of PCI/PMI by November 2023.

Taking these time limitations into consideration, the Commission has tasked JRC to elaborate a draft hydrogen CBA methodology. This will consider the input received from ENTSOG and ACER. This H2 methodology has the purpose to bridge the gap between the 1st hydrogen PMI/PCI process under the revised TEN-E Regulation and the ENTSOG methodology to come in time for the next PCI/PMI process.

This hydrogen CBA methodology has been developed in a transparent manner, including extensive consultation of Member States and all relevant stakeholders.

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) countries[1]. 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[2].

The revised TEN-E Regulation, 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;
- provides rules for the cross-border allocation of costs and risk-related incentives for projects on the Union list.

(1) https://energy.ec.europa.eu/topics/infrastructure/trans-european-networks-energy_en
(2) https://ec.europa.eu/info/news/in-focus-making-eus-energy-infrastructure-fit-climate-neutrality-2021-jun-15_en

1.2 General criteria for candidate hydrogen projects

In its assessment of applications received, the Commission shall check the compliance with respect to the general criteria foreseen in Article 4(1) to TEN-E Regulation. In particular, the application for the 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) to 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) to TEN-E Regulation. In particular, to verify compliance with this criterion, the application must include the calculation of the Net Present Value (NPV) of the candidate project along the whole duration of the technical lifetime of the project.

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

- 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
- 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)(d) of Annex IV to TEN-E Regulation: "*for hydrogen transmission, the project enables the transmission of hydrogen across the borders of the Member States concerned, or increases existing cross-border hydrogen transport capacity at a border between two Member States by at least 10 % compared to the situation prior to the commissioning of the project, and the project sufficiently demonstrates that it is an essential part of a planned cross-border hydrogen network and provides sufficient proof of existing plans and cooperation with neighbouring countries and network operators or, for projects decreasing energy isolation of non-interconnected systems in one or more Member States, the project aims to supply, directly or indirectly, at least two Member States*;", and in point (1)(e) of Annex IV to TEN-E Regulation: "*for hydrogen storage or hydrogen reception facilities referred to in point (3) of Annex II, the project aims to supply, directly or indirectly, at least two Member States;*"

According to the aforementioned options, the application shall clearly describe the Member States directly or indirectly involved, the increase of existing cross-border capacity achievable thanks to the project, the importance of the project as an essential part of a planned cross-border hydrogen network ad, if applicable, the Member States directly or indirectly supplied.

In particular, project promoters must ensure that their applications belong to the following hydrogen infrastructure categories as stated in point (3) of the Annex II to TEN-E Regulation:

- pipelines for the transport, mainly at high pressure, of hydrogen, including repurposed natural gas infrastructure, giving access to multiple network users on a transparent and non-discriminatory basis;
- storage facilities connected to the high-pressure hydrogen pipelines;
- reception, storage and regasification or decompression facilities for liquefied hydrogen or hydrogen embedded in other chemical substances with the objective of injecting the hydrogen, where applicable, into the grid;
- any equipment or installation essential for the hydrogen system to operate safely, securely and efficiently or to enable bi-directional capacity, including compressor stations; and
- any equipment or installation allowing for hydrogen or hydrogen-derived fuels use in the transport sector within the TEN-T core network identified in accordance with Chapter III of Regulation (EU) No 1315/2013 of the European Parliament and of the Council [2].

Any of the assets listed in points (a) to (d) may be newly constructed or repurposed from natural gas to hydrogen, or a combination of the two.

To verify the compliance with general and specific criteria, project promoters shall provide all the necessary underlying information and details.

1.3 Specific criteria for candidate hydrogen projects

Pursuant to Article 4(3)(d) of TEN-E Regulation, project promoters shall clearly show that the project contributes significantly to:

— sustainability, including by reducing greenhouse gas emissions, by enhancing the deployment of renewable or low carbon hydrogen, with an emphasis on hydrogen from renewable sources in particular in hard-to-abate end-use applications in the industry and transport sectors, , in which more energy efficient solutions are not feasible, and supporting variable renewable power generation by offering flexibility, storage solutions, or both,

and the project contributes significantly to at least one of the following specific criteria:

— market integration, including by connecting existing or emerging hydrogen networks of Member States, or otherwise contributing to the emergence of an Union-wide network for the transport and storage of hydrogen, and ensuring interoperability of connected systems;

— security of supply and flexibility, including through appropriate connections and facilitating secure and reliable system operation;

— competition, including by allowing access to multiple supply sources and network users on a transparent and non-discriminatory basis.

2 General approach

Similarly to the methodological approach exploited for candidate electricity transmission projects [3] and gas infrastructure projects [4], the assessment of candidate hydrogen projects shall take into consideration pertinent assumptions concerning future scenarios, the definition of the reference network used to assess the impact of the project; and the techniques to be used in calculating costs and benefits for the candidate hydrogen 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 hydrogen projects, such scenarios shall consider possible development for the electricity, gas and hydrogen systems, energy changes 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 ENTSOs methodologies.

2.1 Assumptions

A list of common parameters and assumptions used in the methodology is provided below. Assumptions should be aligned with the latest TYNDP scenarios[3]:

— 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 [5]. 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;

— Discount rate. As a general assumption, a 4% 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;

— Hydrogen production cost for each Member State and for each year within the study horizon;

— Hydrogen demand: for each Member State and for each year within the CBA horizon.

— Fuel demands for each Member State and for each year within the study horizon (see B3);

(3) Also taking into consideration additional provisions on network development plans stemming from future legislative initiatives.

- Fuel prices for each Member State and for each year within the study horizon (see B3); and
- Shadow 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 shadow cost of carbon values in Tables 5 and 6 of Commission Notice 2021/C 373/01 [6].

3 Project Cost-Benefit Analysis (CBA) for candidate PCIs

The assessment of candidate PCI hydrogen 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 hydrogen project must be calculated taking into consideration two configurations:

- the "with case", where the candidate project is realised, it is inserted in the system and, if profitable, realizes during its lifetime benefits that are larger than total costs; and
- the "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 hydrogen projects is equal to the difference in the "with" case (i.e. the hydrogen project is built) and the "without case" (i.e. the hydrogen 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 costs are calculated for one year of operation, although the technical lifetime of a candidate hydrogen project is higher. Consequently, to fully capture the net benefits created by the candidate project in time, this hydrogen CBA methodology require the use of the discounted cash-flow method: in particular, annual cash flows considering costs and benefits for the system in nominal terms will be discounted using the discount rate.

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, although such monetization may be feasible in future assessments. In such cases the quantitative/qualitative assessment 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; and
- **qualitative**: they are expressed in qualitative terms (for instance, "++", "+", "0", etc.).

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

Benefit [unit]	Specific criterion - Article TEN-E
B1 - Variation of GHG emissions [€/a]	Sustainability - Article 4(3), Annex IV (5)(a)
B2 - Integration of renewable and low-carbon hydrogen into the system [%]	Sustainability - Article 4(3), Annex IV (5)(a)
B3 – Substitution effect – Fuel switching [€/a]	Competition - Article 4(3)(d)(iii), Annex IV (5)(d)
B4 - Reduction of curtailed hydrogen demand [GWh/a]	Security of supply and flexibility - Article 4(3)(d)(ii) and Annex IV 5(c)
B5 – Improvement of market integration [qualitative]	Market integration: Article 4(3)(d)(i) and Annex IV 5(b)

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. Project promoters must ensure that the calculation are performed in a way to avoid double counting benefits.

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 hydrogen project.
- Relevance: Hydrogen projects are key infrastructural projects for integrating and enabling the consumption of renewable and low carbon hydrogen, for replacing the use of non-renewable hydrogen, natural gas and, under the proper socio-economic and technological conditions, enabling a cost effective solution to provide flexibility and, if need be, store energy (directly via compressed or liquefied hydrogen or indirectly via other mediums such as ammonia, methanol, solid-state systems, etc.). It will be measured as the contribution of a project to GHG emission reductions in various end-use applications in hard-to-abate sectors, such as industry or transport; flexibility and seasonal storage options for renewable electricity generation, as stated in the Annex IV (5)(a) to TEN-E Regulation.

Benefit Calculation:

- Modelling needs: Modelling needs shall be compatible with the methodology used by project promoters for calculating GHG emission savings (see 'Calculation process').
- Data needs: Data needs shall be compatible with the methodology used by project promoters for calculating GHG emission savings (see 'Calculation process').
- 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.

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(d) and Annex IV (5)(a) of TEN-E Regulation.

GHG emissions can be reduced by enhancing the deployment of renewable and low carbon hydrogen, with an emphasis on hydrogen from renewable sources.

In this respect, the Greenhouse Gas Protocol[4], the most widely used international accounting tool for quantifying and measuring GHG emissions, breaks down emissions in three categories:

- Scope 1 emissions, that are defined as those caused directly by an activity;
- Scope 2 emissions, which count indirect emissions resulting from energy consumption; and
- Scope 3 emissions, defined as all other indirect emissions caused along the whole value chain.

In the context of evaluating the variation of GHG emissions achievable thanks to candidate hydrogen projects, project promoters shall take into consideration scope 1 and scope 2 emissions.

Calculation process

1. Project promoters shall calculate GHG emissions savings achievable thanks to the candidate hydrogen project from increase of low-carbon and renewable hydrogen deployed in the system, with an emphasis on hydrogen from renewable sources, and pursuant to the provisions set in point (4)(a)(ii) of Annex II to TEN-E Regulation. In line with the Commission technical guidance on climate proofing of infrastructure [6], project promoters should follow, where applicable, the EIB Project Carbon Footprint Methodology [7] to quantify GHG emissions.
2. If project promoters decide to not use the EIB Project Carbon Footprint Methodology, they shall duly describe in their application their reasons. In alternative, GHG emission can be calculated using the following approaches:

(4) https://www.ghgprotocol.org/

a. methodology referred to in Article 28(5) of Directive (EU) 2018/2001 [8];

b. the standard ISO 14067 “Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification”[5];

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”[6]; and

d. Innovation Fund methodology for GHG emission avoidance calculation [9].

3. The life-cycle greenhouse gas emissions must include all indirect emissions. Any of aforementioned alternative approaches allows to calculate the GHG emission savings achievable by comparing two situations:

— GHG emissions in the “with case”, $emission|_{with}$, and

— GHG emissions in the “without case”, $emission|_{without}$

4. The variation of GHG emissions achievable thanks to the candidate project converted in monetary terms by using the social cost of carbon - $ShCost_{CO_2}$:

$$B_1 = \sum [emission|_{without} - emission|_{with}] \cdot ShCost_{CO_2}$$

5. 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.

Main elements to consider:

— Carbon footprint of the renewable and\or low-carbon hydrogen integrated in the system thanks to the candidate hydrogen project

— Operational data of the candidate hydrogen project: efficiency, technical constraints, etc.

— Specific information required as input information for the alternative approaches described in point 1 above.

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

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

3.1.2 B2 – Integration of renewable and low-carbon hydrogen into the system

Benefit Definition:

- Definition: Integration of renewable and low-carbon hydrogen achievable thanks to the candidate hydrogen project.
- Relevance: The integration of low-carbon and particularly renewable hydrogen in the system, achievable thanks to the candidate hydrogen projects, can support the decarbonisation of the EU energy system. This is particularly relevant for hard-to-decarbonise sectors, such as industry and transport.

Benefit Calculation:

- Modelling needs: Accurate assessment of the amount of renewable and low-carbon hydrogen integrated in the system would require a detailed modelling exercise simulating a larger portion of the electricity, gas, hydrogen, industrial and transport systems 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, industrial and transport systems (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 amount of hydrogen produced from fossil origin which is replaced by renewable or low-carbon hydrogen. Then, the benefit is finally expressed in relative and, therefore, qualitative terms.
- The analysis should provide a breakdown in low-carbon and renewable hydrogen integrated in the system thanks to candidate hydrogen projects.

Link with specific criteria TEN-E Regulation

- Sustainability: Article 4(3)(d) and Annex IV (5)(a) of the TEN-E Regulation

A candidate hydrogen project can bring benefits stemming from the substitution of fuels with low-carbon and particularly alternatives. 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. Low-carbon and particularly renewable hydrogen produced as fuel substitute can be either consumed locally, stored and shipped from production to the consumption point in different forms or, when dedicated transportation infrastructure will be available, injected into the hydrogen grid.

Calculation process

1. By assuming that the hydrogen demand does not change between the "with" and the "without" case, (i.e. hydrogen demand is a scenario variable), the amount of replaced hydrogen is equal to the increased amount of low-carbon and particularly renewable hydrogen $\Delta H2_{RES} + \Delta H2_{lowcarbon}$.
2. The project promoter evaluates the increased amount of renewable hydrogen integrated into the system thanks to the candidate hydrogen project following one of the two approaches below:
    a. In case a detailed modelling exercise is carried out, the project promoter must evaluate the operation of the modelled electricity, gas and hydrogen systems 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 as output the variation in renewable hydrogen production achievable thanks to the project as well as, if any, of the related production costs.
    b. In case of simplified assumptions, the project promoter shall calculate the input data required to calculate the indicator using assumptions based on its knowledge of the operational capability of

the project as well as of general assumptions about the relevant portion of the EU electricity, gas and hydrogen systems concerned by the candidate hydrogen project. All the assumptions must be duly justified and referenced.

3. The variation of the share of renewable and low-carbon hydrogen integrated into the system is expressed as described below:

$$share_{H2,renewable} = \frac{\mathrm{QH2}_{renewable}}{\mathrm{QH2}}$$

$$share_{H2,low-carbon} = \frac{\mathrm{QH2}_{low-carbon}}{\mathrm{QH2}}$$

$$B_{2,H2,renewable} = share_{H2,renewable}|_{with} - share_{H2,renewable}|_{without}$$

$$B_{2,H2,low-carbon} = share_{H2,low-carbon}|_{with} - share_{H2,low-carbon}|_{without}$$

$$B_2 = B_{2,H2,renewable} + B_{2,H2,low-carbon}$$

Project promoters shall provide the values of the benefit B_2 and the sub-indicators $B_{2,H2,renewable}$ and $B_{2,H2,low-carbon}$, as well as all the information needed to check and replicate their calculation.

<u>Main elements to consider</u>

— Increased integration of renewable and low-carbon hydrogen in the system:

- 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, gas and hydrogen EU systems. 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, gas and hydrogen systems achieved thanks to the candidate hydrogen project.

3.1.3 B3 – Substitution effect – Fuel switching

Benefit Definition:

- Definition: Economic impact of substitution effect (fuel switching) enabled by the candidate hydrogen project.
- Relevance: The integration of low-carbon and particularly renewable hydrogen in the system, achievable thanks to the candidate hydrogen projects, can support EU supply diversification by facilitating the access to indigenous sources of hydrogen supply.

Benefit Calculation:

- Modelling needs: Accurate assessment of the amount of renewable and low-carbon hydrogen integrated in the system would require a detailed modelling exercise simulating a larger portion of the electricity, gas, oil and hydrogen systems 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, oil and hydrogen systems (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: The benefit is expressed in quantitative terms and is monetised as the potential cost saving resulting from the replacement of fuels of fossil origin with low carbon and particularly renewable hydrogen and/or hydrogen based fuels.
- The analysis should provide a breakdown in low-carbon and renewable hydrogen integrated in the system thanks to candidate hydrogen projects.

Link with specific criteria TEN-E Regulation

- Competition: Article 4(3)(d)(iii) and Annex IV (5)(d) to TEN-E Regulation

A candidate hydrogen project can bring benefits stemming from the substitution of fuels with alternatives produced starting from renewable and/or low carbon hydrogen, especially when produced in the EU. While substituting fuels enabled by hydrogen projects might not currently be cost-competitive compared to fossil-fuel alternatives, learning curve effects, economy of scale and massive RES installed capacity might gradually make renewable and/or low carbon based alternatives cheaper. Renewable and/or low carbon fuels produced as fuel substitute can be either consumed locally, stored and shipped from production to the consumption point in different forms or, when dedicated transportation 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 [4].

Calculation process

This benefit is calculated as replacement of fuels with hydrogen or hydrogen derived fuels:

$$B_3 = \sum_{i=1}^{n} \left(Q_{fossil\ fuel\ i}\big|_{without} * P_{fossil\ fuel\ i} - Q_{from\ H2\ fuel\ i}\big|_{with} * P_{from\ H2\ fuel\ i} \right) +$$

$$-\Delta QH2_{RENEW} * P_{RENEW\ H2} - \Delta QH2_{LC} * P_{LC\ H2}$$

where:

- Q is the quantity of $fuel_i$ (fossil origin) expressed in energy terms (such as GWh) used in the "without" case and the quantity of fuel (H2 based) in the "with" case. All quantities need to be expressed in the same units.
- $fuel_{i=1\ to\ n}$ is any fuel replaced by hydrogen or hydrogen-based corresponding alternative driven by the new project;
- P_{fuel} is the price of the specific replaced fuel (in €/GWh);
- $\Delta QH2_{RENEW}/\Delta QH2_{LC}$ are the amount of low-carbon and renewable hydrogen which are replacing the use of fossil-based fuels in "with" case (in GWh); and
- $P_{RENEW\ H2}/P_{LC\ H2}$ are the prices of low-carbon and renewable hydrogen which are replacing the use of fossil-based fuels in "with" case (in €/GWh)

Values should always be showed both in quantities of switched fuel and monetised terms.

3.1.4 B4 – 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 hydrogen 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 transportation capacity in the hydrogen network to allow hydrogen to flow to local consumption nodes. In this respect, the integration of hydrogen infrastructure 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 hydrogen project, potentially up to the European level. Simplified approaches might be allowed considering the scale of the candidate hydrogen project and the related impact on cross-border hydrogen flows and/or the more efficient electrolyser operations.
- 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 hydrogen 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: The benefit is expressed in quantitative terms as avoided hydrogen demand curtailment (expressed in GWh/a) achievable thanks to the candidate hydrogen project.

Link with specific criteria TEN-E Regulation:

- Security of supply and flexibility - Article 4(3)(d)(ii) and Annex IV 5(c) of the TEN-E Regulation

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 hydrogen project may play a role in increasing security of supply by mitigating such occurrences thanks to their production.

Calculation process

The benefit B_4, conceptually similar to the benefit "Avoided curtailment demand" considered in the ENTSOG methodology [4], can be calculated as follows:

1. Project promoters evaluate the operation of the modelled the electricity, gas and hydrogen systems 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 benefit related to the reduction of hydrogen demand curtailment in each Member State achievable thanks to the candidate hydrogen project can be calculated by project promoters as follows.

$$B_4 = \sum_z (Demand\_curtailment_z|_{without} - Demand\_curtailment_z|_{with})$$

Main elements to consider

- Avoided hydrogen demand curtailment:
  - Running a detailed EU hydrogen, gas and electricity models might correspond to data requirement and data granularity comparable to the ones concerning ENTSOs TYNDPs.

- No extensive data requirements if project promoters use assumptions on the operation of the electricity, gas and hydrogen systems achieved thanks to the candidate hydrogen project.

3.1.5 B5 – Improvement of market integration

Benefit Definition:

- Definition: Improvements in connecting existing or emerging hydrogen networks of Member States achievable thanks to the candidate hydrogen project.
- Relevance: The completion of the EU energy market requires the removal of technical barriers preventing the efficient use of energy assets across the EU. This is particularly relevant for the upcoming EU hydrogen system, which, in its inception, might strongly rely on bottom-up initiatives (such as "hydrogen valleys" or "hydrogen islands"). In this respect, the candidate hydrogen project can support the integration of the EU hydrogen market at the level of interconnections among EU Member States.

Benefit Calculation:

- Modelling needs: An accurate assessment of the improvement in market integration in terms of price convergence would require a detailed modelling exercise simulating the European hydrogen market. The use of a simplified approach would not require any specific modelling capability.
- Data needs: An accurate assessment of the improvement in market integration in terms of price convergence would require extensive data requirements (price and quantities for hydrogen demand and supply, transportation and storage capacities, etc.) to allow the simulation of the (future) European hydrogen system. The use of a simplified approach would not require specific data requirements besides the number of hydrogen subsystems connected thanks to the candidate hydrogen project.
- How the benefit is expressed: The benefit is expressed in qualitative terms (see 'Calculation process' section for further details).

Link with specific criteria TEN-E Regulation:

- Market integration: Article 4(3)(d)(i) of TEN-E Regulation

The development of an efficient EU hydrogen market is a key element of EU energy policy towards the 2050 objective of carbon neutrality. The capability of enabling the decarbonisation of hard-to-abate sectors as well as its importance in several industrial processes picked the interest of many countries which recently released ambitious national hydrogen strategies. In this framework, one the leading development models imagined in the EU and worldwide is represented by the so-called "hydrogen valleys" or "hydrogen islands", with several uncorrelated bottom-up initiatives supporting the initial development of the hydrogen supply chain[7].

In this respect, a candidate hydrogen project can (also) support the development of an EU-wide hydrogen system by being part of the interconnecting infrastructure linking, across borders, these separate initiatives. By fostering the level of market integration of the EU hydrogen system in its incipience, a candidate hydrogen project can reinforce collaboration between EU Member States, and neighbouring countries, towards the achievement of their decarbonisation targets.

The improvement in market integration as a result of the realization of candidate hydrogen projects could be measured in terms of price convergence once the internal EU hydrogen market becomes mature enough. A difference in marginal price between two connected countries can be the result of a transmission tariff, an infrastructure limitation, or both. In this respect, local hydrogen marginal prices would be expected to converge as a result of the availability of increased cross-border hydrogen interconnection capacity. This approach is conceptually similar to the indicator "Weighted Marginal Price Deviation" described ENTSOG TYNPD 2020 CBA methodology [10].

Calculation process

The benefit B_5 can be calculated using one of the following two approaches:

a. *Simplified approach*:

(7) https://h2v.eu/

1. Project promoters evaluate the number of countries connected by hydrogen infrastructure, $N_{countries}$, in both “with” and “without” cases.
2. The improvement of market integration achievable thanks to the candidate hydrogen project, can be calculated by project promoters as follows:

$$B_5 = (N_{countries}|_{with} - N_{countries}|_{without})$$

b. *Detailed approach* (prerequisite: establishment of a mature EU hydrogen market):

1. Project promoters run simulations of the operation of the EU hydrogen market in both “with” and “without” cases.
2. As output of the simulation, project promoters calculate the Weighted Marginal Price Deviation (WMPD) as follows:

$$WMPD = \sum_{t}^{N} \sum_{z=1}^{Z} \left(\left| MP_z(\mathrm{t}) - REF\,EX(\mathrm{t}) \right| * \frac{D_i(\mathrm{t})}{D_{EU}(\mathrm{t})} \right)$$

where:

N is the number of analysed points in time[8];

Z is the number of countries modelled in the simulation;

$MP_z(t)$ is the hydrogen marginal price in the *z*-th country in the specific point in time;

$REF\ EX(t)$ is the demand-weighted average of EU marginal Prices in the specific point in time;

$D_z(t)$ is the hydrogen demand in the *z*-th country in the specific point in time;;

$D_{EU}(t)$ is a total hydrogen demand in Europe in the specific point in time

3. Project promoters calculate the benefit B_5 as follows:

$$B_5 = \frac{(WMPD|_{without} - WMPD|_{with})}{WMPD|_{without}}$$

B_5 can assume any value between 0 and 1: low values of B_5 would result in higher levels of price convergence and, consequently, in improved levels of market integration.

(8) Points in time are representations of operating points of the system. They could represent the totality of occurrences simulated in the modelling framework or a significant and representative subset of it.

3.2 Costs

The project promoter shall provide CAPEX and OPEX for each year analysed in the study horizon, assumptions on authorisation, construction time and decommissioning (if relevant). 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).

3.3 Project value – NPV and B/C – calculation

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

The profitability of a project is assessed by calculating the Net Present Value (NPV) as the difference between the present value of all monetized benefits and the present value of all costs, discounted using the social discount rate as discount factor

$$NPV = \sum_{t=0}^{t=Lifetime} \frac{\sum_j B_{j,t} - \sum_k C_{k,t}}{(1+r)^t}$$

If the NPV is positive, then the project is deemed profitable from the socio-economic perspective as its benefits outweigh its costs, in line with the provisions set in Article 4(1)(b) of TEN-E Regulation.

3.4 Transparency and confidentiality

In submitting their CBA, project promoters for candidate hydrogen 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.

References

[1] Regulation (EU) 2022/869 of the European Parliament and of the Council of 30 May 2022 on guidelines for trans-European energy infrastructure, amending Regulations (EC) No 715/2009, (EU) 2019/942 and (EU) 2019/943 and Directives 2009/73/EC and (EU) 2019/944, and repealing Regulation (EU) No 347/2013.

[2] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network, and repealing Decision No 661/2010/EU.

[3] 3rd ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects – Draft version – 28 January 2020.

[4] 2nd ENTSOG Methodology for Cost-Benefit Analysis of Gas Infrastructure Projects – October 2018.

[5] Commission Delegated Regulation (EU) No 480/2014 of 3 March 2014 supplementing Regulation (EU) No 1303/2013 of the European Parliament and of the Council laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund.

[6] Commission Notice - Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (2021/C 373/01).

[7] European Investment Bank. Methodologies for the assessment of project greenhouse gas emissions and emission variations. Version 11.2. February 2022.

[8] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast).

[9] European Commission. Methodology for GHG emission Avoidance Calculation. Innovation Fund Small Scale Projects. Version 2.0. February 2021.

[10] ENTSOG. Ten Year Network Development Plan 2020. Annex D – Methodology. July 2021.

List of abbreviations and definitions

CBA	Cost-benefit analysis
EC	European Commission
EIB	European Investment Bank
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
GHG	Greenhouse gasses
JRC	Joint Research Centre
NPV	Net Present Value
WMPD	Weighted Marginal Price Deviation

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