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Contact information
Name: Jean-Francois VUILLAUME
Address: European Commission – JRC, P.O. Box 2, 1755 ZG, Petten, the Netherlands
Email: Jean-Francois.Vuillaume@ec.europa.eu
Tel.: +31224565160

Name: Luca GANDOSSI
Address: European Commission – JRC, P.O. Box 2, 1755 ZG, Petten, the Netherlands
Email: Luca.GANDOSSI@ec.europa.eu
Tel.: +31224565250

Name: Barbara DIZ
Address: European Commission – DG ENERGY, 1040 Brussels, Belgium
Email: barbara.diz@ec.europa.eu
Tel.: +3222987869

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https://joint-research-centre.ec.europa.eu

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Abstract

This report presents the developed Cost-Benefit Analysis (CBA) methodology for candidate CO_2 transport and storage 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 socio-economically desirable, in other words if its prospective or potential system benefits (referred in the following as "benefits") outweigh its costs or at providing a base for comparing different actions/decisions/investments. A CBA methodology must describe the common principles as well as clarifying the different steps a user must carry out to perform the exercise.

This CBA methodology for candidate CO_2 transport and storage projects (in the following, "cross-border CO_2 networks CBA methodology") has been developed by the JRC, the European Commission (the "Commission") science and knowledge service, in compliance with the requirements set in Article 11(8) of 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. As regards the priority thematic area of cross-border CO_2 networks, the revised TEN-E has broaden its scope including elements related to carbon dioxide transport and storage.

The cross-border CO_2 networks CBA methodology has been developed to ensure a harmonised system-wide CBA 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 cross-border CO_2 networks 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. 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 check3.

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 towards 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 project 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.

A project of common interest needs to meet general criteria and is assessed against specific criteria as set out in the TEN-E Regulation.

[1] At the time of writing, the following methodologies developed by the ENTSOs are under public consultation:
- 4th ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects: draft version 4.0 for public consultation (20 December 2022); and
- ENTSOG Single-Sector Cost-Benefit Analysis (CBA) Methodology – Preliminary draft (28 February 2023).

1.2 General criteria for candidate CO_2 transport and storage projects

A CO_2 transport and storage PCI candidate needs to demonstrate, in line with Art. 4(1) of the TEN-E Regulation, that:

- the project is necessary for the priority thematic area "cross-border carbon dioxide network" set out in point 13 in Annex I 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;
- a candidate PCI 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 States, , and has a significant cross-border impact as set out in point (1)(i) of Annex IV to TEN-E Regulation.

A CO_2 transport and storage PMI candidate needs to demonstrate, as described in Article 4(2) of TEN-E Regulation, that:

- the project contributes significantly to the objectives referred to in Article 1(1), and those of the third country,;
- the potential overall benefits of the project at Union level, assessed in accordance with the relevant specific criteria, outweigh its costs, including in the longer term;
- the project is located on the territory of at least one Member State and on the territory of at least one third country and has a significant cross-border impact in line with point (2)(c) of Annex IV to TEN-E Regulation.;
- there is a high level of convergence of the policy framework of the third country or countries involved and legal enforcement mechanisms to support the policy objectives of the Union are demonstrated, ensuring a well-functioning internal energy market, security of supply based on solidarity and cooperation, and an energy system moving towards the objective of climate neutrality in line with the Paris Agreement;
- the third country or countries involved support the priority status of the project, as set out in Article 7 of the TEN-E Regulation, and commit to complying with a similar timeline for accelerated implementation and other policy and regulatory support measures as applies to projects of common interest in the Union.

  In any case a PMI candidate that include carbon dioxide storage elements shall be necessary to allow the cross-border transport and storage of carbon dioxide, and the third country where the project is located shall have an adequate legal framework based on demonstrated effective enforcement mechanisms to ensure that standards and safeguards apply to the project, preventing any carbon dioxide leaks, and concerning climate, human health and ecosystems as regards the safety and effectiveness of the permanent storage of carbon-dioxide, which are at least at the same level as those provided by Union law.

In general, a candidate project can consider either CO_2 transport elements, or CO_2 transport and storage components. Standalone CO_2 storage projects are not eligible as PCI/PMI.

In addition, proposed CO_2 transport and storage projects shall be presented as part of a plan, developed by at least two Member States, for the development of cross-border carbon dioxide transport and storage infrastructure (point 6 of Annex III(2) of the TEN-E Regulation).

All candidate projects shall therefore be necessary for the cross-border carbon dioxide networks priority thematic area in accordance with Annex I(13), it must present net positive benefits in accordance with this methodology, and it must demonstrate a significant cross-border impact according to the relevant provisions of the TEN-E Regulation.

In its assessment of applications received, the Regional Group shall check the compliance with respect to the rules in terms of energy infrastructure categories set for CO_2 transport and storage facilities in Annex II(5) to TEN-E Regulation. In particular, project promoters must ensure that their applications are compliant with the following rules:

i. dedicated pipelines, other than upstream pipeline network, used to transport CO_2 from more than one source, for the purpose of permanent geological storage of CO_2 pursuant to Directive 2009/31/EC;

ii. fixed facilities for liquefaction, buffer storage and converters of CO_2 in view of its further transportation through pipelines and in dedicated modes of transport such as ship, barge, truck, and train;

iii. without prejudice to any prohibition of geological storage of CO_2 in a Member States, surface and injection facilities associated with infrastructure within a geological formation that is used, in accordance with Directive 2009/31/EC, for the permanent geological storage of CO_2, where they do not involve the use of CO_2 for the enhanced recovery of hydrocarbons and are necessary to allow the cross-border transport and storage of CO_2;

iv. any equipment or installation essential for the system in question to operate properly, securely and efficiently, including protection, monitoring and control systems.

As established in the TEN-E Regulation, the infrastructure category for cross-border CO_2 networks includes only a specific part of the CCS value chain: transport and storage of carbon dioxide and not capture elements. In practice, this means that any infrastructure item related to CO_2 capture facilities (e.g. in the same site) or with an upstream nature should not be part of a candidate PCI/PMI.

In particular, upstream pipelines are specifically excluded from the eligible infrastructure elements. In the context of CO_2 networks infrastructure, "upstream" means those pipelines that directly connect an emitting source, i.e. a producer of CO_2 emissions, to the main transporting pipeline that is potentially shared across multiple sources and/or recipients. In other words, pipelines that connect a single source to a broader network should be considered to be upstream and excluded from the PCI/PMI application. A possible softening of this criterion might be considered in the case of pipelines and associated equipment in case it is duly justified that those would enable future connections, in line with the spirit of TEN-E Regulation.

1.3 Specific criteria for candidate CO_2 transport and storage projects

Pursuant article 4(3)(c) of the TEN-E Regulation, the project promoter shall clearly show how the candidate project contributes significantly to sustainability through the reduction of CO_2 emissions in the connected industrial installations and contributes to all of the following specific criteria:

(i) avoiding carbon dioxide emissions while maintaining security of supply;

(ii) increasing the resilience and security of transport and storage of CO_2;

(iii) the efficient use of resources, by enabling the connection of multiple CO_2sources and storage sites via common infrastructure and minimising environmental burden and risks.

These criteria are included as benefits in this cross-border CO_2 networks CBA methodology; further guidance on their consideration is provided later in section 3.

2 General approach

In line with the provisions set in Article 11 of TEN-E Regulation and similarly to the methodological approach used for candidate electricity transmission projects [2] and gas infrastructure projects [3], the assessment of candidate CO_2 transport and storage 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 CO_2 transport and storage project.

This CBA methodology addresses only those TEN-E Regulation provisions relating to the cost-benefit analysis of cross-border carbon dioxide networks candidate PCIs and PMIs. The CBA methodology builds on previous guidelines, considering the new requirements laid down in Regulation (EU) 2022/869 as well as best practices and lessons learnt from previous experiences. Project promoters should clearly and convincingly build a case for their project following the TEN-E Regulation requirements and the indications in this CBA methodology.

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 cross-border CO_2 networks CBA methodology to be carried out by project promoters are described below:

- clear identification of input information for the assessment of the relevant candidate 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 calculations carried-out for the evaluation of benefits (see section 3.1), within the study horizon;
- 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 Assumptions

A list of common parameters and assumptions ensures consistency across all candidate cross-border CO_2 networks projects. Some information are 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 CO_2 networks 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 cross-border CO_2 networks projects is provided:

- Duration of the study horizon. As a general assumption, 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) 480/2014 [4]. This means that the duration of the study horizon of the whole project shall be capped at a maximum economic life of 25 years. The duration of the study horizon shall not be in any case higher than the study horizon of the harmonised energy system-wide CBA 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 TEN energy infrastructure categories. The discount rate should in any case be compatible with the same value defined in the harmonized energy system-wide cost-benefit analysis methodology for projects on the Union list failing under the energy infrastructure categories set out in point (1)a, (b), (d) and (f) and point (3) of the under Annex II to TEN-E Regulation.

- 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 the most updated ones[2].
- Emission and, when possible, monetisation factors for indirect non-CO_2 emissions, for each Member State and for each year within the CBA horizon. Examples of reference monetisation values for select pollutants as found in [6] are reported in Table 1.
- Classification of synthetic fuels and prices, for each Member State and for each year within the CBA horizon. This assumption should be consistent with the most updated policy scenarios from the Commission and/or TYNDP scenarios.

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: [6]

The parameters listed below can be subjected to sensitivity analyses carried out by relevant project promoters for candidate cross-border CO_2 networks projects. The list is not exhaustive and shall be complemented with relevant information provided in the templates for candidate submission:

- fuel and CO_2 prices;
- 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[3]:

- projects “Under consideration”;
- projects “Planned but not yet in permitting”;
- projects “Permitting”, and;
- projects “Under construction”.

[2] In particular Tables 5 and 6 of Commission Notice 2021/C 373/01 [4], 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].

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

3 CBA assessment for candidate projects

The assessment of candidate CO_2 transport and storage projects shall be carried out taking the societal perspective, in line with the provisions set in Article 4(1) of TEN-E Regulation, to ensure that the potential overall project benefits, assessed in accordance with the relevant specific criteria, outweigh its costs. Performances of a candidate CO_2 transport and storage project must be assessed taking into consideration two configurations:

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

The calculation of the difference of indicators between the "with" and the "without" cases allow to calculate the benefits brought by the project. For instance, the amount of CO_2 transported and stored by a candidate project is equal to the difference in production in the "with" case (i.e. the CO_2 pipeline is built) and the "without case" (i.e. the CO_2 pipeline is not built).

In some cases, the calculation of benefits does not need a complex modelling exercise. In other cases, simplifications might be introduced to reduce the calculation complexity.

Monetised benefits and costs are calculated for each year of operation of the horizon study, although the technical lifetime of equipment and installations constituting a candidate cross-border CO_2 networks project could be longer. Consequently, to compare the total benefits generated by the candidate project during its lifetime with the related total costs, this CBA methodology requires the use of the discounted cash-flow method for the calculation of the ENPV of the candidate project: in particular, annual cash flows considering costs and benefits in nominal terms shall be discounted using the discount rate as defined in section 2.1of this CBA methodology.

3.1 Benefits

While priority should be given to monetized indicators which allow the compliance with the provisions set in Article 4(1)(b) of TEN-E Regulation and the calculation of the ENPV of candidate project, it is observed that not all indicators can be monetized; consequently, the following definitions for indicators are introduced:

- **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.).

Benefits stemming from candidate cross-border CO_2 networks projects shall be calculated by project promoters with annual granularity within the study horizon, taking into consideration the assumptions and the sensitivities mentioned in section 2.1.

The table below shows the link between each benefit and the related Article under the TEN-E Regulation

Table 2. Summary of benefits considered in the cross-border CO_2 networks CBA methodology

Benefit	Specific criterion – Article TEN-E
B1 – Variation of GHG emissions	Sustainability –Article 4(3)(c)(i)
B2 – Increase of the resilience and the security of the infrastructure	Resilience and security of transport and storage - Article 4(3)(c)(ii)
B3 – Multiple CO_2 sources and storage sites via common infrastructure	Efficient use of resources - Article 4(3)(c)(iii)
B4 – Reduction of the environmental burden and risks	Mitigation of environmental burden and risks – Article 4(3)(c)(iii)

Source: Own elaboration.

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

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

All 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.

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 in the case of monetised values).

3.1.1 B1 – Variation of GHG emissions

This indicator is the monetisation of the net avoidance of CO_2 emissions. It does not only comprise CO_2 but in general the CO_2 equivalent to the reduction of all the GHG[4] emission that are obtained thanks to the realisation of the project. Hence, this type of benefit pertains to the sustainability domain as it directly focuses on the climate impacts of the infrastructure. It represents the net GHG reduction (deducting GHG emissions that are caused by the project itself).

This indicator should be obtained considering not only the calculation of the abated GHG emissions but also the justification of the origin of the CO_2 from industrial installations (TEN-E, Article 4(3)(c)) and in absence of alternative technological solutions (TEN-E, Annex IV(8)(a)).

Hence, the generation of CO_2 should be unavoidable, meaning that it should be duly justified by its origin (e.g. hard-to-abate heavy industrial emitters, such as cement, lime, chemistry, steel factory etc.) and by the lack of technical alternatives, despite optimisation (e.g. through energy efficiency or electrification integrating renewables). In any case, the CO_2 generated by energy production sources using fossil fuels should be excluded.

Quantitatively, the benefit is calculated as the variation between GHG emissions under the project scenario that implies the capture, transport and injection, and the alternative status quo, i.e. the reference scenario where the emissions are released directly in the atmosphere.

The net avoided GHG emissions aggregated over the study horizon (meaning the sum of the GHG emissions saved every year ("y") during 25 years since the commission date of the project, deducting the GHG emissions generated during both the construction and operation *phases ("n")* of the project) can be calculated according to the following equation [7] [8]:

$$\Delta GHG_{\_net} = \sum_{y=1}^{n} Ref_{\_abatement,y} - \sum_{y=1}^{n} \left(Proj_{\_construction,y} + Proj_{\_pipeline,y} + Proj_{\_other\_means\_transport,y} + Proj_{\_injection,y} + Proj_{\_leakage,y} \right)$$

Where:

- $\Delta GHG_{\_net}$ = total net GHG emissions avoided by the project, in tonnes of CO_2e;
- $Proj_{\_abatement,\ y}$ = absolute GHG emissions avoided by the project, in tonnes of CO_2e; determined in accordance with Commission Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012;

[4] The greenhouse gases that must be taken into account in emissions calculations shall be at least those listed in the EU Emissions Trading System (EU ETS) Directive 2003/87/EC, Annex II: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6). Emissions factors for methane and nitrous oxide, when given, may be converted into CO_2 equivalents ("CO_2e").

- $Proj_{construction,y}$ = GHG emissions generated during the construction of the project, including all the activities necessary for the project to be implemented, in year y, in tonnes CO_2e;
- $Proj_{pipeline,y}$ = GHG emissions from the operation of the transport of CO_2 by pipelines, in year y, in tonnes CO_2e.
- $Proj_{other\_means\_transport,y}$ = GHG emissions due to the transportation of CO_2 in tank trucks, rail or other road modals and in sea tankers or other maritime modals, in year y, in tonnes CO_2e. To be calculated based on distance travelled, type of modal and load, according to the parameters and equations provided in the most updated Methodology for GHG Emission Avoidance Calculation under the Innovation Fund[5];
- $Proj_{terminal,y}$ = GHG emissions from the operation of CO_2 fixed facilities for liquefaction and buffer storage, in year y, in tonnes CO_2e;
- $Proj_{injection,y}$ = GHG emissions from the injection in a storage site permitted under Directive 2009/31/EC, in year y, in tonnes CO_2e. This includes emissions from fuel use by associated booster stations and other combustion activities including on-site power plants; venting from injection. It shall be calculated according to Regulation (EU) 2018/2066, Annex IV, Section 23.
- $Proj_{leakage,y}$ = estimation of the expected GHG leakages from the operation of any of the infrastructure items included in the project: transport modes (pipeline, shipping, road, railway), injection activities and storage, and fixed facilities for liquefaction and buffer storage, in tonnes CO_2e.

The corresponding year specific value can be calculated from the previous formula, as:

GHG emission reduction in year y= Reference scenario emissions in y – Project scenario emissions in y

The economic present value of the indicator B1 is calculated within the study horizon since the beginning of the construction phase, using the discounted cash- flow approach. Hence, an annual value of GHG emission avoided is multiplied by the year specific the Shadow Cost of Carbon ($ShCostCO_2$). The value to be applied as monetary amount representing the benefit of avoided GHG emissions:

$$B1_y = \Delta GHG_y \times ShCostCO_2$$

3.1.2 B2 – Increase of resilience and security of the infrastructure

A critical infrastructure is defined as an asset or a whole system whose continuous operation is deemed essential for the security of public society. Any damage, destruction or disruption occurring to EU critical infrastructure by extreme climate events, natural disasters, terrorism, criminal activity or malicious behaviour, may have a significant negative impact for the security of the EU and the well-being of its citizens. Challenges for critical infrastructures are also arising from the increased digitalisation of systems and networks. This trend makes such systems smarter and more efficient but it introduces significant risks as an increased exposure to cyberattacks and cybersecurity incidents potentially jeopardises the security of the critical infrastructure.

In this respect, a cross-border CO_2 network has the attributes to qualify as a critical infrastructure: it is a key system to allow the EU to reach its 2050 climate neutrality objective by transporting and storing in permanent geological storage significant amounts of CO_2 emissions that cannot be reduced with other reasonable alternatives. At the same time, the revised TEN-E Regulation introduces the possibility that the carbon dioxide transported by a cross-border CO_2 network is utilised for producing synthetic gaseous fuels.

A full quantitative assessment of the impact that a candidate CO_2 transport and storage project has on resilience and security of the cross-border CO_2 network would need an extensive modelling exercise, able to represent the ability of a candidate project to withstand and recover from extreme climate events, natural disasters, terrorism, criminal activity or malicious behaviour, cyberattacks and cybersecurity incidents.

[5] Commission Delegated Regulation (EU) 2019/856 of 26 February 2019 supplementing Directive 2003/87/EC of the European Parliament and of the Council with regard to the operation of the Innovation Fund

Taking this into consideration, project promoters shall demonstrate in a qualitative way that their candidate projects are contributing at increasing the resilience and the security of the cross-border CO_2 network. The impact of the candidate project shall be evaluated with the following metrics while considering:

- if the candidate project does not change (or changes marginally) the standard level of resilience and security of the cross-border CO_2 network, it will receive the score "0";
- if the candidate project brings to moderate improvements on the standard market procedures that ensure the level of resilience and security of the cross-border CO_2 network, it will receive the score "+"; and
- if the candidate project maximize the level of resilience and security (increased efficiency and top-technological solutions) of the cross-border CO_2 network by bringing new technical improvements or best practices measures when compared to other projects in the market it will receive the score "++".

Project promoters shall duly justify, provide references and describe in their applications how significant and impactful are their candidate projects in increasing the level of resilience and security. Each application should also include an explanation of the project's capability to deliver successfully and in a timely manner.

3.1.3 B3 – Multiple CO_2 sources and storage sites via common infrastructure

This criterion refers to the future potential to connect multiple CO_2 sources and storage sites via the proposed cross-European network infrastructure. It relies in the concept of optimization of the infrastructure to be deployed and has both a qualitative and quantitative dimension.

The project promoter should provide qualitative arguments concerning the project's capability to unlock demand for CCS, i.e. multiple potential routes to storage for emission intensive industries and Member States which might not have (permissible) domestic storage capacities. The project promoter could delineate future scenarios in which additional demand for CO_2 transport infrastructure from existing or anticipated developments in adjacent industries or sectors has grown and outline conditions for these industries or sectors to use the relevant transport infrastructure.

The project promoter should be able to demonstrate the expansion potential of the project and how it is capable of contributing to the generation of a wider network for CO_2 in the region. The demonstration of this benefit can focus on three dimensions which can potentially contribute to the future potential of multiple connections, when other alternatives such optimization (energy efficiency, electrification based on energy from renewable sources) have been exhausted.

- Future connections potential: the project promoter can provide evidence of existing or planned additional CO_2 sources (emitters) within a reasonable distance radius which are not part of the project. This can be done by demonstrating that the proposed CO_2 transport infrastructure is located near potential high emitters (e.g. existing or planned emission-intensive industrial applications, or within an existing or planned industrial cluster).
- Future transport capacity potential: the project promoter can provide evidence that there are prospects to use the capacity of the proposed CO_2 transport infrastructure (pipelines, buffer storage, etc.) from additional sources. The evidence should include a calculation concerning the possible price-savings for future CCS projects due to the over-sizing of the infrastructure project at hand.
- Future storage potential: the project promoter can provide evidence of network expansion potential by demonstrating that there is planned additional CO_2 storage capacity in the vicinity of the originally envisaged storage site using figures, maps or reports regarding other possible CO_2 sinks in the area. Estimates regarding the potential additional storage capacity and the distance to the original storage site should be provided.

In summary, project promoters shall at a minimum show that their project is not only a point-to-point project and how it will contribute to enabling a network from a cross-European perspective. They shall provide a qualitative (geographical) study/assessment concerning the potential for future connections (e.g. list of emitters/storage opportunities in the area etc.) and, if possible, a business case-type argument. Any initiatives or existing and anticipated industrial activity in the vicinity of the project should be noted included in this assessment.

Duplication of infrastructure between different candidates project shall be avoided, meaning that the same infrastructure items (e.g. a subproject comprising fixed facilities for CO_2 liquefaction and buffer storage in a port terminal) shall be included in the application of different candidates.

The impact of the candidate project shall be evaluated with the following metrics:

- if the candidate project does not duly justify its potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure, it will receive the score "0";
- if the candidate project duly justifies to have moderate potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure it will receive the score "+"; and;
- if the candidate project duly justifies to have full potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure, it will receive the score "++".

3.1.4 B4 – Mitigation of environmental burden and risks

The permanent neutralisation via storage of CO_2 in geological formations or its usage for producing synthetic gas fuels is an option to mitigate industrial emissions and to remove carbon from the atmosphere The development of this type of energy infrastructure should however be sustainable and prevent negative impacts on biodiversity and ecosystems mainly related to the realisation of the project and arising from CO_2 leakages. To be EU taxonomy[6] compliant (technical screening criteria), the CO_2 transported from the installation where it is captured to the injection point should not lead to CO_2 leakages above 0.5 % of the mass of CO_2 transported.

Directive 2009/31/EC ("CCS Directive")[7] provides the legal basis for the selection by Member States of geological storage sites: in particular, it describes that a site should be selected as a CO_2 storage site only if there is no significant risk of leakage, and if in any case no significant environmental or health impacts are likely to occur. From a broader perspective, a candidate CO_2 transport and storage project can contribute at mitigating such environmental burden and risks, for instance by implementing design and/or planning corrective solutions aimed at reducing the probability of occurrence and/or the magnitude of a damage such as CO_2 leakage, loss of biodiversity and impairment of ecosystems. In general, any candidate projects should aim at maximizing all the possible measures related to the mitigation of environmental risks. This is of paramount importance both during the design & construction phase, as well as during the whole operation of the project.

Taking this into consideration, project promoters shall demonstrate that their candidate CO_2 transport and storage projects are contributing at mitigating environmental burden and risk. Hence, the impact of the candidate project shall be evaluated with the following metrics:

- if the candidate project does not minimises (or just marginally) environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, it will receive the score "0";
- if the candidate project slightly minimises environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, it will receive the score "+"; and;
- if the candidate project leads to significant minimisation of the environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, meaning that the project is “best in class” of its type in terms of minimising any negative impact on the environment, it will receive the score "++".

Project promoters shall duly justify, provide references and describe in their applications how significant and impactful are their candidate projects in terms of environmental burden and risks.

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[6] Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives

[7] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (europa.eu)

As regards PMI candidate projects for the storage of CO_2, the project shall be necessary to allow the cross-border transport and storage of CO_2 and the third country where the project is located shall have an adequate legal framework based on demonstrated effective mechanisms to ensure standards and safeguards preventing any leaks and concerning climate, human health and ecosystems as regards the safety and effectiveness of the permanent storage of CO_2 are at least at the same level as those provided by the Union law. It should be presumed that the European Economic Area meets those standards and safeguards.

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;
- decommissioning and waste management costs; and
- other external costs.

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

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

3.3 Project value calculation

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 social 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[8].

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

[8] More detailed information on the project value calculation can be found in the latest CBA methodology developed by the ENTSOs.

4 Transparency and confidentiality

In submitting their CBA application, project promoters for candidate energy storage 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 ENPV and BCR calculations.

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) 2019/94.

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

[3] ENTSOG, 2nd ENTSOG Methodology for Cost-Benefit Analysis of Gas Infrastructure Projects, 2018.

[4] 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.

[5] European Investment Bank, EIB Group 2021Climate Bank Roadmap Progress Report. 28 July 2022.

[6] Chemical Energy Storage in the Book "Storage and Hybridization of Nuclear Energy: Techno –Economic Integration of Renewable and Nuclear Energy". Revankar, Shripad T., 2019. Science Direct, pp. 177 – 227. http://dx.doi.org/10.1016/B978-0-12-813975-2.00006-5 (Chapter Six)

[7] Ramboll – Ecorys. 2017. Support the Selection Process Of PCI Candidates in the Thematic Area of Cross-Border Carbon Dioxide Networks. Cost-Benefit Analysis Methodology and PCI Application Template Final Report. Report. February 21st, 2017.

[8] EC, Innovation Fund (InnovFund) Annex C: Call for proposals Methodology for GHG Emission Avoidance Calculation, Innovation Fund Large-scale Projects InnovFund- LSC-2021, 2022.

List of abbreviations and definitions

ACER	European Union Agency for the Cooperation of Energy Regulators
BCR	Benefit-Cost Ratio
CBA	Cost-benefit analysis
CCS	Carbon Capture and Storage
CCU	Carbon Capture with Utilization
CO_2	Carbon Dioxide
EC	European Commission
ENPV	Economic Net Present Value
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
PCI	Projects of Common Interest
PMI	Projects of Mutual Interest
RES	Renewable Energy Sources
TEN-E	Trans-European Networks for Energy

List of tables

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

1. Introduction

The consultation of the harmonised system-wide cost-benefit analysis for candidate cross-border carbon dioxide networks projects is part of the process for the development of assessment methodologies for the first PCI and PMI List. A period of public consultation from 7th October 2022 to 6th January 2023, with the objective to seek input to the draft methodology under the revised TEN-E Regulation. The consultation has been carried out through EUSurvey[9], the European Commission's official survey management tool.

The consultation was open to the public and stakeholders, who were invited to answer questions for the overall approach of the methodology as well as questions for each individual indicator (from B1 to B4) of the methodology.

As it concerns the first, the public was consulted on the following questions:

- 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)?

As it concerns the indicators (from B1 to B4) of the methodology, 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

Six stakeholders submitted contributions during the public consultation period: four project promotors, one NGO and one public authority.

Regarding the overall approach of the methodology, there were no significant concerns. There were also another positive comments related to the assumptions chapter. It is exposed that they are well defined.

As regards the indicators, some comments relate to the clarification of the specific elements of each benefit, for example the unavoidable nature CO_2 sources and the inclusion of the cost of CO_2 leakage. Those comments are tackled in the updated methodology.

The results of the answers related to the indicators are shown in the figure below.

[9] https://ec.europa.eu/eusurvey/home/about

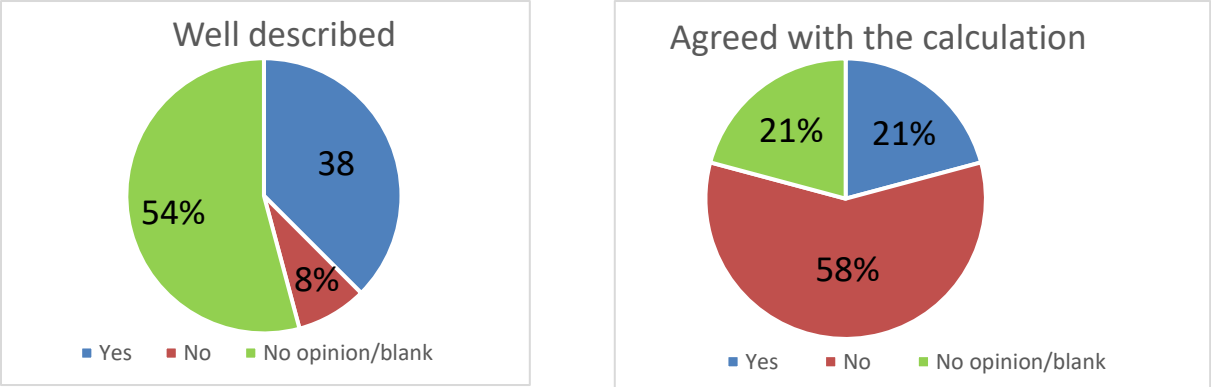

Figure 1. Answers related to the benefits.

As it is indicated in the **Figure 1** on the left, the percentage of negative responses to the question if the indicator is well described in line with the legal base is 8%. It corresponds to 2 negative responses related to indicator B1. None of the other indicators has received a response indicating that they were not well described in line with the legal base.

The second question "if you agree with the proposed method for calculating" has received contributions related to the indicators B1, B2, B3 and B4. Consequently, the indicators B1, B2, B3 and B4 have been clarified as it will be explained in **Table 2** and **Table 3**.

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

The following tables provide a summary of the modification to the draft CO2 networks CBA methodology in line with the comments received

Table 3. Result of the public consultation for each indicator

Indicator	Result
B1 - Variation of GHG emissions	Clarification
B2 - Increase the resilience and the security of the infrastructure	Clarification
B3 - Multiple CO_2 sources and storage sites via common infrastructure	Clarification
B4 - Reduction of the environmental burden and risks	Clarification

In any case, the changes considered are not major and presented in the following table:

Table 4. Changes in the methodology due to the public consultation

Indicator	Epigraph of this methodology	Type of change	Text
B1 - Variation of GHG emissions	3.1.1	Clarification	This indicator should be calculated considering not only the calculation of the GHG emissions but also the justification of the origin of the CO_2 from industrial installations (TEN-E, Article 4(3)(c)) and in absence of alternative technological solutions (TEN-E, Annex IV(8)(a)). Hence, the generation of CO_2 should be unavoidable, meaning that it should be duly justified by the origin of the CO_2 (e.g. industrial hard-to-abate heavy emitters, such as cement, lime, chemistry, steel factory etc.) and by the lack of technical alternatives, so the production CO_2 cannot be avoided despite optimisation (e.g. through energy efficiency or electrification integrating renewables). In any case, CO_2 generated in energy production sources using fossil fuels should be excluded.

			The GHG emissions to be considered in the formula are the following: $$\Delta GHG_{net} = \sum_{y=1}^{n} Proj_{\_abatement,y} - \sum_{y=1}^{n} (Proj_{\_construction,y} + Proj_{\_pipeline,y} + Proj_{\_injection,y} + Proj_{\_other\_means\_transport,y} + Proj_{\_leakage,y})$$ Where: • ΔGHG_{net} = total net GHG emissions avoided by the project, in tonnes of equivalent CO_2; • $Proj_{\_abatement,y}$ = absolute GHG emissions avoided by the project, in tonnes of CO_2e; determined in accordance with Commission Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012; • $Proj_{\_construction,y}$ = GHG emissions generated during the construction of the project, including all the activities necessary for the project to be implemented, in year y, in tonnes CO_2e; • $Proj_{\_pipeline,y}$ = GHG emissions from the operation of the transport of CO_2 by pipelines, in year y, in tonnes CO_2e. • $Proj_{\_other\_means\_transport,y}$ = GHG emissions due to the transportation of CO_2 in tank trucks, rail or other road modals and in sea tankers or other maritime modals, in year y, in tonnes CO_2e. To be calculated based on distance travelled, type of modal and load, according to the parameters and equations provided in the most updated Methodology for GHG Emission Avoidance Calculation under the Innovation Fund; • $Proj_{\_terminal,y}$ = GHG emissions from the operation of CO_2 fixed facilities for liquefaction and buffer storage, in year y, in tonnes CO_2e; • $Proj_{\_injection,y}$ = GHG emissions from the injection in a storage site permitted under Directive 2009/31/EC, in year y, in tonnes CO_2e. This includes emissions from fuel use by associated booster stations and other combustion activities including on-site power plants; venting from injection. It shall be calculated according to Regulation (EU) 2018/2066, Annex IV, Section 23. • $Proj_{\_leakage,y}$ = estimation of the expected GHG leakages from the operation of any of the infrastructure items included in the project: transport modes (pipeline, shipping, road, railway), injection activities and storage, and fixed facilities for liquefaction and buffer storage, in tonnes CO_2e

B2 - Increase the resilience and the security of the infrastructure	3.1.2	Clarification	The impact of the candidate project shall be evaluated with the following metrics while considering: • if the candidate project does not change (or changes marginally) the standard level of resilience and security of the cross-border CO_2 network, it should receive the score "0"; • if the candidate project brings to moderate improvements on the standard market procedures that ensure the level of resilience and security of the cross-border CO_2 network, it should receive the score "+"; and • if the candidate project maximize the level of resilience and security (increased efficiency and top-technological solutions) of the cross-border CO_2 network by bringing new technical improvements or best practices measures when compared to other projects in the market, it should receive the score "++".
B3 - Multiple CO_2 sources and storage sites via common infrastructure	3.1.3	Clarification	The impact of the candidate project shall be evaluated with the following metrics: • if the candidate project does not duly justify its potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure, it will receive the score "0"; • if the candidate project duly justifies to have moderate potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure it will receive the score "+"; and; • if the candidate project duly justifies to have full potential to allow an efficient use of resources, by enabling the connection of multiple carbon dioxide sources via common infrastructure, it will receive the score "++". *[Deletion of the references to a possible extension of the economic or regulatory lifetime of the assets]*
B4 - Reduction of the environmental burden and risks	3.1.4	Clarification	The impact of the candidate project shall be evaluated with the following metrics: • if the candidate project does not minimises (or just marginally) environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, it should receive the score "0"; • if the candidate project slightly minimises environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, it should receive the score "+"; and; • if the candidate project leads to significant minimisation of the environmental burden and risks related to CO_2 leakage, biodiversity and ecosystems, meaning that the project is "best in class" of its type in terms of minimising any negative impact on the environment, it should receive the score "++".

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