PROPOSED NEW BASELINE AND MONITORING METHODOLOGY OR METHODOLOGICAL TOOL FORM FOR EMISSION REDUCTIONS ACTIVITIES
(Version 02.0)

INFORMATION TO BE COMPLETED BY THE SECRETARIAT AND METHODOLOGIES EXPERT PANEL	
Type of standard	New baseline and monitoring methodology
Unique reference number and title of the proposed new methodology or new methodological tool	>>
Date when this form was received at UNFCCC secretariat:	Click or tap to enter a date.
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- Please clearly distinguish between proper methodology text, tables and equations and explanatory notes, using the following colour coding:
    - Methodology text shall be written in **black** fonts.
    - Guidance from the UNFCCC is provided in **blue** fonts and can be deleted.
    - Explanatory notes shall be written in **grey** fonts. Please note that explanatory notes are solely for the sake of methodology submission and consideration. Do not include guidance to activity participant in explanatory notes. Please note upon methodology approval, explanatory notes will be deleted.

[1] Format for footnotes.

SECTION A. Summary and applicability of the baseline and monitoring methodology or methodological tool

A.1. Title, submission date and version

Title: Production/Manufacture of Low Carbon Intensive Hydrogen through electrolysis of water powered primarily by renewable electricity.

Submission date: 01st Oct, 2025

Version: 1.0

A.2. If this methodology or methodological tool is based on a previous submission or an approved Article 6.4 mechanism methodology or methodological tool, please state the reference numbers here. Explain briefly the main differences and their rationale.

>> This methodology is derived from the draft methodology **"Production/Manufacture of Low Carbon Intensive Ammonia through electrolysis of water, air separation and synthesis of hydrogen and nitrogen" (A6.4-PNM001)**, which is currently under consideration by the Methodology Panel.

The present submission revises and adapts the hydrogen production component of that methodology, with the following key differences:

1. **Scope Expansion**: The scope is limited to standalone green hydrogen production as an eligible project activity, independent of ammonia synthesis.
2. **Technology Coverage**: This methodology applies exclusively to the production of green hydrogen through the electrolysis of water powered primarily by renewable electricity. Electrolysis pathways include alkaline, proton exchange membrane (PEM), solid oxide, and other commercially available electrolyser technologies, provided that the electricity input meets the renewable energy requirements set under this methodology.
3. **Baseline Clarification**: Baseline scenario approaches (Historical, BAT, Benchmark) are explicitly defined for hydrogen-only projects, with BAT including SMR/ATR with CCS and benchmarks referencing IEA/CertifHy/IRENA data.
4. **Monitoring Adjustments**: Monitoring parameters are revised to focus on hydrogen production, electricity consumption, water use, hydrogen leakage, and backup fuels, excluding downstream ammonia-related variables.

The rationale for this adaptation is to broaden the applicability of the original draft methodology to support standalone green hydrogen projects under Article 6.4, reflecting the growing importance of hydrogen across multiple sectors beyond ammonia production.

A.3. Summary description of the methodology or methodological tool, including major baseline and monitoring methodological steps.

>> This methodology is globally applicable to project activities that produce hydrogen that is less carbon intensive than conventional hydrogen production, primarily using renewable electricity through:

- Production of hydrogen (H_2) via electrolysis of water powered by renewable energy sources such as solar, wind, hydro, geothermal, or hybrid renewable systems.

The baseline scenario is determined as the conservative among the following approaches, consistent with paragraph 33 of the *Baseline Standard*:

I. **Best Available Technology (BAT)** – applicable to greenfield projects where no prior fossil hydrogen production exists.

II. **Existing Actual or Historical Emissions** – applicable to brownfield projects where existing fossil-based hydrogen production is replaced or retrofitted.

III. **Ambitious Benchmark**, where such benchmarks are defined by an applicable host Party or international standard.

- For greenfield projects, the baseline emission factor is derived from the BAT emissions intensity of fossil hydrogen production applicable to the host country.
- For brownfield projects, the baseline emission factor is determined from historical emissions data representing at least the previous three years of actual operation and is corrected for downward adjustment to align with the host Party's long-term decarbonization pathway.

Monitoring parameters include hydrogen production, renewable and grid electricity consumption, water use, and fugitive hydrogen emissions. All subprocesses for hydrogen production shall be primarily powered by renewable electricity sourced from dedicated or contracted renewable energy facilities.

Emissions arising from renewable energy diversion, grid electricity use, water consumption, and fugitive hydrogen release are comprehensively covered under the monitoring framework and corresponding sections on methodology, recording, and verification.

Life-cycle emissions are considered for both the baseline and project activity emissions.

SECTION B.	**Proposed new baseline and monitoring methodology or methodological tool**

1. Introduction

1. The following table presents a summary of the key elements of a methodology:

Table 1. Methodology key elements

Type of GHG mitigation measure(s)	☒ Fuel/feedstock switch ☒ Technology switch ☐ GHG destruction ☒ GHG formation avoidance ☐ Engineered carbon dioxide removal ☐ Nature based carbon dioxide removal
Types of mitigation outcomes achieved under this methodology	☒ Emission reductions ☐ Removals
Are the mitigation outcomes under this methodology at risk of reversal?	☐ Yes ☒ No
Typical projects eligible under the methodology	Projects that produce hydrogen through the electrolysis of water powered primarily by renewable electricity. This includes project activities where electrolysers are directly supplied by dedicated renewable energy plants or renewable power purchase agreements (PPAs). Limited reliance on grid electricity (not exceeding 10% of total input) is permitted, provided that associated emissions are conservatively accounted for in the project activity emissions.

2. Scope and entry into force

2.1. Scope

2. This methodology applies to project activities involving the production of low carbon intensive hydrogen through renewable or low-emission processes, replacing conventional high-emission hydrogen production such as steam methane reforming (SMR), autothermal reforming (ATR), or coal gasification without CCS.

The methodology covers:

- Electrolysis of water powered primarily by renewable electricity (solar, wind, hydro, geothermal, or hybrid RE),
- Electrolysis with partial grid electricity use, capped at 10% of total electricity input,

The methodology is globally applicable across all sectors where hydrogen is used (transport, refining, industrial feedstock, power generation, chemicals, etc.). The project boundary is limited to hydrogen production and its immediate inputs (electricity, water, and auxiliary systems).

[The scope defines without ambiguity the extent or ranges covered by the document.]

2.2. Entry into force

[For the UNFCCC secretariat to complete - Leave blank]

2.3. Applicability of sectoral scopes

3. Designated operational entities validating and verifying Article 6.4 activities that use this methodology shall apply sectoral scope(s):

[For the UNFCCC secretariat to complete – leave blank]

3. Definitions

4. In addition to the definitions contained in the 'Article 6.4 mechanism Glossary of Terms', the following definitions apply for the purpose of this methodology:

(a) Autothermal Reforming (ATR): A hydrogen production process that combines partial oxidation and steam reforming of hydrocarbons, typically natural gas. In the context of this methodology, ATR is considered part of the baseline (grey hydrogen) or BAT (with CCS).

(b) Electrolyser: An electrochemical device that splits water into hydrogen and oxygen using electricity. Types include alkaline, proton exchange membrane (PEM), solid oxide electrolysers, and anion exchange electrolysers.

(c) Fugitive Hydrogen Emissions: Unintended releases of hydrogen during production, storage, or transport that may contribute indirectly to global warming due to atmospheric reactions.

(d) Green Hydrogen: Hydrogen produced through renewable or low-carbon pathways (e.g., electrolysis powered by renewable energy, biomass/biogas reforming with CCS, PEC or thermochemical cycles), with significantly lower GHG intensity compared to conventional hydrogen production.

(e) Grid Electricity Share: The proportion of total electricity input to the hydrogen production system that is supplied from the national or regional grid. Under this methodology, it shall not exceed 10%.

(f) Historical Emissions Intensity: The past actual GHG emissions per unit of hydrogen produced at a facility, calculated as tonnes of CO_2 equivalent per tonne of hydrogen (tCO_2e/tH_2).

(g) Leakage Emissions: Indirect GHG emissions occurring outside the project boundary but attributable to the project activity, such as water treatment emissions, energy diversion, or displaced fossil-based hydrogen production.

(h) Low Carbon Intensive Hydrogen: Hydrogen produced with a life-cycle greenhouse gas intensity substantially lower than conventional hydrogen produced via fossil-based processes (e.g., SMR, ATR, or coal gasification without CCS). Under this methodology, it refers to hydrogen produced primarily through renewable-powered electrolysis.

(i) Steam Methane Reforming (SMR): A conventional hydrogen production process using natural gas as feedstock, considered part of the baseline scenario in this methodology.

(j) Water Consumption (Process): The net amount of water withdrawn and used for hydrogen production, excluding recycled or reused water.

[Provide, in alphabetical order, definitions of key terms and acronyms that are used in the methodology or methodological tool. Ensure all defined terms are used in the methodology or methodological tool.

Do not include terms already defined by the Article 6.4 Mechanism Glossary of Terms.

Please refrain from proposing definitions inconsistent with terms already defined by the Article 6.4 regulatory framework]

4. Normative references

5. This proposed baseline and monitoring methodology is based on the following proposed new methodologies and/or approved or consolidated methodologies:

(a) The draft methodology "Production/Manufacture of Low Carbon Intensive Ammonia through electrolysis of water, air separation and synthesis of hydrogen and nitrogen" (PNM001), from which the hydrogen production component has been adapted into a standalone methodology.

[Indicate in the sub-paragraphs the proposed new methodologies or approved and consolidated methodologies from the Article 6.4 mechanism and from other GHG certification schemes upon which the proposed methodology or methodological tool is based. Use one sub-paragraph per methodology and add more sub-paragraphs as needed.]

6. This methodology also refers to the latest approved versions of the following methodological tools:

(a) Methodology: *"Hydrogen production from electrolysis of water"*, AM0124 / Version 1.1 / Sectoral scope: 1, 5 / EB 119.

(b) A6.4-MEP005-A01 – Draft Standard: *Setting the baseline in mechanism methodologies* (v.03.0).

(c) A6.4-MEP005-A02 – Draft Standard: *Addressing leakage in mechanism methodologies* (v.02.0).

[Indicate the methodological tools from the Article 6.4 mechanism and from other GHG certification schemes upon which the proposed methodology or methodological tool is based. Use one sub-paragraph per methodological tool and add more sub-paragraphs as needed.]

7. This methodology is based on the following sources of information:

(a) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Section 3.2, Chapter 3: Chemical Industry Emissions.

(b) *The Future of Hydrogen*, International Energy Agency (IEA), 2019.

(c) *Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal*, International Renewable Energy Agency (IRENA), 2020.

(d) *Renewable Energy–Green Hydrogen–Land–Water Nexus in India*, Council on Energy, Environment and Water (CEEW), 2023.

(e) *Green Hydrogen Testing Infrastructure and Facilities in India*, Council on Energy, Environment and Water (CEEW), 2022.

(f) Peer-reviewed publications on electrolyser technologies, fugitive hydrogen emissions, water footprint of hydrogen production, and life-cycle GHG accounting for hydrogen.

[List major sources of data or information to substantiate elements of the proposed new methodology. Use one sub-paragraph per source and add more sub-paragraphs as needed.]

5. Applicability

8. The methodology is applicable under the following conditions:

(a) The project activity involves the production of low-carbon hydrogen through one or more of the following eligible pathways:

(i) Electrolysis of water powered primarily by renewable electricity (solar, wind, hydro, geothermal, or hybrid RE systems);

(ii) Electrolysis with partial grid electricity use, capped at 10% of total electricity consumption, with associated emissions accounted for using the applicable grid emission factor.

This shall be verified at the initial validation and at each verification of emission reductions.

(b) At least 90% of total electricity input to the hydrogen production process must be sourced from renewable energy. Grid electricity use shall not exceed 10% of total consumption. This shall be verified at the initial validation and at each verification of emission reductions.

(c) The project activity shall demonstrate that all renewable electricity used for hydrogen production is sourced from:

(i) Dedicated renewable energy installations directly connected to the hydrogen production facility; or

(ii) Renewable electricity supplied through contractual arrangements such as power purchase agreements (PPAs), renewable energy certificates, or equivalent instruments recognized by the host Party.

This shall be verified at the initial validation and at the start of each crediting period.

(d) Freshwater extraction for the project shall not exceed 5% of locally available renewable freshwater resources. This shall be verified at the initial validation and at each verification of emission reductions using project monitoring data and official hydrological or governmental data sources.

(e) The project activity shall demonstrate, ex ante, the availability of surplus freshwater resources within the project's hydrological catchment area based on credible and verifiable data sources.

Where surplus freshwater availability cannot be demonstrated, potential leakage associated with freshwater diversion or displacement of other users shall be identified and addressed in accordance with the latest version of the “Standard: Addressing leakage in mechanism methodologies”.

The ex ante demonstration of surplus freshwater availability shall be assessed at the initial validation. Leakage assessments, where applicable, shall be verified at each verification of emission reductions.

(f) Use of seawater, desalinated water, industrial effluent, or treated/recycled wastewater is permitted and encouraged and may eliminate the need for a separate leakage assessment under paragraph 8(e) where such sources fully replace freshwater extraction.

This shall be verified at the initial validation and at each verification of emission reductions.

(g) For retrofit (brownfield) project activities, any co-located grey hydrogen production facilities, including steam methane reforming (SMR), autothermal reforming (ATR), or coal gasification facilities without carbon capture and storage, shall be:

(i) Permanently decommissioned; or

(ii) Capped at baseline production levels with appropriate monitoring provisions to prevent leakage from continued fossil-based hydrogen production.

This shall be verified at the initial validation and at each verification of emission reductions.

(h) The project activity shall demonstrate additionality in accordance with the latest applicable versions of the Article 6.4 mechanism standards, methodological tools, and procedures relating to the demonstration of additionality.

This shall be assessed at the initial validation.

(i) The project activity shall be consistent with the host Party’s nationally determined contribution (NDC), long-term low greenhouse gas emission development strategy (LT-LEDS), and declared net-zero commitments.

This shall be assessed at the initial validation and at the start of each crediting period.

[Provide the conditions to which projects can apply this methodology as per the requirements of the valid version of the “Standard: Setting the baseline in mechanism methodologies” (hereinafter referred to as the baseline standard), including section 1 of its appendix.

Indicate clearly whether when the applicability conditions should be re-assessed in accordance with Appendix 1 section 1 of the baseline standard.

If necessary, explain under which conditions the methodology is not applicable.

Add more paragraphs or sub-paragraphs as needed]

9. This methodology shall not apply to the following project activities:

(a) Projects where fossil-based hydrogen production (such as SMR, ATR, or coal gasification without CCS) continues to operate, expand, or increase capacity at the same site without being capped or decommissioned.

(b) Projects where grid electricity use exceeds 10 % of the total electricity consumption for hydrogen production, or where renewable electricity supply cannot be independently metered and verified.

(c) Projects unable to demonstrate compliance with the freshwater sustainability condition under paragraph 8(c), including:
• Failure to demonstrate ex-ante availability of surplus freshwater resources within the project's hydrological catchment;
• Failure to conduct a leakage assessment where surplus freshwater cannot be demonstrated, in accordance with the *Standard: Addressing leakage in mechanism methodologies*.

(d) Projects that utilize unabated fossil feedstocks for hydrogen production or operate blended systems without complete separation of renewable and fossil hydrogen production streams.

(e) Projects that fail to demonstrate additionality in accordance with the Article 6.4 mechanism standards.

(f) Projects that contradict or are inconsistent with the host Party's NDC, LT-LEDS, or declared net-zero commitments.

[Add explanatory notes]

6. Avoidance of double-counting

10. The methodology ensures that emission reductions are not subject to double-counting in line with Section 8 of the Appendix to the Standard: Setting the baseline in mechanism methodologies. Emission reductions are credited only for the hydrogen production process covered within the defined activity boundary. Renewable electricity supplied to the hydrogen production facility is accounted for exclusively within the project boundary and must not be claimed simultaneously under any other mitigation activity, renewable energy certificate scheme, or host country inventory outside of the Article 6.4 framework. Similarly, hydrogen produced under this methodology must not be simultaneously reported as emission reductions under other schemes or double-credited in relation to end-use sectors.

[Elaborate how double-counting is avoided as per the requirements of section 8 of the Appendix to the baseline standard.]

11. Double counting is further avoided by:

(a) Ensuring the host Party accounts for Article 6.4 authorizations in its NDC balance;

(b) Clear delineation of renewable energy sourcing (dedicated plants or contractual PPAs);

(c) Monitoring and reporting of electricity input, hydrogen production, and by-product utilization to prevent overlap with other crediting or certification systems (e.g., Guarantees of Origin, CertifHy).

[Add explanatory notes]

7. Demonstration of alignment with the policies, options and implementation plans with regard to the NDC and LT-LEDS of the host Party and the long-term temperature goal of the Paris Agreement and long-term goals of the Paris Agreement

12. Activity participants shall provide to the DOE responsible to perform the validation of the Article 6.4 project an assessment, undertaken by the DNA of the host Party, of the activity's consistency with Decision 3/CMA.3 paragraph 40 (c) and paragraph 27 (a) as part of the host Party's approval.

8. Activity Boundary

13. The activity boundary for this methodology covers all facilities, processes, and systems directly associated with hydrogen production, including:

(a) Electrolyser or equivalent hydrogen production units,

(b) Electricity supply systems (renewable plants, grid connection, and backup),

(c) Water intake and treatment systems,

(d) Ancillary systems required for hydrogen production, compression, and purification.

[*Provide a description of the boundary of typical projects applying the proposed new methodology as per the requirements of the baseline standard (Appendix 1, section 2) and the "Standard: Addressing leakage in mechanism methodologies" (hereinafter referred to as the leakage standard).*

Please clarify whether the activity boundary is defined at the methodology level or at the activity level.]

Table 2. Emissions sources and sinks included in or excluded from the activity boundary

	Source	GHG			Justification / Explanation
BASELINE	*Hydrogen production from fossil pathways (SMR, ATR, coal gasification, without CCS)*	CO_2	☒ Included ☐ Not included	☐ Controlled ☐ Related to ☒ Affected by	The baseline processes are considered energy intensive processes. Conventional hydrogen production is a major emitter of CO2. In the conventional fossil fuels-based electricity generation process that is consumed to produce hydrogen, CO2 will be the main GHG emitted.
		CH_4	☒ Included ☐ Not included	☐ Controlled ☐ Related to ☒ Affected by	Methane gas emission is also considered if it is a feedstock in the production of hydrogen (coal, natural gas etc)

Source		GHG			Justification / Explanation
		N_2O	☐ Included ☒ Not included	☐ Controlled ☐ Related to ☐ Affected by	Nitrous oxides are considered insignificant and therefore not considered
		Other (e.g., CO_2 from electricity used in fossil plants)	☒ Included ☐ Not included	☐ Controlled ☒ Related to ☐ Affected by	If electricity input to baseline fossil hydrogen is relevant.
ACTIVITY	Electricity consumption for electrolysis (grid fallback)	CO_2	☒ Included ☐ Not included	☒ Controlled ☐ Related to ☐ Affected by	Indirect emissions from non-renewable grid electricity supply.
		CH_4	☐ Included ☒ Not included	☐ Controlled ☐ Related to ☐ Affected by	Negligible contribution in grid electricity
		N_2O	☐ Included ☒ Not included	☐ Controlled ☐ Related to ☐ Affected by	Nitrous oxides are considered insignificant and therefore not considered
		-----	☐ Included ☐ Not included	☐ Controlled ☐ Related to ☐ Affected by	
	Fossil fuel use on-site (if any, e.g., backup systems)	CO_2	☒ Included ☐ Not included	☒ Controlled ☐ Related to ☐ Affected by	Conservatively accounted if used.
		CH_4	☐ Included ☒ Not included	☐ Controlled ☐ Related to ☐ Affected by	There is no presence of methane gas
		N_2O	☐ Included ☒ Not included	☐ Controlled ☐ Related to ☐ Affected by	Not applicable
	Physical hydrogen leaks in storage, compression, transport	H_2 (as indirect GHG)	☒ Included ☐ Not included	☒ Controlled ☐ Related to ☐ Affected by	Fugitive hydrogen emissions converted to CO_2e using GWP(H_2).
	Water treatment & desalination for electrolysis	CO_2	☒ Included ☐ Not included	☒ Controlled ☐ Related to ☐ Affected by	if fossil energy is used for treatment/pumping.
LEAKAGE	Diversion of renewable electricity from grid/system	CO_2	☒ Included ☐ Not included	☐ Controlled ☐ Related to ☒ Affected by	Emissions if renewable supply would otherwise have displaced fossil generation.

	Source	GHG			Justification / Explanation
	Increased regional water stress due to project activity	CO_2	☒ Included ☐ Not included	☐ Controlled ☐ Related to ☒ Affected by	If additional fossil energy is required for water treatment/desalination.

9. Demonstration of additionality

9.1. Regulatory analysis

14. The activity participant of the project or CP shall demonstrate that the mitigation activity is not a legal requirement. However, the activity participant shall ensure that all the rules and regulations related to the hydrogen production process is mandatorily adhered to. The statutory documents (Environmental Impact Assessment, license to operate and other terms and conditions etc) shall be made available during the validation process.

15. The activity participant shall obtain the Host Party approval (through its DNA)

1. If the host Party approves the project, the approval shall include:

2. Confirmation that, and information on how, the project fosters sustainable development in the host Party.

3. Approval of any potential renewal of the crediting period, if the Party intends to allow the project to continue beyond the first crediting period, where the Party has specified that the crediting periods of A6.4 activities that it intends to host may be renewed pursuant to paragraph 27(b) of the RMPs;6

4. Explanation of how the project relates to the implementation of its NDC and how the expected GHG emission reductions or net GHG removals contribute to the host Party's NDC, and the purposes referred to in Article 6, paragraph 1.

5. Authorization of the activity participants

[Elaborate how activity participants shall undertake the regulatory analysis based on the requirements of the "Standard: Demonstration of additionality in mechanism methodologies" (hereinafter referred to as the additionality standard).]

16. Activity participants must conduct a comprehensive review of the legal and regulatory landscape including:

(i) national climate policies and hydrogen roadmaps;

(ii) renewable energy mandates and targets;

(iii) industrial decarbonization requirements;

(iv) environmental regulations affecting hydrogen production;

(v) sectoral policies in target markets (steel, chemicals, transport); and

(vi) any carbon pricing mechanisms or emissions standards.

The analysis should distinguish between aspirational policies and legally binding requirements, demonstrating that while supportive frameworks may exist, renewable hydrogen production is not legally mandated.

[Add explanatory notes]

9.2. Avoidance of locking-in the level of emissions

17. In accordance with paragraph 30 of the Standard: Demonstration of Additionality in Mechanism Methodologies (A6.4-STAN-METH-003), this methodology addresses the avoidance of lock-in of high-emission pathways at the methodology level through mandatory eligibility conditions applicable to all project activities.

Lock-in refers to situations where an activity commits the host country to long-term fossil-based hydrogen production infrastructure, thereby constraining future decarbonization options.

Project activities shall be eligible under this methodology only if they comply with the following conditions:

a) Hydrogen shall be produced exclusively through electrolysis powered by renewable electricity;

b) No fossil fuel combustion shall occur within the physical boundary of the hydrogen production facility;

c) The project shall not install new fossil-based hydrogen production capacity;

d) For brownfield or retrofit projects, existing fossil-based hydrogen units (e.g., SMR, ATR, coal gasification) shall be permanently decommissioned or capped at pre-project production levels;

e) Renewable electricity shall constitute at least 95% of total annual electricity consumption, excluding limited emergency backup;

f) No long-term fossil fuel supply contracts shall be entered into as part of the project activity.

Projects failing to meet any of the above eligibility conditions shall not be registered under this methodology.

[Elaborate how activity participants shall demonstrate that typical projects eligible under the methodology activities avoid locking-in the level of emissions based on the requirements of the additionality standard.]

18. These design-level restrictions ensure that project activities do not extend the lifetime of high-emission assets, create dependency on fossil fuels, or crowd out renewable infrastructure investments, thereby preventing lock-in of emissions in alignment with paragraph 30 of the Additionality Standard.

[Add explanatory notes]

9.3. Investment analysis, Barrier analysis and Common practice analysis

The activity participant shall demonstrate additionality based on the additionality standard: Demonstration of additionality in mechanism methodologies Version 01.2

[This section and its subsections can be removed if additionality is demonstrated through performance-based approach]

9.3.1. Investment analysis

19. Activity participants shall demonstrate financial additionality by conducting an investment analysis in accordance with the “Standard: Demonstration of additionality in mechanism methodologies Version 01.2” and the applicable investment analysis tool adopted under the Article 6.4 mechanism.

    The investment analysis shall demonstrate that, in the absence of revenues from A6.4 emission reductions (A6.4ERs), the proposed project activity would not be financially attractive or financially viable and therefore would be unlikely to be implemented.

20. Activity participants shall identify realistic and credible alternative scenarios to the proposed project activity, taking into account prevailing technologies, market conditions, regulatory requirements, and sectoral practices applicable within the host country or region.

    The alternative scenarios shall include, where applicable:

    a) For greenfield projects:

    I. Production of hydrogen through renewable electricity-based electrolysis without registration under the Article 6.4 mechanism;

    II. Hydrogen production using conventional fossil fuel-based technologies, including steam methane reforming (SMR), autothermal reforming (ATR), coal gasification, or other commercially established fossil-based pathways;

    III. Hydrogen production using grid electricity-based electrolysis where such electricity supply reflects prevailing grid conditions and applicable regulatory requirements;

    IV. Other technically feasible and economically viable hydrogen production pathways capable of providing comparable outputs.

    b) For brownfield or retrofit projects:

    I. Continuation of the existing fossil-based hydrogen production system without implementation of the retrofit activity;

    II. Partial retrofit or efficiency improvement measures within the existing facility;

    III. Conversion of the existing facility to renewable electricity-based hydrogen production without registration under the Article 6.4 mechanism;

    IV. Other technically feasible and economically viable retrofit or replacement alternatives capable of providing comparable outputs.

21. Activity participants shall apply the following types of investment analysis:

    a) For greenfield activities, the investment comparison analysis shall be applied by comparing the proposed project activity with the identified alternative scenarios;

    b) For brownfield or retrofit activities where multiple credible alternatives exist, the investment comparison analysis shall be applied;

c) Where the only credible alternative is continuation of the existing situation prior to implementation of the project activity, the benchmark analysis may be applied.

22. Where the investment comparison analysis is applied, the net present value (NPV) or internal rate of return (IRR) may be used as the primary financial indicator, provided that the selected indicator is appropriate for the project type and investment characteristics.

Where the benchmark analysis is applied, an appropriate financial indicator such as the internal rate of return (IRR) or NPV shall be used.

The financial benchmark shall be derived conservatively and shall reflect financing conditions commonly applicable to the country, sector, technology type, and project circumstances.

23. The investment analysis shall include all relevant costs, revenues, and financial parameters associated with the project activity and alternative scenarios, including where applicable:

a) Capital expenditure (CAPEX), including electrolyser systems, renewable electricity infrastructure, storage systems, compression systems, balance of plant, and grid interconnection costs;

b) Operational expenditure (OPEX), including maintenance, stack replacement, water treatment, labor, and operating consumables;

c) Electricity procurement costs, including costs associated with renewable electricity generation, power purchase agreements (PPAs), and grid electricity consumption where applicable;

d) Hydrogen sales revenues and other project revenues supported by credible evidence including market studies, offtake agreements, published price forecasts, or regulatory support mechanisms;

e) Financing assumptions including debt-to-equity ratios, cost of capital, interest rates, and technology-specific risk premiums; and

f) Revenues associated with A6.4ERs, which shall be excluded when assessing the financial attractiveness of the project activity without carbon market support.

24. The assumptions, parameters, data sources, and financial inputs used in the investment analysis shall be transparent, internally consistent, conservative, and substantiated by credible and verifiable evidence.

The analysis shall be based on data and information available at the start date of the project activity and shall be consistent with information presented to investors, lenders, or internal decision-making bodies.

25. Activity participants shall conduct a sensitivity analysis to demonstrate that the conclusion regarding financial non-viability without revenues from A6.4ERs is robust to reasonable variations in key assumptions and parameters.

The sensitivity analysis shall apply a variation of at least ±10% to parameters that constitute more than 20% of total project costs or total project revenues, including where applicable, but not limited to:

a) Electricity prices;

b) Hydrogen sales prices;

c) Capital expenditure;

d) Operational expenditure;

e) Financing conditions; and

f) Carbon prices or policy incentives.

26. The investment analysis shall demonstrate that the proposed project activity is not financially attractive or financially viable in the absence of revenues from A6.4ERs and therefore satisfies the financial additionality requirements of the Article 6.4 mechanism.

27. The investment analysis approach described above ensures consistency with the requirements of the "Standard: Demonstration of additionality in mechanism methodologies" and reflects conservative assumptions appropriate for hydrogen production activities involving renewable electricity-based hydrogen production pathways.

[Elaborate how activity participants shall conduct the investment analysis to demonstrate that the activity is financially additional based on the requirements of the additionality standard.]

28. The investment analysis shall consider all relevant costs, revenues, and financial parameters associated with the proposed project activity and identified alternative scenarios, including CAPEX, OPEX, electricity costs, hydrogen revenues, financing assumptions, and applicable financial indicators such as NPV and IRR.

The analysis shall be based on transparent, conservative, and verifiable assumptions consistent with information available at the start date of the project activity.

Where applicable, the activity participant shall conduct a sensitivity analysis to demonstrate that the conclusion regarding financial non-viability without revenues from A6.4ERs remains robust under reasonable variations in key parameters, including electricity prices, hydrogen prices, CAPEX, OPEX, and financing conditions.

The sensitivity analysis shall apply a variation of at least ±10% to parameters that constitute more than 20% of total project costs or total project revenues.

[Add explanatory notes]

9.3.2. Barrier analysis

29. In accordance with paragraphs 52 and 53 of the Standard: Demonstration of Additionality in Mechanism Methodologies (A6.4-STAN-METH-003, Version 01.2), barrier analysis may only be applied to activities implemented at the level of individual households or undertaken by small public or private entities that typically do not have access to commercial or public third-party finance.

[Elaborate how activity participants shall conduct the barrier analysis to demonstrate that these barriers would prevent the implementation of the activity based on the requirements of the additionality standard.]

9.3.3. Common practice analysis

30. Activity participants shall conduct the common practice analysis in accordance with the provisions and steps of Approach A (Comparable Activities) under the Article 6.4 Methodological Tool: Common Practice Analysis (A6.4-AMT-001 Version 01.0).

31. The common practice analysis shall assess whether renewable-powered hydrogen production using water electrolysis represents common practice within the host country or applicable geographical region.

The assessment shall apply a time-bound approach considering hydrogen production facilities commissioned during the most recent three years prior to the start date of the proposed Article 6.4 activity.

32. The indicator of common practice (F) shall be determined as follows:

$$F = \frac{P_{sim}}{P_{all}} \times 100$$

Where:

- F = Share of similar low-emission hydrogen production activities in the host country or applicable geographical region (%)
- P_{sim} = Installed production capacity or production output of similar low-emission hydrogen production activities
- P_{all} = Total installed production capacity or production output of all comparable hydrogen production activities

33. Comparable activities shall include hydrogen production facilities providing similar industrial outputs within the applicable geographical boundary, including fossil fuel-based hydrogen production pathways such as steam methane reforming (SMR), autothermal reforming (ATR), coal gasification, and renewable-powered electrolysis systems.

Similar activities shall include hydrogen production activities using renewable electricity-based electrolysis technologies with comparable scale, operational characteristics, and end-use applications.

34. The common practice threshold (F_{max}) shall be set at 20% for countries other than Least Developed Countries (LDCs) and Small Island Developing States (SIDS), consistent with paragraph 67(b) of A6.4-AMT-001 for time-bound approaches.

Where:

$$F < F_{max}$$

the proposed Article 6.4 activity shall be considered not common practice.

35. The analysis shall exclude:

- Activities registered under the Article 6.4 mechanism;
- Pilot-scale or demonstration facilities that are not commercially operational;
- Facilities that are not comparable in terms of scale, technology maturity, or industrial application.

36. If there are no similar renewable-powered hydrogen production activities operating within the host country or applicable geographical region at the start date of the proposed activity, the activity shall be deemed not common practice.

[Elaborate how activity participants shall conduct the analysis of common practice based on the requirements of the additionality standard and on the common practice tool.]

37. The common practice analysis ensures that the proposed activity represents a technology or practice that has not yet achieved widespread commercial deployment within the host country or applicable geographical region. The application of a time-bound approach using recent capacity additions reflects current market conditions and technological penetration trends while maintaining consistency with the provisions of A6.4-AMT-001.

[Add explanatory notes]

10. Baseline scenario

10.1. Selection of the baseline approaches from paragraph 36 of the rules, modalities and procedures

38. For hydrogen production projects under this methodology, the baseline scenario shall be determined using one of the three approaches listed in paragraph 36 of the Rules, Modalities and Procedures (RMPs):

a) Best Available Technology (BAT):

The baseline is set at the GHG emissions intensity of the most efficient fossil-based hydrogen production technology considered economically feasible and environmentally sound under host country circumstances (e.g., modern SMR or ATR without CCS). This approach shall be applied to greenfield projects where no historical operational data exist.

b) Ambitious Benchmark Approach:

The baseline is set at a conservative benchmark level, at least at the average emission level of best-performing comparable hydrogen production activities globally or regionally, adjusted for host country conditions.

c) Existing Actual or Historical Emissions Approach:

The baseline is set based on actual or historical emissions from conventional hydrogen production (e.g., SMR, coal gasification, ATR without CCS), adjusted downward in line with the Baseline Standard. This approach shall be applied to brownfield projects or retrofits where verified operational data for fossil hydrogen facilities are available.

For this methodology, Option (a) – Best Available Technology (BAT) shall apply to greenfield projects, and Option (c) – Existing Actual or Historical Emissions shall apply to brownfield or retrofit projects.

This dual-application framework ensures that baseline emissions are grounded in verifiable and conservative data consistent with host Party conditions, while maintaining differentiation between new installations and conversions of existing facilities.

[Indicate which approach from paragraph 36 of the RMPs is used to set the baseline for each component of typical projects eligible under this methodology.]

[Choose only one option for each of the emission reduction components[2]]

☐ Best available technologies that represent an economically feasible and environmentally sound course of action, where appropriate.

☐ An ambitious benchmark approach where the baseline is set at least at the average emission level of the best performing comparable activities providing similar outputs and services in a defined scope in similar social, economic, environmental and technological circumstances.

☐ An approach based on existing actual or historical emissions, adjusted downwards to ensure alignment with paragraph 33 of the RMP.

[Justify the choice in according with the baseline standard.]

39. The choice of the dual approach (BAT for greenfield / Historical for brownfield) is justified for the following reasons:

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[2] As per paragraph 19 of the baseline standard

Data realism and representativeness:

• For brownfield projects, host countries and project developers maintain plant-level operational data (fuel consumption, hydrogen output, efficiency), making the historical performance of conventional facilities the most transparent and auditable baseline reference.

• For greenfield projects, where such data do not exist, the use of the most efficient commercially deployed fossil-based production route (BAT) provides a conservative and standardized baseline that avoids speculative or inflated assumptions.

Environmental integrity and differentiation:

• Differentiating between BAT and historical emissions prevents over-crediting and ensures that new installations are benchmarked against the best feasible conventional performance, while retrofits are measured against actual past operations.

• This aligns with paragraph 33 (iii) of the Baseline Standard, which requires baselines to decline progressively and remain below the business-as-usual (BAU) level.

Conservativeness through downward adjustment:

• Both BAT and historical factors are subject to downward adjustment as per paragraph 64 of the Baseline Standard to ensure consistency with long-term decarbonization pathways.

• A minimum decline rate of 1 % per year shall be maintained across the crediting period for all project types.

Alignment with host Party policies:

• Host Parties may align the downward adjustment factor with their NDC and LT-LEDS commitments, ensuring coherence between project-level baselines and national mitigation goals.

In summary, this approach ensures applicability to both greenfield and brownfield hydrogen production projects, maintaining methodological rigor, transparency, and conservativeness while aligning with international and national climate policy frameworks.

[Add explanatory notes]

10.2. Application of the selected approach, prior to implementation of a downward adjustment

10.2.1. Procedure for the identification of the baseline scenario

40. The baseline scenario shall be identified in accordance with the selected approach, as determined by project type:

(a) **For Greenfield Projects – Best Available Technology (BAT) Approach**

Where no historical operational data exist, the baseline shall be established using the Best Available Technology (BAT) approach, as per sections 6.1.2–6.1.4 of the Baseline Standard.

The BAT shall represent the most efficient fossil-based hydrogen production technology commercially available and technically feasible under host country circumstances (e.g., modern steam methane reforming or autothermal reforming systems without CCS).

Emission intensities for BAT-based systems are derived from credible international references such as IEA (2021), IPCC (2006/2019), or host country energy statistics, expressed in tCO_2e/tH_2.

(b) For Brownfield or Retrofit Projects – Historical Emissions Approach:

Where verified historical data are available for existing conventional hydrogen production facilities, the baseline shall be determined using the Existing Actual or Historical Emissions approach, in line with sections 6.3.2 and 6.3.3 of the Baseline Standard.

Plant-level or sectoral data shall be collected for at least the three most recent consecutive years prior to project implementation, expressed in tCO_2e/tH_2. Where multiple facilities exist, a weighted average of production and emission intensity shall be used to ensure representativeness.This approach reflects real-world performance, avoids hypothetical assumptions, and enables transparent downward adjustment as per paragraph 33(iii) of the RMP.

(c) Benchmark Approach (for comparison only):

In cases where comparable global or regional hydrogen performance data are required, a benchmark may be referenced using peer-reviewed or agency-published datasets (e.g., IEA, IRENA, IPHE), adjusted to reflect host country operating conditions, consistent with section 6.2.2 of the Baseline Standard.

Baseline geographical reference area

In accordance with paragraph 21 of the Standard: Setting the Baseline in Mechanism Methodologies (A6.4-STAN-METH-004), the baseline geographical reference area for this methodology is defined as the **national level**, corresponding to the host Party in which the project activity is implemented. This is justified because hydrogen production technologies, feedstock availability, regulatory standards, and energy market conditions are determined primarily at the national level. Therefore, national data most accurately reflect the emissions that would occur in the absence of the project activity.

41. In determining baseline emissions, the activity participant shall consider all applicable policies, regulations, legal requirements, and sectoral decarbonization pathways relevant to hydrogen production in the host Party, in accordance with the “Standard: Setting the baseline in mechanism methodologies”.

The baseline determination shall incorporate:

a) Any policies, regulations, or legally binding requirements that are currently in force or are scheduled to enter into effect during the crediting period, unless such policies explicitly rely upon the Article 6.4 mechanism for implementation. All mandatory requirements applicable to the hydrogen, energy, industrial, or emissions sectors shall be assumed to be effectively enforced.

b) National or sub-national targets, strategies, or sectoral transition pathways relevant to:

- Hydrogen production;
- Renewable energy deployment;
- Industrial decarbonization;
- Energy efficiency improvements;
- Low-carbon fuel adoption; and
- Greenhouse gas mitigation commitments.

Such targets and pathways shall only be considered where supported by implemented or planned policy instruments, regulatory measures, or official government strategies, including nationally determined contributions (NDCs), long-term low greenhouse gas emission development strategies (LT-LEDS), hydrogen missions, industrial transition roadmaps, or sector-specific regulations.

[Explain how the baseline scenario is identified based on the approach from paragraph 36 of the RMPs and as per guidance from section 5.1.2 of the baseline standard.

For baselines based on approach 36(i) of the RMP (BAT), please refer to sections 6.1.2, 6.1.3 and 6.1.4 of the baseline standard.

For baselines based on approach 36(ii) of the RMP (Ambitious Benchmark), please refer to sections 6.2.2 of the baseline standard.

For baselines based on approach 36(iii) of the RMP (Existing actual or historical emissions approach), please refer to sections 6.3.2 and 6.3.3 of the baseline standard.]

42. For hydrogen production, fossil-based processes provide the most accurate representation of prevailing baseline conditions. Typical emission intensities include:

- Steam Methane Reforming (SMR): 9–12 tCO_2e/tH_2 (depending on fuel composition, efficiency, and auxiliary energy use);
- Autothermal Reforming (ATR) without CCS: 10–13 tCO_2e/tH_2;
- Coal Gasification: 18–20 tCO_2e/tH_2;
- ATR or SMR with CCS (BAT reference): 3–4 tCO_2e/tH_2.

These values are based on IEA Hydrogen Roadmap (2021) and IPCC Guidelines (2019 Refinement to 2006).

Accordingly:

- For brownfield projects, the baseline shall be anchored in verified historical emissions data (SMR/Coal-based), representing actual past performance in the host country.
- For greenfield projects, the BAT emission factor shall represent the most efficient conventional fossil-based alternative that is technologically and economically viable under host country conditions.

This dual framework ensures that baselines are robust, transparent, and aligned with both Article 6.4 mechanism requirements and the Baseline Standard. It allows the methodology to be applied consistently across diverse project contexts while ensuring that all baseline values are conservative and below business-as-usual levels.

[Add explanatory notes]

10.2.2. Calculation of baseline emissions prior to downward adjustment

43. Baseline emissions prior to downward adjustment shall be calculated using the following general equation:

$$BE_y = H_y * EF_{BL} \quad \text{Equation (1)}$$

Where:

- BE_y = Baseline emissions in year y (tCO_2e)
- H_y = Quantity of hydrogen produced in year y (tH2)
- EF_{BL} = Baseline emission factor (tCO_2e/tH_2), determined as followed:

  i. For brownfield projects, EF_{BL} = SE_{Hist}, representing the weighted average historical emission intensity of fossil-based hydrogen production (e.g., SMR, ATR, coal gasification) over the preceding three full calendar years prior to project implementation, in accordance with paragraph 36(iii) of the RMP and section 6.3.3 of the Baseline Standard.

  ii. For greenfield projects, EF_{BL} = EF_{BAT}, corresponding to the emission intensity of the Best Available Technology (BAT) identified as the most economically feasible and environmentally sound fossil-based hydrogen production pathway applicable under host country conditions, consistent with paragraph 36(i) of the RMP and section 6.1.2 of the Baseline Standard.

The baseline emission factor (EF_{BL}) shall subsequently be adjusted downward in accordance with paragraph 33(iii) of the RMP and paragraph 64 of the Baseline Standard to align with the host country's decarbonization trajectory and ensure environmental integrity.

The downward adjustment factor (AF_y,o) shall be expressed in tCO_2e/year and applied such that the effective baseline intensity decreases by at least 1% per year over the crediting period, ensuring progressive alignment with the host country's NDC and long-term net-zero objectives.

Historical Actual Emissions

In this option, the baseline emissions are determined based on the weighted average emissions intensity of actual fossil-based hydrogen production in the host country (or comparable region) over the three most recent full calendar years prior to the project start date. This approach ensures that the baseline reflects real-world operational performance, accounting for regional fuel mixes, technology penetration, plant efficiencies, and grid or auxiliary energy emissions, thereby avoiding hypothetical or theoretical assumptions.

If the host country has evaluated and notified a standardized historical emissions baseline for hydrogen production (e.g., via a published National GHG Inventory, energy statistics, or sectoral reporting), that value may be directly adopted, provided it meets the criteria below.

Otherwise, the following structured methodology shall be applied:

Step 1: Define Scope and Data Boundaries

Objective:

Establish a representative, verifiable, and temporally relevant emissions baseline based on actual historical hydrogen production data.

Scope:

Technology Coverage: Include all fossil-based hydrogen production pathways operating in the defined geographical scope (e.g., national, sub-national, or regional), including:

- Steam Methane Reforming (SMR)
- Autothermal Reforming (ATR)
- Coal Gasification
- Partial Oxidation (POX)
- Other fossil-based processes (e.g., refinery off-gas reforming)

- Exclusions:
    - Electrolytic (green) hydrogen production
    - Biomass-based or waste-derived hydrogen (unless co-fired with fossil fuels and emissions are separately accounted)
    - Hydrogen production facilities that ceased operations >12 months prior to the start of the historical period
- Temporal Coverage:
  Use data from the three most recent consecutive calendar years prior to the project's start date (e.g., if project starts in 2025, use 2022–2024 data).

  Minimum requirement: At least 3 full years of continuous, verified data.

- Geographical Scope:
  Preferably national-level data. If unava ilable or statistically insignificant, regional or comparable country data may be used, provided justification is given for comparability (fuel mix, technology, regulation, climate).

Step 2: Identify and Collect Data Sources

Data must be sourced from official, verifiable, and publicly accessible records. Acceptable sources include:

- National Statistical Agencies (e.g., energy balances, industrial production surveys)

- National GHG Inventories submitted to the UNFCCC (CRF tables, especially Energy Sector and Industrial Processes)
- Ministry of Energy or Industry Reports
- Corporate Sustainability or Emissions Reports (if aggregated and anonymized to protect confidentiality)
- International Databases:
  - IEA Energy Statistics and Balances
  - IEA Hydrogen Projects Database (for facility-level data where available)
  - UNFCCC CDM Project Databases (for historical performance of registered hydrogen projects)
  - EEA (European Environment Agency) or other regional bodies (if applicable)
- Peer-reviewed studies or technical reports from recognized institutions (e.g., JRC, IRENA, World Bank), only if primary data is unavailable and methodology is transparent.

Note: If plant-level data is unavailable, use aggregated national or sectoral data. In such cases, emissions intensity must be calculated using total sectoral hydrogen output and total associated CO_2 emissions.

Step 3: Verify and Quality-Assure Data

Before calculation, all data must undergo quality assurance (QA):

- Completeness Check: Ensure no major hydrogen-producing facilities or feedstocks are omitted.
- Consistency Check: Verify units (tonnes H_2 produced, tonnes CO_2e emitted) and time alignment (calendar years).
- Accuracy Check: Cross-reference with multiple sources where possible (e.g., IEA vs. national inventory).
- Outlier Treatment: Facilities with abnormally high or low emissions due to one-off events (e.g., shutdowns, flaring incidents) may be excluded only if documented and justified.
- CO_2e Accounting: Emissions must include:
  - Direct process emissions (combustion, reforming reactions)
  - Indirect emissions from purchased electricity/steam (if not generated on-site)
  - Upstream methane leakage (if using natural gas — apply IPCC or national emission factors)
  - CO_2 from auxiliary boilers or utilities

All emissions must be reported in tonnes CO_2-equivalent (tCO_2e) using GWP100 values from IPCC AR6 (or latest accepted version).

Step 4: Calculate Historical Specific Emissions Factor (SE_{Hist})

The baseline is determined from the weighted average of emissions intensity from actual fossil-based hydrogen production over the three most recent years prior to the project start.

$$BE_{y,hist} = SE_{Hist} * H_y \qquad \text{Equation (2)}$$

Where:

- SE_{Hist} = Average historical specific emissions factor for hydrogen production (tCO_2e/tH_2).

Historical intensity shall be calculated as:

$$SE_{Hist} = \frac{\sum_{t=1}^{T}(E_{t,H2})}{\sum_{t=1}^{T}(H_t)} \qquad \text{Equation (3)}$$

Where:

- $E_{t,H2}$ = Actual CO_2 emissions from fossil-based hydrogen production in year t (tCO_2e).
- H_t = Hydrogen production in year t (tH_2).
- T = Number of historical years (minimum of 3).

Step 5: Document and Justify Methodology

All calculations, data sources, assumptions, and exclusions must be fully documented in the baseline report, including:

- List of included facilities and technologies
- Data sources with URLs or references
- QA/QC procedures applied
- Rationale for geographical/temporal scope
- Treatment of missing or outlier data
- Conversion factors and GWP values used

This documentation must be retained for verification and potential review by Designated Operational Entities (DOEs) or UNFCCC secretariat.

Step 6: Review and Adjustment (if required)

If during the crediting period, new historical data becomes available (e.g., national inventory updates), or if the original dataset is found to be non-representative (e.g., due to major structural changes in the sector), a one-time revision of SE_Hist may be permitted, subject to:

- Justification of material change
- Approval by relevant national authority or UNFCCC body
- Retrospective adjustment only if agreed in the monitoring methodology

Best Available Technology (BAT) Approach

When the project is classified as a **greenfield project**, baseline emissions shall be determined using the *Best Available Technology (BAT)* approach in accordance with paragraph 36(i) of the RMP and section 6.1 of the *Baseline Standard*.
This ensures that the baseline reflects the most efficient, economically feasible, and environmentally sound fossil-based hydrogen production technology applicable under host-country conditions.

Step 1: Define Objectives and Scope

Objective:
To identify and establish the baseline emission factor representing the most efficient and environmentally sound fossil-based hydrogen production technology (BAT) that is commercially available and technically feasible in the host country or region.

Scope:
The BAT determination shall consider all commercially deployed hydrogen production technologies using fossil feedstocks and may include:

- Steam Methane Reforming (SMR), with or without Carbon Capture and Storage (CCS);
- Autothermal Reforming (ATR), with or without CCS;
- Coal Gasification with Carbon Capture and Storage;
- Partial Oxidation (POX) using fossil feedstocks.

Inclusions:

- Technologies that are operational, proven at industrial scale, and compliant with applicable host-country environmental and safety regulations.
- Auxiliary processes integral to hydrogen production (e.g., air separation, reforming heat recovery, CO_2 removal).

Exclusions:

- Pilot or demonstration-scale plants not yet commercially proven.
- Novel or emerging processes lacking verified life-cycle GHG performance data.
- Fully renewable or biomass-based hydrogen technologies (as these would constitute project activity, not baseline).

Temporal and Geographical Coverage:

- The BAT assessment must reflect the most recent three-year period prior to project registration to ensure relevance.
- Data should preferably be host-country specific; if unavailable, comparable regional or global data adjusted for feedstock quality, energy mix, and regulatory context may be used.

Step 2: Identify and Collect Data Sources

The identification of BAT and its associated emission intensity must rely on transparent, verifiable, and authoritative data sources. Acceptable sources include:

Primary (preferred) sources:

- **National industrial or energy authorities** (e.g., Ministry of Energy, Ministry of Industry) providing performance benchmarks or efficiency standards.
- **National GHG inventories or sectoral benchmark documents** that identify best-performing hydrogen facilities.
- **Host-country or regional environmental regulations** that define efficiency or emissions limits for hydrogen or syngas production.

Secondary sources (where national data is unavailable):

- **International Energy Agency (IEA)**: *The Future of Hydrogen* and *Hydrogen Projects Database*.
- **IRENA**: *Green Hydrogen Cost and Performance Data* (for comparative efficiency).
- **IPCC 2006 Guidelines (and 2019 Refinement)**: for default emission factors of fossil feedstocks.
- **Peer-reviewed literature** providing verified process-level GHG intensities.
- **Manufacturer or EPC technical data sheets** for commercial hydrogen reforming technologies (e.g., SMR with/without CCS).

Data Quality and Selection Criteria:

- Prefer datasets derived from commercial-scale operations (≥100 t H_2/day).
- Use life-cycle or process-level GHG intensities expressed in tCO_2e/tH_2.
- If multiple datasets are available, select the lowest-emission configuration that is technically and economically feasible under host-country circumstances (e.g., fuel prices, CCS availability, regulatory environment).
- All data sources, assumptions, and conversion factors shall be clearly referenced in the baseline documentation.

Step 3: Verify and Quality-Assure Data

Before determining the BAT-specific emission factor, all identified data and sources must undergo a rigorous quality assurance (QA) and verification process to ensure transparency, consistency, and conservativeness.

(a) Completeness Check:

- Confirm that all commercially mature fossil-based hydrogen production technologies have been considered (e.g., SMR, ATR, coal gasification, POX, SMR/ATR + CCS).

- Verify that all relevant process emissions and energy inputs (feedstock combustion, reforming reactions, auxiliary utilities, and electricity use) are included.
- Ensure inclusion of upstream and indirect emissions associated with feedstock extraction and processing, in line with IPCC 2019 Refinement guidance.

(b) Consistency Check:

- Ensure that emission intensities are expressed in uniform units (tCO_2e per tH_2) and derived using consistent system boundaries (cradle-to-gate or well-to-gate).
- Verify that datasets correspond to similar operating conditions (pressure, temperature, energy input type, capture rate for CCS) and are temporally aligned (latest available 3 years).
- Apply harmonized GWP values (GWP100 from IPCC AR6 or most recent approved version).

(c) Accuracy and Cross-Verification:

- Cross-check emission factors across at least two independent sources (e.g., IEA vs. IPCC or peer-reviewed literature).
- Where multiple data points exist, select the median or lower-bound (more conservative) value, ensuring that it represents a commercially achievable configuration.
- Exclude outliers (e.g., pilot plants, one-off efficiency claims) unless verified through third-party datasets.

(d) Documentation:

All data sources, calculations, assumptions, and QA/QC procedures must be fully documented and traceable. The justification for data inclusion or exclusion shall be clearly provided in the baseline documentation for validation by the DOE.

Step 4: Calculate the Best Available Technology (BAT) Baseline Emission Factor

Once verified, the BAT baseline emission factor is determined from the emissions intensity of the most efficient, commercially available fossil-based hydrogen production configuration that is both technically feasible and economically viable under host-country conditions.

The general calculation is given by:

$$EF_{BAT} = \frac{E_{BAT}}{H_{BAT}} \qquad \text{Equation (4)}$$

Where:

- EF_{BAT} = Baseline emission factor representing BAT (tCO_2e/tH_2)

- E_{BAT} = Total annual GHG emissions (process + combustion + indirect) from the BAT configuration (tCO_2e/year)
- H_{BAT} = Annual hydrogen output associated with BAT (tH_2/year)

If multiple BAT-qualified technologies exist (e.g., SMR + CCS and ATR + CCS), the final BAT baseline factor shall be the weighted average of their emission intensities, weighted by installed capacity or production output in the host country:

$$EF_{(BAT,avg)} = \frac{\sum_{i=1}^{n} \mathrm{EF}_{\mathrm{BAT,i}} * H_i}{\sum_{i=1}^{n} \mathrm{H_i}} \quad \text{Equation (5)}$$

Where:

- $\mathrm{EF_{BAT,i}}$ = Emission factor of each BAT technology *i* (tCO_2e/tH_2)
- H_i = Hydrogen production from technology *i* (tH_2)
- n = Number of BAT-compliant technologies considered

The resulting $EF_{(BAT)}$ value serves as the baseline emission factor for greenfield hydrogen projects and will be used in Equation (1):

$$BE_y = H_y * EF_{BAT} \quad \text{Equation (6)}$$

All underlying data, assumptions, and calculations shall be transparently reported for validation and cross-referencing with host-country or international benchmarks (e.g., IEA, IPCC, IRENA).

Step 5: Document and Justify Methodology

To ensure transparency, traceability, and replicability of the BAT baseline determination, all data sources, analytical steps, and assumptions shall be fully documented.
The documentation shall include, at minimum:

(a) Technology and System Definition

- Description of all technologies evaluated (e.g., SMR + CCS, ATR + CCS, POX + CCS).
- Identification of system boundaries (process, utilities, upstream emissions).
- Justification for technology selection as the Best Available Technology (economic feasibility, maturity, environmental soundness).

(b) Data Sources and Parameters

- Complete list of data sources (e.g., IEA Hydrogen Roadmap, IPCC Guidelines 2019 Refinement, IRENA Hydrogen Report, peer-reviewed journals, host-country datasets).
- References and publication years of emission factors, efficiency values, and CCS capture rates.
- Input parameters (e.g., energy consumption [GJ/tH_2], capture rate [%], grid emission factor [tCO_2/MWh]).

(c) Analytical Assumptions and Justifications

- Economic viability thresholds applied (CAPEX/OPEX, carbon pricing scenarios).
- Boundary conditions such as temperature, pressure, and feedstock composition.
- Reasoning for exclusion of pilot or experimental technologies.

(d) Quality Control and Verification Evidence

- Description of QA/QC procedures applied (cross-checking, uncertainty analysis, harmonization of GWP values).
- Independent or third-party verification references, where available.

All supporting documentation shall be archived and made available to Designated Operational Entities (DOEs) and host-country authorities for validation.

Step 6: Review and Adjustment (if required)

To ensure that the BAT baseline remains conservative and aligned with technological progress and host-country decarbonization goals, the emission factor shall be periodically reviewed and adjusted as follows:

(a) Trigger for Review

A review of the BAT emission factor shall occur when:

- New commercially available hydrogen production technologies achieve ≥5 % lower GHG intensity than the current BAT;
- Host-country regulations introduce new efficiency or emission standards applicable to hydrogen production;
- The average global or regional BAT benchmark (e.g., IEA, IPCC, IRENA) changes by more than 5 % over the crediting period.

(b) Procedure for Adjustment

- Reassess candidate technologies using the methodology outlined in Steps 1–4.
- Update the BAT emission factor (EF_{BAT}) using the latest verified data.
- Apply a minimum annual reduction rate of 1 % to reflect expected technological learning and regulatory tightening, consistent with paragraph 33(iii) of the Baseline Standard.
- Any recalculated or adjusted baseline factor shall be subject to validation by the DOE prior to implementation.

(c) Documentation of Revision

Each review must include:

- Description of the new BAT benchmark or performance data;
- Rationale for adjustment and quantitative change in EF_{BAT};
- Effective date of implementation for the revised baseline.

This ensures that the BAT-based baseline remains environmentally credible, conservative, and consistent with the Article 6.4 mechanism's long-term mitigation objectives.

[Explain how baseline emissions prior to the downward adjustment is determined. Provide the equations and potential options choices.]

10.3. Calculation of the downward adjusted baseline

44. The downward adjusted baseline ensures that baseline emissions for hydrogen production decline over time in accordance with paragraph 33(iii) of the Rules, Modalities and Procedures (RMP) and the requirements of the "Standard: Setting the baseline in mechanism methodologies" (A6.4-STAN-METH-004).

The downward adjustment shall be applied to the baseline emission factor determined under the applicable baseline approach provisions of this methodology (i.e. the BAT-based baseline emission factor for greenfield activities or the historical emissions-based baseline emission factor for brownfield activities), ensuring progressive improvement in baseline performance throughout the crediting period.

For brownfield activities where the baseline is determined based on existing actual or historical emissions, the downward adjustment in the calendar year of the start date of the first crediting period shall incorporate uncertainty in accordance with paragraph 64 of the baseline standard.

The downward adjusted baseline emissions in year y shall be calculated as follows:

$$BE_{DA,y} = H_y \times EF_{DA,y} \quad \text{Equation (7)}$$

Where:

- $BE_{DA,y}$ = Downward adjusted baseline emissions in year y (tCO_2e/year)
- H_y = Quantity of hydrogen produced in year y (tH_2/year)
- $EF_{DA,y}$ = Downward adjusted baseline emission factor for year y (tCO_2e/tH_2)

45. For brownfield activities where the baseline is determined based on existing actual or historical emissions, the downward adjustment in the calendar year corresponding to the start date of the first crediting period shall incorporate uncertainty in accordance with paragraph 64 of the baseline standard.

The uncertainty at the lower bound of the uncertainty interval relative to the central estimate of the ex-ante quantified unadjusted baseline emission factor during the first crediting period shall be determined at a 95% confidence level.

The uncertainty value shall be determined using conservative uncertainty propagation methods based on the relative uncertainties associated with key monitored parameters, including fuel consumption, electricity consumption, hydrogen production, metering systems, and applicable emission factors.

The determination of uncertainty shall consider all significant causes of uncertainty, including but not limited to:

a) Measurement uncertainty;

b) Data variability;

c) Sampling uncertainty;

d) Metering uncertainty;

e) Uncertainty associated with electricity consumption data;

f) Uncertainty associated with hydrogen production data;

g) Uncertainty associated with fuel consumption data; and

h) Uncertainty associated with emission factors.

The uncertainty-adjusted baseline emission factor for the first year of the crediting period shall be calculated as follows:

$$EF_{DA,UNC,y1} = EF_{BL,y1} \times (1 - UNC_{BL,CP1}) \quad \text{Equation (8)}$$

Where:

- $EF_{DA,UNC,y1}$ = Uncertainty-adjusted baseline emission factor in year y1 (tCO_2e/tH_2)
- $EF_{BL,y1}$= Unadjusted baseline emission factor in year y1 determined in accordance with paragraph 30 of this methodology (tCO_2e/tH_2)
- $UNC_{BL,CP1}$ = Uncertainty at the lower bound of the uncertainty interval relative to the central estimate of the ex-ante quantified baseline emission factor during the first crediting period (fraction)
- Y_1 = Calendar year corresponding to the start date of the first crediting period

46. The minimum downward adjusted baseline emission factor for the first year of the crediting period shall be determined as follows:

$$EF_{DA,min,y1} = EF_{BL,y1} - (EF_{BL,y1} - EF_{PJ,y1}) \times 0.1 \quad \text{Equation (9)}$$

Where:

- $EF_{DA,min,y1}$ = Minimum downward adjusted baseline emission factor in year y1 (tCO_2e/tH_2)
- $EF_{PJ,y1}$= Ex-ante estimated project emission factor in year y1 (tCO_2e/tH_2)

The downward adjusted baseline emission factor for the first year of the crediting period shall be determined as the lower of the uncertainty-adjusted baseline emission factor and the minimum downward adjusted baseline emission factor, as follows:

$$EF_{DA,y1} = min(EF_{DA,min,y1}, EF_{DA,UNC,y1}) \quad \text{Equation (10)}$$

Where:

- $EF_{DA,y1}$ = Downward adjusted baseline emission factor in year y1 (tCO_2e/tH_2)

47. For greenfield activities applying the Best Available Technology (BAT) approach, no uncertainty-based downward adjustment in the first year of the crediting period shall apply.

The downward adjustment in subsequent years (Yn) shall be determined by applying a downward adjustment factor (DAF) based on the host Party's reference year and net-zero target year, as follows:

$$DAF_{Yn} = 1 - (Yn - Y_1) * \max\left(\frac{1}{Y_{netzero} - Y_{reference}}, 0.01\right) \quad \text{Equation (11)}$$

Where:

- DAF_{Yn} = Downward adjustment factor applied in year Yn
- Yn= Calendar year for which the downward adjustment is applied
- $Y_{netzero}$ = Net-zero target year of the host Party
- $Y_{reference}$ = Reference year for the host Party's net-zero target
- Y_1 = Calendar year corresponding to the start date of the first crediting period

The reference year shall correspond to the base year applicable to the host Party's decarbonization trajectory or implementation period under its nationally determined contribution (NDC) or LT-LEDS.

Where the host Party has not defined a net-zero target year or corresponding reference year, the downward adjustment factor shall be calculated as follows:

$$DAF_{Yn} = 1 - (Yn - Y_1) \times 0.01 \qquad \text{Equation (12)}$$

Where the host Party has not defined a net-zero target year or corresponding reference year, a conservative default annual downward adjustment rate of 1% shall apply in accordance with paragraph 71 of the baseline standard.

48. The downward adjusted baseline emission factor for subsequent years shall be calculated as follows:

$$EF_{DA,Yn} = EF_{DA,y1} \times DAF_{Yn} \qquad \text{Equation (13)}$$

Where:

- $EF_{DA,Yn}$ = Downward adjusted baseline emission factor in year Yn (tCO_2e/tH_2)
- $EF_{DA,y1}$= Downward adjusted baseline emission factor in the first year of the crediting period (tCO_2e/tH_2)
- DAF_{Yn} = Downward adjustment factor applied in year Yn

Thus, the downward adjusted baseline emissions in year y shall be calculated as equation (7).

$$BE_{DA,y} = H_y \times EF_{DA,y}$$

[Explain how the downward adjustment is determined and applied, including the quantification of the downward adjustment and the quantification of the resulting downward adjusted baseline for each year of the crediting period based on the requirements of the baseline standard. Include relevant equations and choices/assumptions.]

49. The calculation of the downward adjusted baseline fulfils the requirements of the "Standard: Setting the baseline in mechanism methodologies" (A6.4-STAN-METH-004).

The downward adjustment factor shall be determined based on the host Party's net-zero target year, reference year, nationally determined contribution (NDC), long-term low greenhouse gas emission development strategy (LT-LEDS), or other relevant sectoral decarbonization pathways, while ensuring that the annual downward adjustment rate is not lower than the minimum rate specified in paragraph 71 of the baseline standard.

For baselines determined using existing actual or historical emissions in accordance with approach 36(iii) of the Rules, Modalities and Procedures (RMP), the downward adjustment in the first year of the crediting period shall incorporate uncertainty considerations in accordance with paragraph 64 of the baseline standard. The uncertainty assessment shall be conducted conservatively at a 95% confidence level and shall consider all significant sources of uncertainty associated with the determination of the baseline emission factor.

Where the host Party has not defined a net-zero target year or corresponding decarbonization trajectory, the application of the default downward adjustment rate shall ensure conservativeness in the baseline determination throughout the crediting period.

[For baselines determined as per approach 36 (iii) of the RMP (historical emissions adjusted downwards), indicate how the downward adjustment in the calendar year of the start date of the first crediting period is determined and applied in accordance with paragraph 64 of the baseline standard. If another approach is proposed in accordance with paragraph 64, provide an appropriate justification.]

50. For subsequent years of the crediting period, the downward adjustment shall continue to be applied in accordance with section 7.2 of the baseline standard through the application of a downward adjustment factor reflecting the host Party's decarbonization trajectory, including nationally determined contributions (NDCs), long-term low greenhouse gas emission development strategies (LT-LEDS), net-zero commitments, or other relevant sectoral transition pathways.

Where such national or sectoral trajectories are not available, a conservative default annual downward adjustment rate of 1% shall apply.

The downward adjustment approach ensures that the baseline remains below business-as-usual emissions throughout the crediting period and progressively reflects increasing decarbonization ambition over time.

[For all baseline approaches, either:

(i) Indicate how the downward adjustment in subsequent years is determined and applied in accordance with section 7.2 of the baseline standard, or

(ii) Provide a justification for an exemption of the downward adjustment in subsequent years as per paragraph 65 and 66 of the baseline standard]

51. The downward adjustment approach based on the host Party's net-zero target year, reference year, nationally determined contribution (NDC), long-term low greenhouse gas emission development strategy (LT-LEDS), or other relevant sectoral decarbonization pathways reflects the considerations of section 7.2 of the baseline standard.

The approach ensures that baseline emissions progressively decline over time in line with increasing national and sectoral decarbonization ambition while maintaining conservativeness in the determination of emission reductions.

The application of a minimum annual downward adjustment rate, including in cases where no explicit host Party decarbonization trajectory is available, ensures that the baseline remains below business-as-usual emissions throughout the crediting period and avoids over-crediting.

The downward adjustment approach is applicable to both greenfield activities applying the Best Available Technology (BAT) approach and brownfield activities applying existing actual or historical emissions approaches, thereby ensuring consistency in baseline treatment across activity types and preserving environmental integrity in accordance with paragraph 33(iii) of the Rules, Modalities and Procedures (RMP).

[Add explanatory notes]

10.4. Identification of the conservative BAU scenario

52. The identification of the Business-as-Usual (BAU) scenario shall follow the provisions and requirements of section 8 of the “Standard: Setting the baseline in mechanism methodologies” (A6.4-STAN-METH-004).

The activity proponent shall identify all plausible alternative scenarios to the proposed project activity and determine the most conservative and plausible BAU scenario.

The BAU scenario shall reflect prevailing hydrogen production practices in the host country or region during the most recent three to five years prior to the start date of the project activity, taking into account dominant production technologies, feedstocks, energy sources, and applicable regulatory requirements.

53. The following alternatives shall be considered, where applicable, for the determination of the BAU scenario:

a) Continuation of the existing or historical hydrogen production practices;

b) Implementation of economically viable hydrogen production technologies and practices providing comparable outputs;

c) A combination of continuation of existing practices for the remaining lifetime of existing equipment followed by implementation of economically viable replacement technologies.

Where more than one plausible alternative exists, the most conservative plausible scenario shall be selected as the BAU scenario.

54. The determination of the BAU scenario shall be based on verifiable and publicly available information, including where applicable:

a) National or regional hydrogen production statistics;

b) Technology deployment data;

c) Feedstock consumption data;

d) Energy supply characteristics;

e) Industry reports;

f) Regulatory and policy documents; and

g) Other authoritative national or international data sources.

The data used for determining the BAU scenario shall reflect the most recent available information covering a period of at least three years prior to the start date of the project activity.

55. The BAU scenario shall incorporate all legally binding regulations, policies, standards, and requirements applicable during the baseline period, including where relevant:

a) Energy efficiency requirements;

b) Emission standards or limits;

c) Mandatory pollution control measures; and

d) Other legally enforceable sectoral requirements affecting hydrogen production technologies or operational performance.

Voluntary measures, aspirational targets, or non-binding initiatives shall not be considered mandatory elements of the BAU scenario unless supported by enforceable regulatory instruments.

56. The BAU scenario shall exclude technologies or practices that:

a) Are not commercially established at industrial scale within the host country or comparable markets;

b) Do not represent plausible baseline alternatives under prevailing market and regulatory conditions; or

c) Are dependent on policy incentives, subsidies, or support mechanisms that are not legally binding or broadly implemented during the baseline period.

Low-carbon hydrogen production pathways, including renewable electricity-based electrolysis, shall only be considered part of the BAU scenario where they represent an established and significant share of hydrogen production within the applicable geographical reference area during the baseline period.

57. The conservative BAU scenario shall be determined through the following stepwise procedure:

(i) Identification of hydrogen production technologies, feedstocks, and energy inputs used within the applicable geographical reference area during the baseline period;

(ii) Identification of plausible alternative hydrogen production pathways;

(iii) Determination of the associated emission factors and emissions intensities for each plausible alternative scenario;

(iv) Incorporation of applicable legally binding regulatory requirements and sectoral policies;

(v) Exclusion of non-plausible, non-commercial, or emerging technologies that do not represent realistic baseline alternatives; and

(vi) Selection of the most conservative plausible BAU scenario consistent with prevailing market conditions, technological practice, and applicable regulations.

58. The BAU scenario and the associated baseline assumptions shall be validated against authoritative national statistics, industry data, regulatory information, and other credible sources to ensure consistency, transparency, and conservativeness in the determination of baseline emissions.

[Explain how the conservative BAU is determined as per the requirements from section 8 of the baseline standard.]

10.4.1. Calculation of the conservative BAU emissions

59. The calculation of the conservative Business-as-Usual (BAU) emissions shall follow the provisions and requirements of section 8 of the “Standard: Setting the baseline in mechanism methodologies” (A6.4-STAN-METH-004).

The BAU emissions shall represent the most plausible and conservative fossil-based hydrogen production pathway that would have occurred in the absence of the project activity.

The determination of the BAU scenario and associated emissions shall be undertaken ex ante at the start of the crediting period and reassessed at each renewal of the crediting period.

60. For greenfield activities, the BAU emissions shall be determined using the Best Available Technology (BAT) approach in accordance with paragraph 36(i) of the Rules, Modalities and Procedures (RMP).

The BAT approach shall represent the most efficient fossil-based hydrogen production technology that is technically feasible, economically viable, commercially established, and commonly applied under comparable national or regional conditions at the time of project implementation.

61. For brownfield activities, the BAU emissions shall be determined using existing actual or historical emissions in accordance with paragraph 36(iii) of the Rules, Modalities and Procedures (RMP).

The baseline emission factor shall be determined based on the weighted average greenhouse gas emissions intensity of the existing hydrogen production facility over the most recent three consecutive years prior to the implementation of the project activity.

The historical emissions intensity shall reflect direct process emissions, energy-related emissions, and other significant emission sources associated with fossil-based hydrogen production.

62. The conservative BAU emissions in year y shall be calculated as follows:

$$BE_{BAU,y} = E_{H2,y} \times RA \qquad \text{Equation (14)}$$

Where:

- $BE_{BAU,y}$ = Conservative BAU emissions in year y (tCO_2e)
- $E_{H2,y}$ = Emissions associated with hydrogen production in year y (tCO_2e)
- RA = Regulatory adjustment factor accounting for mandatory efficiency improvements or legally binding regulatory requirements

63. Emissions associated with hydrogen production shall be calculated as follows:

$$E_{H2,y} = H_y \times I_{H2} \qquad \text{Equation (15)}$$

Where:

- H_y = Quantity of hydrogen produced in year y (tH_2)
- I_{H2} = Greenhouse gas emissions intensity of hydrogen production (tCO_2e/tH_2)

The greenhouse gas emissions intensity shall be determined based on the applicable fossil-based hydrogen production pathway identified under the BAU scenario.

64. For brownfield activities, the historical greenhouse gas emissions intensity shall be determined as the weighted average emissions intensity over the most recent three consecutive years prior to the implementation of the project activity, as follows:

$$I_{H2} = \frac{\sum_{t=1}^{T}(E_{t,H2})}{\sum_{t=1}^{T}(H_t)} \qquad \text{Equation (16)}$$

Where:

- $E_{t,H2}$ = Actual greenhouse gas emissions from hydrogen production in historical year t (tCO_2e)
- H_t = Quantity of hydrogen produced in historical year t (tH_2)
- T = Number of historical years considered, which shall be at least three consecutive years

65. Where legally binding regulations applicable during the baseline period require mandatory efficiency improvements, emission reductions, or operational performance standards affecting hydrogen production facilities, a regulatory adjustment factor shall be applied conservatively to the BAU emissions.

The regulatory adjustment factor shall be calculated as follows:

$$RA = (1 - x) \qquad \text{Equation (17)}$$

Where:

- RA = Regulatory adjustment factor
- x = Mandatory efficiency improvement or emissions reduction requirement expressed as a fraction

Where no mandatory regulatory adjustment applies, the value of RA shall be equal to 1.

66. In determining the BAU scenario and quantifying BAU emissions, the activity participant shall identify and incorporate:

a) Any policies, regulations, or legal requirements that are active or scheduled to take effect during the crediting period, unless such policies formally integrate or explicitly rely upon the Article 6.4 mechanism as an instrument for implementation. All legally binding requirements applicable to the sector shall be assumed to be enforced, while recognizing that regulatory environments may vary across jurisdictions;

b) Any specific national or sub-national targets, strategies, or sectoral decarbonization plans relevant to hydrogen production, renewable energy use, industrial emissions, or low-carbon fuel deployment, provided that such targets are supported by implemented or planned policy frameworks. General aspirational goals not supported by sector-specific implementation measures shall not be considered in determining the BAU scenario.

67. For brownfield activities applying historical emissions approaches, the conservative BAU emissions shall incorporate uncertainty considerations in accordance with section 8 and Appendix 1 of the baseline standard.

The uncertainty at the lower bound of the uncertainty interval relative to the central estimate of the ex-ante quantified BAU emissions during the first crediting period shall be determined at a 95% confidence level.

The determination of uncertainty shall consider all significant causes of uncertainty, including but not limited to:

a) Measurement uncertainty;

b) Metering uncertainty;

c) Sampling uncertainty;

d) Data variability;

e) Uncertainty associated with fuel consumption data;

f) Uncertainty associated with electricity consumption data;

g) Uncertainty associated with hydrogen production data; and

h) Uncertainty associated with emission factors.

The uncertainty-adjusted conservative BAU emissions shall be determined by applying a conservative downward adjustment to the ex-ante quantified BAU emissions.

68. The uncertainty-adjusted conservative BAU emissions for year y shall be calculated as follows:

$$BAU_{CONS,UNC,y} = BAU_y \times (1 - UNC_{BAU,CP1,y}) \quad \text{Equation (18)}$$

Where:

- $BAU_{CONS,UNC,y}$ = Uncertainty-adjusted conservative BAU emissions in year y (tCO_2e)
- BAU_y= Ex-ante quantified BAU emissions in year y (tCO_2e)
- $UNC_{BAU,CP1,y}$ = Uncertainty at the lower bound of the uncertainty interval relative to the central estimate of the ex-ante quantified BAU emissions during the first crediting period (fraction)

The uncertainty assessment shall be conducted conservatively at a 95% confidence level and shall consider all significant sources of uncertainty associated with the determination of BAU emissions.

69. Where uncertainty-adjusted BAU emissions and minimum conservative BAU emissions are both determined, the lower value shall be selected as the conservative BAU emissions for the purpose of baseline determination and emission reduction calculation.

[Explain how the conservative BAU emissions are determined based on the requirements in section 8 of the baseline standard. Include relevant equations and choices/assumptions.

In case another approach for ensuring that the crediting baseline is below BAU is chosen, as per paragraph 77(b), please provide a justification.]

10.5. Comparison of the downward adjusted baseline and the conservative business-as-usual baseline

70. In accordance with section 9 of the "Standard: Setting the baseline in mechanism methodologies" (A6.4-STAN-METH-004), the downward-adjusted baseline emissions shall be compared with the conservative Business-as-Usual (BAU) emissions for each year of the crediting period.

The final baseline emissions for year y shall be determined as the lower of the downward-adjusted baseline emissions and the conservative BAU emissions, as follows:

$$BE_{y,Final} = \min\left(BE_{DA,y},\ BAU_{CONS,UNC,y}\right) \quad \text{Equation (19)}$$

Where:

- $BE_{DA,y}$ = Downward adjusted baseline emissions in year y (tCO_2e/year)
- $BAU_{CONS,UNC,y}$ = Conservative BAU emissions in year y, including uncertainty adjustments where applicable (tCO_2e)

[Explain how the comparison is made as per the requirements from section 9 of the baseline standard and whether further adjustment to the baseline emissions is needed].

71. The comparison of the downward-adjusted baseline emissions and the conservative BAU emissions ensures that the final baseline remains conservative and below the most plausible business-as-usual emissions trajectory throughout the crediting period.

Where the downward-adjusted baseline emissions are lower than the conservative BAU emissions, the downward-adjusted baseline emissions shall be applied as the final baseline emissions.

Where the conservative BAU emissions are lower than the downward-adjusted baseline emissions, the conservative BAU emissions shall be applied as the final baseline emissions.

72. The comparison approach described above ensures consistency with section 9 of the baseline standard and prevents over-crediting by applying the most conservative baseline value for each year of the crediting period.

The downward-adjusted baseline emissions and conservative BAU emissions shall be reassessed at the renewal of each crediting period using the most recent available data, applicable regulatory requirements, sectoral decarbonization pathways, and relevant national circumstances.

No further adjustment to the baseline emissions is proposed under this methodology beyond the application of the downward adjustment and conservative BAU determination approaches described above.

73. The application of the lower value between the downward-adjusted baseline emissions and the conservative BAU emissions ensures that credited emission reductions remain conservative, environmentally robust, and aligned with the long-term objectives of the Paris Agreement and the Rules, Modalities and Procedures (RMP) for the Article 6.4 mechanism.

[Add explanatory notes]

11. Activity scenario

11.1. Calculation of activity emissions

74. Activity emissions refer to the total direct and indirect greenhouse gas (GHG) emissions resulting from the implementation of the green hydrogen production project. These emissions must be compared with baseline emissions to determine the net mitigation impact.

• Activity emissions sources include:

- Indirect emissions resulting from grid electricity consumption for electrolysers, compressors, and auxiliary equipment;
- Direct emissions from combustion of fossil fuels for auxiliary or backup operations (if applicable);
- Emissions associated with water treatment, desalination, and pumping for hydrogen production;
- Physical leaks of hydrogen during production, compression, storage, and distribution stages.

• Data Sources and Assumptions

- **Primary Data Sources (Preferred):**
  Where possible, real-time operational data from the project facility shall be used, including:

1. Onsite monitoring of electricity consumption in electrolysers, compressors, and balance-of-plant equipment;
2. Renewable energy supply and grid electricity mix data (for indirect emissions calculations);
3. Hydrogen production efficiency (e.g., kWh/kg H_2) based on electrolyser performance;
4. Measurement of physical hydrogen leaks via calibrated monitoring devices.

• Other Data Sources include:

1. Plant-level monitoring systems (SCADA, IoT sensors, smart meters, and leak detection sensors);
2. Process control system records for direct and indirect emissions;
3. Electricity consumption records and renewable power purchase agreements (PPAs).

- **Secondary Data Sources (if Primary Data is Unavailable):**

  1. IPCC Emission Factors Database (for fossil fuel combustion, industrial processes, and GWP values);
  2. International Energy Agency (IEA) publications on hydrogen production and emissions intensities;
  3. International Renewable Energy Agency (IRENA) reports on hydrogen and electrolyser performance;
  4. Peer-reviewed literature on water footprint and fugitive hydrogen emissions.

- **Regional/National References:**

  1. Regional or national grid emission factors (e.g., IEA, EPA, or host Party inventory data) shall be applied.
  2. Country-specific water treatment emission factors should be used where available.

- **Ensuring Data Conservativeness:**

  1. If multiple datasets exist, the most conservative (highest emissions factor) shall be applied;
  2. Data sources must be selected based on geographical, technological, and temporal relevance;
  3. In cases of uncertainty, default values from IPCC or IEA shall be applied to avoid underestimation of emissions.

Steps for calculating activity emissions in green hydrogen production

Step 1: Define system boundary for activity emissions
Activity emissions are calculated for the following project components:

- Hydrogen production (electrolysis or equivalent zero/low-carbon pathway);
- Water treatment, desalination and pumping;
- Grid electricity consumption (≤10% of supply);
- Backup or auxiliary fossil fuel use (e.g., diesel for start-up, compressors);
- Cooling and balance-of-plant energy use (if significant);
- Fugitive hydrogen leaks during production, compression, storage, and distribution.

Step 2: Calculate emissions from grid electricity consumption

$$AE_{y,Elec} = C_{y,Elec,Grid} * EF_{Elec,Grid} \qquad \text{Equation (20)}$$

Where:

- $AE_{y,Elec}$ = Emissions from grid electricity in year *y* (tCO_2e).
- $C_{y,Elec,Grid}$ = Electricity consumed from grid in year *y* (MWh).
- $EF_{Elec,Grid}$ = Grid emission factor (tCO_2e/MWh), using host Party or IEA data.

Note: Electricity sourced from onsite renewables or certified PPAs is treated as zero-emission.

Step 3: Calculate emissions from fossil fuel use (if applicable)

$$AE_{y,Fossil} = \sum i\left(FC_{i,y} * NCV_i * EF_i\right) \qquad \text{Equation (21)}$$

Where:

- $AE_{y,Fossil}$ = Emissions from fossil fuel use in year *y* (tCO_2e).
- $FC_{i,y}$ = Quantity of fossil fuel *i* consumed (t or m^3).
- NCV_i = Net calorific value of fuel *i* (TJ/unit).
- EF_i = Emission factor of fuel *i* (tCO_2e/TJ).

Note: Includes fuel used in auxiliary boilers, backup generators, or hydrogen compressors.

Step 4: Calculate emissions from water treatment, desalination and pumping

$$AE_{y,Water} = W_y * EF_{Water} \qquad \text{Equation (22)}$$

Where:

- $AE_{y,Water}$ = Emissions from water treatment in year *y* (tCO_2e).
- W_y = Volume of water used for hydrogen production (m^3).
- EF_{Water} = Emission factor for water treatment and pumping (tCO_2e/m^3).

Note: Desalination and reverse osmosis are included. Recycled water streams may reduce Wy.

Step 5: Calculate fugitive hydrogen emissions

$$AE_{y,Leak} = H_{y,Prod} * PL_{(y,H2)} * GWP_{H2} \qquad \text{Equation (23)}$$

Where:

- $AE_{y,Leak}$ = Emissions from hydrogen leakage in year *y* (tCO_2e).
- $H_{y,Prod}$ = Hydrogen produced in year *y* (tH_2).
- $PL_{(y,H2)}$ = Percentage of hydrogen lost as leakage (% of production).
- GWP_{H2} = Global warming potential of hydrogen (tCO_2e/tH_2), as per the latest IPCC assessment.

Note: Fugitive emissions include leaks in pipelines, compressors, valves, storage tanks, and distribution systems.

Step 6: Calculate total activity emissions

$$AE_y = AE_{y,Elec} + AE_{y,Fossil} + AE_{y,Water} + AE_{y,Leak} \quad \text{Equation (24)}$$

Where:

- AE_y = Total activity emissions in year *y* (tCO_2e).

[Explain how the activity emissions are calculated for each year of the crediting period. Include relevant equations, choices and assumptions.]

75. • Renewable electricity input:

    - Electricity sourced from new or dedicated renewable energy plants (≥90% of electrolyser supply) is considered emission-free, provided double counting is avoided through appropriate instruments (e.g., renewable energy certificates, power purchase agreements, or direct grid connection).

• Grid electricity consumption:

    - Up to 10% of electricity may be drawn from the grid for stability, start-up, or emergency operations. Emissions shall be calculated using the official host Party grid emission factor. Where unavailable, default factors from the IEA or IPCC Emission Factor Database shall be applied.

• Fossil fuel use:

    - If fossil fuels are used in auxiliary or backup equipment (e.g., diesel generators, compressors, or start-up boilers), emissions shall be included using IPCC default NCVs and emission factors. If no fossil fuels are consumed, this component may be conservatively set to zero, but monitoring evidence must be provided.

• Water treatment and desalination:

    - Where electrolysis requires treated water, emissions from pumping, desalination, or purification must be included. In the case of recycled or wastewater use, W_y may be reduced accordingly. Default emission factors for water treatment may be sourced from host country inventories, the IPCC, or peer-reviewed literature.

• Fugitive hydrogen emissions:

    - Hydrogen leakage has indirect radiative forcing impacts by influencing methane and ozone concentrations. To capture this, fugitive hydrogen losses must be monitored through flow meters, leak detection systems, or material balance. The most recent IPCC Global Warming Potential (GWP) values must be applied. If no direct monitoring data is available, conservative leakage rates from peer-reviewed studies shall be used.

- Conservativeness principle:
  - Where multiple datasets exist for an emission factor, the most conservative (highest) value shall be applied.
  - If primary data are unavailable, secondary data shall be selected based on geographical, technological, and temporal relevance.
  - All assumptions and justifications must be transparently documented in the monitoring plan.

[Add explanatory notes]

12. Leakage

12.1. Identification of leakage emission sources

76. Leakage emissions refer to increases in greenhouse gas (GHG) emissions occurring outside the project boundary but attributable to the Article 6.4 activity. For green hydrogen production projects, potential sources of leakage include:

Step 1.1 Transfer of Baseline Equipment (Applies to brownfield project activities)

Leakage may occur if fossil-based hydrogen production equipment (such as steam methane reformers, partial oxidation units, or autothermal reformers) replaced by the project is reused elsewhere, continuing to generate GHG emissions. In accordance with paragraph 82(b) of the Standard, this methodology requires either:

- Proof of permanent decommissioning or scrapping of the baseline equipment; or
- Quantification of continued emissions if the equipment is reused.

When functional baseline equipment is replaced but not destroyed, and continues to be used for the same purpose as in the baseline scenario, project proponents must estimate leakage emissions based on the anticipated annual operating hours, fuel consumption, hydrogen output quantity, and relevant emission factors of the relocated equipment.

In cases where the baseline equipment is dismantled and its components are repurposed in a disaggregated manner across different locations and for different functions, any associated leakage emissions are not required to be considered and may be neglected, as the equipment no longer functions in its original capacity and does not contribute to continued baseline service delivery.

Step 1.2 Diversion of Renewable Electricity

Leakage may result from diversion of renewable electricity from the grid or other consumers, leading to increased fossil-based generation elsewhere. If the project diverts pre-existing renewable electricity capacity that was previously serving other consumers, those consumers may be forced to rely on higher-emission grid electricity or fossil-based alternatives.

The methodology includes procedures to:

- Assess the source and dedication status of renewable electricity supply;
- Identify whether renewable capacity is greenfield (dedicated to the project) or diverted from existing uses;
- Quantify associated emissions using grid emission factors or displacement factors where diversion occurs.

Step 1.3 Market Leakage from Hydrogen Production Displacement

Leakage may occur through market effects where the green hydrogen production displaces conventional hydrogen production or alternative fuels, causing fossil-based hydrogen production to increase elsewhere or shift to regions with higher emission intensities.

The methodology requires:

- Assessment of regional and global hydrogen market dynamics;
- Analysis of whether the project displaces low-emission hydrogen producers;
- Quantification of potential production shifts and their emission implications;
- Consideration of market leakage effects on alternative fuel markets.

Step 1.4 Hydrogen Transport and Distribution Losses

Leakage occurs through physical losses of hydrogen during transport, storage, compression, and distribution beyond the project boundary. Hydrogen losses represent both direct GHG emissions (due to hydrogen's global warming potential) and indirect emissions from the energy required to replace lost hydrogen.

This includes:

- Compression losses during hydrogen storage and transport;
- Pipeline transfer losses beyond the facility boundary;
- Storage tank venting and purging losses;
- Loading and unloading losses during transport.

Step 1.5 Water Resource Competition

Leakage may result from water resource competition, where the diversion of freshwater for electrolysis induces additional pumping, treatment, or sourcing from alternative supplies elsewhere, leading to increased energy consumption and associated emissions.

The methodology includes procedures to:

- Assess local water availability and competing uses;
- Identify potential displacement effects on other water users;
- Quantify emissions from additional pumping, treatment, or alternative water sourcing;
- Evaluate impacts on drinking water resources and agricultural uses.

Step 1.6 Supply Chain Leakage

Leakage may occur through supply chain emissions, including:

- Emissions from manufacture of electrolysers and major equipment;
- Production and transport of replacement parts and consumables;
- Emissions from imported renewable electricity equipment (solar panels, wind turbines);
- Construction-related emissions for dedicated renewable energy infrastructure.

Step 1.7 Land Use Change Effects

For greenfield project activities, leakage may occur through indirect environmental effects triggered by the project, including:

- Land-use change associated with hydrogen production facilities;
- Land-use change for dedicated renewable energy infrastructure (solar farms, wind farms);
- Transmission line corridors and associated infrastructure;
- Access road construction and site preparation.

[Explain which are the leakage emissions sources that may be attributable to the Article 6.4 activity based on the requirements as per paragraph 12 of the leakage standard.]

77. Not all identified leakage sources are material. Only those exceeding 1% of total baseline emissions or 10,000 tCO_2e/year must be accounted for, consistent with the leakage standard. Diversion of renewable electricity is only considered leakage if the renewable capacity was pre-existing and not dedicated to the project. Supply chain emissions related to equipment manufacture may be considered outside the project boundary but must be conservatively estimated if significant. Transfer of baseline equipment leakage applies only to brownfield projects where existing hydrogen production equipment is replaced but continues operating elsewhere.

[Add explanatory notes]

12.2. Avoidance or minimization of leakage

78. Activity participants shall minimize leakage through:

Equipment Transfer Avoidance:

- Ensuring permanent decommissioning or scrapping of replaced baseline equipment;
- Providing documentation of equipment disposal or destruction;
- Where equipment transfer is unavoidable, implementing monitoring of relocated equipment emissions.

Renewable Electricity Leakage Avoidance:

- Ensuring dedicated renewable electricity generation through greenfield renewable plants;
- Establishing contractual renewable energy procurement (e.g., PPAs or REC-backed supply) that demonstrates additionality;

- Preventing diversion from other users through dedicated grid connections or on-site generation;
- Limiting grid electricity use to maximum 10% of total electricity consumption.

Hydrogen Distribution Leakage Minimization:

- Implementing robust monitoring of hydrogen storage, compression, and pipeline transfer;
- Installing advanced leak detection and repair (LDAR) systems;
- Using high-integrity materials and connections for hydrogen handling;
- Implementing regular maintenance and inspection programs.

Water Resource Leakage Avoidance:

- Limiting water consumption to maximum 5% of locally available water resources;
- Encouraging water recycling and closed-loop systems;
- Using non-freshwater inputs (e.g., seawater with renewable-powered desalination);
- Implementing water-efficient electrolysis technologies.

Market Leakage Minimization:

- Demonstrating that potential market leakage is negligible or mitigated by host country policies;
- Targeting applications where green hydrogen provides additional demand rather than displacing low-emission alternatives;
- Ensuring project outputs remain identical to pre-project conditions in terms of service delivery.

Supply Chain Leakage Minimization:

- Sourcing equipment from manufacturers with low-emission production processes;
- Prioritizing local sourcing where feasible to reduce transport emissions;
- Implementing equipment longevity and maintenance programs to reduce replacement frequency.

[Explain how the negative leakage emissions sources identified above shall be avoided or minimized based on the requirements as per paragraph 14 of the leakage standard.]

79. Avoidance of leakage shall be demonstrated in the monitoring plan through project design documentation (e.g., renewable plant ownership, dedicated grid connections, water source agreements). Leak minimization measures must include advanced leak detection and repair (LDAR) systems with specified detection thresholds and repair timelines. Where avoidance is not possible, conservative default emission factors must be applied to account for leakage. Equipment transfer documentation must include certificates of destruction or detailed monitoring plans for relocated equipment

[Add explanatory notes]

12.3. Addressing leakage emissions

80. Leakage emissions that cannot be avoided or minimized shall be deducted from the emission reductions claimed. Total leakage emissions in year y are calculated as:

$$LE_{\gamma} = LE_{\gamma}{}^{\text{Elec}} + LE_{\gamma}{}^{\text{H2}} + LE_{\gamma}{}^{\text{Water}} + LE_{\gamma}{}^{\text{supply}} + LE_{\gamma}{}^{\text{Euip}} + LE_{\gamma}{}^{\text{Env}} + LE_{\gamma}{}^{\text{Market}} \quad \text{Eq (25)}$$

Where:

- $LE_{\gamma}{}^{\text{Elec}}$ = Leakage from diversion of renewable electricity (tCO_2e)
- $LE_{\gamma}{}^{\text{H2}}$ = Leakage from hydrogen transport and distribution losses (tCO_2e)
- $LE_{\gamma}{}^{\text{Water}}$ = Leakage from additional water pumping/treatment induced outside the boundary (tCO_2e)
- $LE_{\gamma}{}^{\text{supply}}$ = Leakage from supply chain emissions attributable to electrolysers or major equipment replacement (tCO_2e)
- $LE_{\gamma}{}^{\text{Euip}}$ = Leakage from transferred baseline equipment (tCO_2e)
- $LE_{\gamma}{}^{\text{Env}}$ = Leakage from indirect environmental emissions including land use change (tCO_2e)
- $LE_{\gamma}{}^{\text{Market}}$ = Leakage from market displacement effects (tCO_2e)

Detailed Calculation Methods:

1. Leakage from Transferred Baseline Equipment

This provision applies only to brownfield project activities where baseline hydrogen production equipment is not disposed of or scrapped and continues to be used for the same purpose.

$$LE_{\gamma}{}^{\text{Euip}} = Q_{\text{output},\gamma} * EF_{\text{e}}q_{\text{uip}} \quad \text{Equation (26)}$$

Where:

- $Q_{\text{output},\gamma}$: Hydrogen output from transferred equipment (tH_2/year)
- $EF_{\text{e}}q_{\text{uip}}$: Emission factor of the baseline equipment (tCO_2e/tH_2)
- Leakage from Renewable Electricity Diversion ($LE_{\gamma}{}^{\text{Elec}}$)

$$LE_{\gamma}{}^{\text{Elec}} = EC_{\gamma}{}^{\text{diverted}} * EF_{marginal} \quad \text{Equation (27)}$$

Where:

- $EC_{\gamma}{}^{\text{diverted}}$: Electricity consumption diverted from other users (MWh/year)
- $EF_{marginal}$: Marginal grid emission factor representing displaced generation (tCO_2e/MWh)

3. Leakage from Hydrogen Distribution

$$LE_{\gamma}^{\mathrm{H2}} = (H_{2\mathrm{lo},\gamma} \times GWP_{\mathrm{h2}}) + (H_{2\mathrm{lo},\gamma} \times EF_{\mathrm{h2,repla}}c_{\mathrm{ement}}) \quad \text{Equation (28)}$$

Where:

- $H_{2\mathrm{lo},\gamma}$: Hydrogen losses during transport and distribution (tH_2/year)
- GWP_{h2} : Global warming potential of hydrogen
- $EF_{\mathrm{h2,repla}}c_{\mathrm{ement}}$: Emission factor for replacement hydrogen production (tCO_2e/tH_2)

4. Leakage from Water Resource Competition (LE_{γ}^{Water})

$$LE_{\gamma}^{\mathrm{Water}} = W_{\mathrm{a}}dd_{\mathrm{itional},\gamma} \times EF_{\mathrm{\beta aseline}}, w_{\mathrm{ater}} \quad \text{Equation (29)}$$

Where:

- $W_{\mathrm{a}}dd_{\mathrm{itional},\gamma}$: Additional water consumption induced elsewhere (m^3/year)
- $EF_{\mathrm{\beta aseline}}, w_{\mathrm{ater}}$: Emission factor for baseline water supply and treatment (tCO_2e/m^3)

5. Leakage from Supply Chain (LE_{γ}^{supply})

$$LE_{\gamma}^{\mathrm{supply}} = \Sigma_{\mathrm{i}} (Equip_{\mathrm{i},\gamma} \times EF_{\mathrm{i,l}}c_{\mathrm{a}}) \quad \text{Equation (30)}$$

Where:

- $Equip_{i,\gamma}$: Quantity of equipment type i manufactured or replaced (units/year)
- $EF_{i,l}c_a$: Life cycle emission factor for equipment type i (tCO_2e/unit)

6. Leakage from Land Use Change (LE_{γ}^{Env})

$$LE_{\gamma}^{\mathrm{Env}} = \Sigma_{\mathrm{h}} (A_{\mathrm{h},\gamma} \times EF_{\mathrm{h,lu}}c) \quad \text{Equation (31)}$$

Where:

- $A_{h,\gamma}$: Area of land use change type h (hectares/year)
- $EF_{h,lu}c$: Emission factor for land use change type h (tCO_2e/hectare)

7. Leakage from Market Effects (LE_{γ}^{Market})

$$LE_{\gamma}^{\mathrm{Market}} = H_{2\mathrm{proj},\gamma} \times EF_{\mathrm{market}}, d_{\mathrm{ispla}}c_{\mathrm{ement}} \quad \text{Equation (32)}$$

Where:

- $H_{2proj,\gamma}$: Hydrogen production from the project (tH_2/year)
- $EF_{market}, d_{ispla}c_{ement}$: Net emission factor from market displacement effects (tCO_2e/tH_2)

Net emission reductions are then calculated as:

$$ER_{\gamma} = BE_{\gamma}^{\mathrm{crediting}} - AE_{\gamma} - LE_{\gamma} \quad \text{Equation (33)}$$

Where:

- ER_{γ} : Net emission reductions in year y (tCO_2e)
- $BE_{\gamma}^{\mathrm{crediting}}$: Crediting baseline emissions in year y (tCO_2e)

- AE_Y : Activity emissions in year y (tCO_2e)
- LE_Y : Total leakage emissions in year y (tCO_2e)

[Explain how negative leakage emissions that cannot be avoided or minimized are discounted from the crediting baseline based on the requirements in section 5.3 of the leakage standard. Include relevant equations, choices and assumptions.]

81. If leakage is found to be immaterial (<1% of baseline or <10,000 tCO_2e/year), it may be excluded, but supporting justification must be provided with quantitative analysis. If leakage is significant, conservative emission factors and the highest credible values must be applied. Where ranges exist in literature or standards, the upper bound values shall be used. For supply chain leakage, life cycle assessment (LCA) studies or peer-reviewed literature should be used; where unavailable, IPCC default factors may be applied with conservative adjustments. Equipment transfer leakage calculations must account for the remaining operational lifetime of transferred equipment and include uncertainty factors. Market leakage assessments should consider both direct and indirect market effects, including cross-sector impacts on alternative fuel markets. Where multiple leakage sources interact, cumulative effects must be assessed to avoid double-counting while ensuring comprehensive coverage. Monitoring and verification of leakage emissions must be conducted using the same rigor as project emission monitoring, with independent verification where leakage exceeds materiality thresholds.

By applying these comprehensive leakage assessment rules, the methodology ensures environmental integrity and alignment with the Paris Agreement's long-term goals while maintaining practical applicability for green hydrogen projects.

[Add explanatory notes]

13. Emission reductions

82. Emission reductions for year y are calculated as the difference between baseline emissions, project activity emissions, and leakage emissions:

$$ER_y = BE_{y,Crediting} - AE_y - LE_y \qquad \text{Equation (34)}$$

Where:

- ER_y = Emission reductions in year y (tCO_2e).
- $BE_{y,Crediting}$ = Crediting baseline emissions in year y (tCO_2e), determined as the minimum of downward-adjusted baseline and conservative BAU baseline.
- AE_y = Activity emissions in year y (tCO_2e), as defined in Section 11.
- LE_y = Leakage emissions in year y (tCO_2e), as defined in Section 12.

[Explain how the emission reductions are calculated for every year of the crediting period. Include relevant equations, choices and assumptions.]

83. Net emission reductions are calculated annually for each year of the crediting period. Where leakage emissions are immaterial (<1% of baseline or <10,000 tCO_2e/year),LEy may be conservatively set to zero, with justification provided.

The methodology applies a conservative hierarchy: baselines decline over time (downward adjustment), activity emissions include all material sources, and leakage is explicitly deducted. This ensures that emission reductions are real, measurable, additional, and consistent with the long-term temperature goal of the Paris Agreement.

[Add explanatory notes]

14. Data and parameters not monitored

[List all data/parameters which are defined ex-ante and do not need to be monitored under the proposed methodology (or methodological tool).]

(Copy this table for each piece of data or parameter)

Data/parameter	***>> GWP H2***
Description	>> Global Warming Potential of hydrogen (indirect radiative forcing effect, CO_2e/kg H_2 lost).
Data unit	>> tCO2e/H2
Equations referred	>> *EQ.*
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Value(s) applied	>> (based on latest IPCC AR6 values)
Source of data	☐ Measured ☒ Other sources
Choice of data or measurement methods and procedures	>> *The latest IPCC approved GWP value for hydrogen shall be applied. If revised values are published during the crediting period, they will replace earlier assumptions.*
Treatment of uncertainty	>> The highest value within the reported range is applied to ensure conservativeness.
Additional comments	>>To be updated upon new IPCC consensus.

Data/parameter	***>> EF_i***
Description	>> Default emission factor of fossil fuel *i* (diesel, natural gas, coal)
Data unit	>> tCO2e/TJ
Equations referred	>> *EQ.*
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Value(s) applied	>> (based on latest IPCC AR6 values)
Source of data	☐ Measured ☒ Other sources

Choice of data or measurement methods and procedures	>> *Default values from IPCC shall be applied unless more conservative host-country factors exist.*
Treatment of uncertainty	>> IPCC defaults are conservative; uncertainty minimized by using maximum values.
Additional comments	>>Only applicable if fossil fuels are used as auxiliary energy.

Data/parameter	***>> EF^{Water}***
Description	>> Emission factor for water treatment, desalination, and pumping.
Data unit	>> $tCO2_e/m^3$
Equations referred	>> *EQ.*
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Value(s) applied	>> country-specific; IPCC defaults used if unavailable
Source of data	☐ Measured ☒ Other sources
Choice of data or measurement methods and procedures	>> *Where country-specific values exist, they shall be applied. Otherwise, peer-reviewed studies and international defaults are acceptable.*
Treatment of uncertainty	>> Upper bound of available range applied to ensure conservativeness
Additional comments	>> Applies only if significant volumes of treated or desalinated water are used.

Data/parameter	***>> $EF_{Elec,Grid}$ (if fixed ex-ante)***
Description	>> Emission factor for grid electricity.
Data unit	>> tCO2e/MWH
Equations referred	>> *EQ.*
Purpose of data	☐ Baseline emissions ☒ Project emissions ☒ Leakage emissions
Value(s) applied	>> Host Party official grid factor (if fixed ex-ante for entire crediting period).
Source of data	☐ Measured ☒ Other sources
Choice of data or measurement methods and procedures	>> *Host country national inventory factor preferred. If unavailable, IEA or IPCC defaults shall be applied.*
Treatment of uncertainty	>> Most conservative value (highest factor) selected where multiple datasets exist.

Additional comments	>> If host country requires annual updates, this parameter shifts to "monitored."

15. Data and parameters monitored

[List all data/parameters which need to be monitored under the proposed methodology or methodological tool, including data and parameters that are determined only once for the crediting period of the project activity but that will become available only after the implementation of the project activity.]

(Copy this table for each piece of data or parameter)

Data/parameter	**>> H_Y**	
Description	>> Quantity of hydrogen produced in year *y*.	
Data unit	>> *tH_2/year*	
Equations referred	>> *Eq.*	
Purpose of data	☒ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	>> *Continuous measurement, aggregated daily, reported annually.*	
Measurement methods and procedures	>> *Direct measurement of hydrogen output using calibrated flow meters or mass balance at electrolyser output.*	
Entity/person responsible for the measurement	>> *Plant operator.*	
Measuring instrument(s)	*Type of instrument*	>> *Flow meters (IEC/ISO-certified).*
	Accuracy class	>> *Minimum ±1%.*
	Calibration requirements	>> 1. *Calibration procedures: Manufacturer's procedures, verified by accredited laboratory.* 2. *Calibration frequency: At least annually, or as required by manufacturer.*
	Location	>> *Outlet of electrolyser system.*
QA/QC procedures	>> Cross-check with production records and SCADA system logs. Backup of all measured data.	
Treatment of uncertainty	>> Conservative rounding down of hydrogen quantities in case of data gaps.	
Additional comment	>> *Primary variable for determining emission reductions.*	

Data/parameter	**>> $C_{y,Elec,Grid}$**	
Description	>> Electricity consumed from the grid by the project activity in year *y*.	
Data unit	>> *MWH/year*	
Equations referred	>> *Eq*	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☒ Leakage emissions	
Measurement and updating frequency	>> *Continuous metering, aggregated monthly, reported annually.*	
Measurement methods and procedures	>> *Direct measurement with certified electricity meters connected to grid feed-in points.*	
Entity/person responsible for the measurement	>> *Electric utility and Plant operator.*	
Measuring instrument(s)	*Type of instrument*	>> *Electricity meter (IEC 62053 or equivalent).*
	Accuracy class	>> *±0.2s or better.*
	Calibration requirements	>> 1. *Calibration procedures: Manufacturer's procedures, verified by accredited laboratory.* 2. *Calibration frequency: Every 3 years or as per host country regulations. .*
	Location	>> *Main substation or grid connection point.*
QA/QC procedures	>> *Reconciliation with utility bills. Discrepancies >2% flagged for review.*	
Treatment of uncertainty	>> If data unavailable, maximum recorded grid intensity is applied.	
Additional comment	>> *Limited to ≤10% of total electricity input.*	

Data/parameter	**>> $FC_{i,y}$**
Description	>> *Quantity of fossil fuel type i consumed in auxiliary systems.*
Data unit	>> *t or m³/year*
Equations referred	>> *Eq.*
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Measurement and updating frequency	>> *Continuous where flow meters installed; otherwise batch records, aggregated annually.*

Measurement methods and procedures	>> *Measured using fuel meters, tank dip measurements, or supplier delivery records.*	
Entity/person responsible for the measurement	>> *Plant operator.*	
Measuring instrument(s)	*Type of instrument*	>> *Fuel flow meters or tank-level sensors.*
	Accuracy class	>> *±1%.*
	Calibration requirements	>> 1. *Calibration procedures: Manufacturer's procedures, or local standards.* 2. *Calibration frequency: Annual calibration .*
	Location	>> *Fuel inlet lines of auxiliary systems*
QA/QC procedures	>> *Cross-check delivery records with consumption logs.*	
Treatment of uncertainty	>> If data unavailable, conservative default factors applied.	
Additional comment	>> *Only relevant if fossil fuels are used.*	

Data/parameter	**>> W_y**	
Description	>> *Volume of water treated and used for hydrogen production in year y.*	
Data unit	>> *m³/year*	
Equations referred	>> *Eq.*	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	>> *Continuous, aggregated monthly, reported annually.*	
Measurement methods and procedures	>> *Flow meters on water intake lines.*	
Entity/person responsible for the measurement	>> *Plant operator.*	
Measuring instrument(s)	*Type of instrument*	>> *Water flow meters (ISO/IEC-certified).*
	Accuracy class	>> *±1%.*
	Calibration requirements	>> 1. *Calibration procedures: Manufacturer's procedures.* 2. *Calibration frequency: Annual calibration.*
	Location	>> *Water treatment inlet.*

QA/QC procedures	>> *Compare meter data with treatment plant logs.*
Treatment of uncertainty	>> Use maximum water factor if measurement gaps exist.
Additional comment	>> *Includes desalination where relevant.*

Data/parameter		**>> $PL_{y,H2}$**
Description		>> *Percentage of hydrogen leaked in production, compression, storage, and distribution.*
Data unit		>> *% of hydrogen produced*
Equations referred		>> *Eq.*
Purpose of data		☐ Baseline emissions ☒ Project emissions ☒ Leakage emissions
Measurement and updating frequency		>> *Continuous monitoring where sensors are installed; otherwise quarterly leak detection surveys.*
Measurement methods and procedures		>> *Material balance of input/output hydrogen, infrared sensors, ultrasonic leak detectors, or tracer gas methods.*
Entity/person responsible for the measurement		>> *Plant operator with third-party verification annually.*
Measuring instrument(s)	*Type of instrument*	>> *Leak detection sensors (infrared, mass spectrometry, ultrasonic).*
	Accuracy class	>> *Detect leakage ≥0.1% of flow.*
	Calibration requirements	>> 1. *Calibration procedures: Manufacturer's procedures.* 2. *Calibration frequency: Quarterly calibration.*
	Location	>> *Electrolyser halls, pipelines, compressors, and storage tanks.*
QA/QC procedures		>> *Cross-check with production-output balances.*
Treatment of uncertainty		>> *Where direct data unavailable, conservative IPCC/peer-reviewed leakage factors applied.*
Additional comment		>> *Captures fugitive hydrogen impact on atmospheric chemistry.*

Data/parameter	**>> $C_{yElec,RE}$**
Description	>> *Quantity of renewable electricity supplied to the hydrogen production facility in year y. This includes direct supply from dedicated renewable plants (solar, wind, hydro, biomass) or renewable PPAs.*
Data unit	>> *MWH/year*
Equations referred	>> *Eq.*

Purpose of data	☒ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	*>> Continuous measurement, aggregated monthly, reported annually.*	
Measurement methods and procedures	>> • *Measured at the delivery point using certified electricity meters connected to renewable generation units or substation.* • *In the case of offsite PPAs, verified through utility-supplied renewable energy certificates (RECs) or guarantees of origin (GOs).*	
Entity/person responsible for the measurement	*>> Plant operator and renewable generator (in case of PPA supply).*	
Measuring instrument(s)	*Type of instrument*	*>> Certified electricity meters (IEC 62053 or equivalent).*
	Accuracy class	*>> ±0.2s or better.*
	Calibration requirements	>> 1. *Calibration procedures: In accordance with IEC/national standards.* 2. *Calibration frequency: At least once every 3 years or as required by host country regulation.*
	Location	*>> Substation connecting renewable plant to hydrogen facility (or grid injection point for RE PPA).*
QA/QC procedures	>> • *Reconciliation with utility billing data, SCADA logs, and renewable generation records.* • *Cross-check against total hydrogen production demand*.	
Treatment of uncertainty	*>> In case of missing data, the minimum (conservative) RE supply is assumed and balance is allocated to grid electricity.*	
Additional comment	>> • *Ensures compliance with methodology condition that ≥90% of electricity input is renewable.* • *Provides a conservative check on grid fallback emissions.*	

15.1. Frequency of submission of monitoring reports

84. For activities involving removals and for emission reduction activities with risks of reversals:

(a) The maximum permissible interval between the start date of the first crediting period and the submission of the first monitoring report is one (1) year; and

(b) The maximum permissible interval between the submission of two consecutive monitoring reports after the first monitoring report is one (1) years.

16. Methodologies principles

[Note: This section is to demonstrate compliance with other provisions contained in the “Standard: Application of the requirements of Chapter V.B (Methodologies) for the development and assessment of Article 6.4 mechanism methodologies” (hereinafter referred to as the methodologies standard)]

16.1. Encouraging ambition over time

85. This methodology encourages ambition over time by requiring the application of downward adjustments to baseline emission factors in accordance with host Party NDCs, LT-LEDS, and global decarbonization pathways (e.g., IEA Net Zero scenarios). This ensures that baseline emissions decline progressively over the crediting period, preventing over-crediting and aligning mitigation outcomes with the long-term temperature goal of the Paris Agreement.

[Demonstrate how the methodology encourages ambition over time based on the requirements of the methodologies standard.]

16.2. Contributing to the equitable sharing of mitigation benefits between participating Parties

86. This methodology contributes to the equitable sharing of mitigation benefits between participating Parties in accordance with paragraphs 31–33 of the Standard: Application of the requirements of Chapter V.B (Methodologies) for the development and assessment of Article 6.4 mechanism methodologies through the following provisions:

- The methodology incorporates host Party nationally determined contributions (NDCs), long-term low-emission development strategies (LT-LEDS), sectoral decarbonization pathways, and applicable national policies into the determination and downward adjustment of baseline emissions;
- Conservative baseline setting, downward adjustment mechanisms, uncertainty treatment, and business-as-usual (BAU) assessments are applied to ensure that credited emission reductions do not exceed actual mitigation outcomes;
- The methodology requires transparent monitoring, reporting, and verification (MRV) of project emissions, baseline emissions, leakages, and renewable electricity consumption in accordance with Article 6.4 mechanism requirements;
- The methodology shall only be applied where the host Party authorizes the activity and confirms the treatment of mitigation outcomes consistent with applicable Article 6 accounting requirements, including corresponding adjustments where applicable; and
- The methodology promotes mitigation activities that support sustainable low-carbon hydrogen deployment while preserving mitigation opportunities for the host Party and ensuring environmental integrity.

[Explain how the provisions included in the methodology for contributing to the equitable sharing of mitigation benefits between participating Parties ensure compliance with the requirements set in paragraph 31 to 33 of the methodologies standard.]

16.3. Encouraging broad participation

87. The methodology encourages broad participation by being globally applicable across all regions and technologies where hydrogen is produced via electrolysis with renewable energy. It avoids restrictive technology requirements and instead provides a flexible but conservative framework that accommodates varying national contexts, renewable resource availability, and electrolysis technologies. This inclusivity reduces barriers for developing countries and promotes broader uptake of hydrogen projects.

[Explain how the methodology or methodological tool complies with the requirements contained in paragraph 51 of the methodologies standard.]

16.4. Attributability of emission reductions or net removals to the Article 6.4 activity

88. The methodology ensures full attributability of emission reductions by clearly defining the system boundary (Section 8) and allocating all monitored emissions to the project activity. All reductions are attributable to the displacement of high-emission fossil hydrogen production pathways (SMR, ATR, coal gasification) with low-carbon electrolysis-based hydrogen. No emission reductions are double-attributed or allocated outside the project boundary.

[If required, explain how the methodology or methodological tool complies section 5 in Appendix 1 of the baseline standard]

16.5. Potential perverse incentives

89. The methodology avoids perverse incentives by:

- Excluding crediting for the continuation or expansion of fossil-based hydrogen production facilities (e.g., SMR, ATR, coal gasification without CCS), thereby ensuring that only genuine low-carbon transitions are rewarded.
- Requiring the baseline to be conservatively defined using BAT, benchmark, or historical emissions adjusted downward, which prevents over-crediting and eliminates the incentive to inflate baseline emissions intensities.
- Ensuring leakages (e.g., fugitive hydrogen emissions, RE diversion) are accounted for transparently, so that project design does not favor higher emissions.

[If required, explain how the methodology or methodological tool addresses section 6 in Appendix 1 of the baseline standard]

16.6. Rebound effects

90. The methodology addresses potential rebound effects by explicitly requiring monitoring of renewable energy diversion, grid fallback electricity, and water consumption. Any increase in fossil-based grid electricity or water stress attributable to the project is conservatively included in project activity emissions or leakage. This prevents projects from causing indirect increases in emissions or unsustainable resource use.

[If applicable, explain how the methodology or methodological tool addresses section 7 in Appendix 1 of the baseline standard.]

Appendix 1. [Name of the appendix]

1. A paragraph

   [Use one or more appendixes to add complementary information to the main part of the methodology which could make the main part of the methodology too long, such as providing additional details, supporting evidence or examples to comply with specific requirements.]

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Document information

Version	*Date*	*Description*
0.2.0	19 August 2025	Revision to incorporate new sections and sub-sections in line with current standards; provide completion instructions, realign their sequence, and allow inclusion of explanatory notes.
01.0	18 December 2024	Initial publication of form template.

Decision Class: Regulatory
Document Type: Form
Business Function: Methodology
Keywords: A6.4 mechanism, developing methodologies and tools

Note: The below Annexure is for reference purpose only and shall be removed after the review by the MEP

Conventional Hydrogen Production Process

Hydrogen can be produced via multiple technological pathways, each with distinct greenhouse gas (GHG) intensities. The variation in life-cycle emissions underscores the importance of setting a conservative and dynamic baseline for crediting under this methodology. Understanding these pathways is critical for establishing appropriate baseline scenarios and ensuring environmental integrity of emission reduction claims.

Section 1.01 Fossil-based Hydrogen Pathways

(a) Steam Methane Reforming (SMR)

Steam Methane Reforming represents the most common hydrogen production method globally, accounting for approximately 95% of current hydrogen production. This process involves reacting methane (natural gas) with steam at high temperatures (700-1000°C) in the presence of a nickel catalyst to produce hydrogen and carbon monoxide, followed by a water-gas shift reaction to convert CO to CO_2.

Technical Characteristics:

- **Emissions:** Typically range from **8–10 $kgCO_2/kgH_2$**, with the emissions being directly proportional to the carbon content of the natural gas feedstock
- **Process Efficiency:** Approximately 65–75%, among the highest of current commercially available production methods
- **Scale Advantages:** Most efficient when operated at large, centralized facilities
- **Mass Balance:** Centralized SMR plants emit more than twice as much CO_2 as the hydrogen produced (mass ratio), reflecting the stoichiometric relationship in the reforming process

Baseline Relevance: SMR without carbon capture serves as the primary benchmark for grey hydrogen and represents the most likely baseline scenario in regions with abundant natural gas resources. The widespread availability of natural gas infrastructure and the mature technology base make SMR the dominant incumbent technology for displacement.

Regional Variations:

- **North America/Europe:** Typically 8-9 $kgCO_2/kgH_2$ due to relatively clean natural gas
- **Middle East/Russia:** May reach 9-10 $kgCO_2/kgH_2$ depending on gas composition and flaring practices
- **Associated Gas Regions:** Higher emissions due to upstream methane leakage and flaring

(b) Coal Gasification

Coal gasification represents the most carbon-intensive hydrogen production pathway, involving the partial oxidation of coal at high temperatures (800-1200°C) to produce syngas, which is then processed through water-gas shift reactions and purification.

Technical Characteristics:

- **Emissions:** Highest among all pathways, typically **14–15 $kgCO_2/kgH_2$**, reflecting coal's high carbon content and lower hydrogen-to-carbon ratio
- **Process Complexity:** Requires extensive gas cleaning and purification due to sulfur, ash, and other impurities
- **Energy Intensity:** Highly polluting and energy intensive, requiring substantial auxiliary power
- **Water Requirements:** Significant water consumption for cooling and gas cleaning processes

Regional Significance:

- **China:** Dominant hydrogen production method, accounting for significant share of global hydrogen from coal
- **India:** Growing utilization in industrial applications
- **Australia/South Africa:** Utilized where abundant low-cost coal is available

Baseline Considerations: Coal gasification represents the upper bound of emission intensity for baseline scenarios and is particularly relevant in coal-dependent economies. This pathway often serves as the conservative baseline assumption in regions where coal-based hydrogen production is historically dominant.

(c) Autothermal Reforming (ATR)

Autothermal reforming combines partial oxidation and steam reforming in a single reactor, offering operational advantages and better compatibility with carbon capture systems.

Technical Characteristics:

- **Emissions:** Similar to SMR, typically **9–11 $kgCO_2/kgH_2$** without carbon capture
- **Process Advantages:** Better heat integration, faster startup, and more flexible operation compared to SMR
- **CCS Compatibility:** More amenable to carbon capture due to higher CO_2 concentration in product stream
- **Operational Flexibility:** Can handle varying feedstock compositions and operational conditions

Carbon Capture Integration: ATR facilities are increasingly designed with carbon capture readiness, making them attractive for "blue hydrogen" applications where emissions reduction is prioritized while maintaining fossil fuel feedstocks.

(d) Fossil + CCS ("Blue Hydrogen")

The integration of carbon capture and storage (CCS) with fossil-based hydrogen production represents a transitional pathway toward low-carbon hydrogen while leveraging existing industrial infrastructure.

Technical Performance:

- **SMR + CCS:** Can achieve **1.5–3 $kgCO_2/kgH_2$** depending on capture efficiency (85-95%)
- **ATR + CCS:** Often more cost-effective for CCS integration due to higher CO_2 concentrations
- **Capture Technologies:** Post-combustion capture, pre-combustion capture, or oxy-fuel combustion

Technology Uncertainties:

- **Permanence:** Long-term storage security remains unproven at commercial scale
- **Leakage Risks:** Potential for CO_2 leakage from storage sites over geological timeframes
- **Cost Challenges:** Additional CAPEX and OPEX for capture, transport, and storage infrastructure
- **Storage Availability:** Geographic constraints on suitable geological formations

Methodological Treatment: Blue hydrogen pathways require careful assessment of capture efficiency, monitoring protocols, and long-term storage verification to avoid over-crediting emission reductions.

Section 1.02 Biogenic and Renewable-based Pathways

(a) Biomass Gasification

Biomass gasification converts organic feedstocks (wood, agricultural residues, municipal waste) into hydrogen through high-temperature thermochemical processes.

Technical Characteristics:

- **Direct Emissions:** Approximately **2–3 $kgCO_2/kgH_2$** from the gasification process itself
- **Carbon Neutrality:** Often considered carbon-neutral since CO_2 emissions are biogenic in origin
- **Feedstock Variability:** Performance varies significantly based on feedstock moisture content, composition, and quality
- **Scale Limitations:** Generally more suitable for distributed production due to feedstock logistics

Lifecycle Considerations:

- **Supply Chain Emissions:** Additional emissions from biomass collection, transport, drying, and preprocessing
- **Sustainability Criteria:** Must ensure sustainable sourcing to maintain carbon neutrality claims
- **Land Use Impacts:** Potential indirect land use change effects if dedicated energy crops are utilized

Baseline Applications: Biomass gasification may represent the baseline in regions with abundant agricultural or forestry residues, particularly where waste disposal alternatives have environmental costs.

(b) Electrolysis of Water

Water electrolysis represents the primary pathway for renewable-based hydrogen production, using electricity to split water into hydrogen and oxygen.

Technical Characteristics:

- **Emissions Range:** Typically **1–2 $kgCO_2/kgH_2$** when using grid electricity, but highly dependent on the carbon intensity of electricity used
- **Technology Types:**
  - **Alkaline Electrolysis:** Mature technology, 60-70% efficiency
  - **Proton Exchange Membrane (PEM):** Higher efficiency (65-75%), faster response times
  - **Solid Oxide Electrolysis (SOEC):** Emerging high-temperature option with potential for >80% efficiency

Renewable Integration:

- **Fully Renewable Power:** With 100% renewable electricity (solar, wind, hydro), emissions approach **0–0.5 $kgCO_2/kgH_2$**
- **Grid Mix Dependence:** Emission intensity scales directly with grid carbon intensity
- **Temporal Matching:** Emissions vary based on time-of-day renewable availability and grid dispatch

Green Hydrogen Definition: This pathway forms the basis for green hydrogen when powered by dedicated renewable energy sources, representing the environmental benchmark for this methodology.

(c) Photolysis and Solar Thermochemical Water Splitting

Direct solar water splitting represents emerging technologies with the potential for zero-emission hydrogen production.

Technical Status:

- **Emission Profile:** Near **0 $kgCO_2/kgH_2$** since they directly utilize solar energy without intermediate electricity conversion
- **Technology Readiness:** Currently at pilot and demonstration stages
- **Efficiency Challenges:** Lower conversion efficiencies compared to PV-electrolysis combinations
- **Development Timeline:** Commercial deployment expected 2030-2040

Research Directions:

- **Photoelectrochemical (PEC) Cells:** Direct sunlight-to-hydrogen conversion
- **Solar Thermochemical Cycles:** High-temperature solar processes for water splitting
- **Hybrid Systems:** Combining photovoltaic and thermal solar inputs

Section 1.03 Emerging Low-Carbon Pathways

(a) Methane Pyrolysis ("Turquoise Hydrogen")

Methane pyrolysis represents a potentially transformative pathway involving the thermal, thermocatalytic, or plasma decomposition of methane into hydrogen and solid carbon, eliminating direct CO_2 emissions.

Technical Approaches:

- **Thermal Pyrolysis:** High-temperature (>1000°C) cracking using external heat sources
- **Thermocatalytic Pyrolysis:** Catalyst-assisted decomposition at moderate temperatures (400-900°C)
- **Plasma Pyrolysis:** Electrical plasma-induced methane cracking with rapid reaction rates

Emission Profile:

- **Direct Emissions:** Potentially near zero if renewable heat sources are utilized
- **Indirect Emissions:** Depend on energy source for heating and electricity for plasma generation
- **Lifecycle Benefits:** Significantly lower than SMR across all impact categories

Economic Advantages:

- **Solid Carbon By-product:** Production of valuable solid carbon materials creates additional revenue streams
- **Carbon Applications:** Electronics, energy storage systems, tire production, agricultural additives, and construction materials
- **Techno-economic Competitiveness:** Potentially cost-competitive with SMR while offering superior environmental performance

Commercial Development:

- **Technology Maturity:** Multiple companies advancing toward commercial demonstration
- **Investment Activity:** Growing venture capital and industrial investment in pyrolysis technologies
- **Policy Support:** Increasing recognition in hydrogen strategies and clean energy policies

Methodological Implications: Turquoise hydrogen may represent a future baseline scenario in regions with abundant low-cost methane and renewable energy for process heat, requiring consideration in dynamic baseline approaches.

Section 1.04 Key Methodological Implications

(a) Baseline Alignment and Technology Selection

Primary Baseline Technologies: This methodology considers SMR, ATR, and coal gasification without CCS as representative baseline pathways, reflecting:

- **Global Prevalence:** These technologies represent >95% of current hydrogen production
- **Regional Appropriateness:** Technology selection varies by local fuel availability and industrial infrastructure
- **Economic Competitiveness:** Incumbent technologies with established supply chains and operational experience

Technology-Specific Baselines:

- **SMR-Dominant Regions:** North America, Europe, Middle East - baseline 8-10 $kgCO_2/kgH_2$
- **Coal-Dependent Regions:** China, India, selected Asian markets - baseline 14-15 $kgCO_2/kgH_2$
- **Mixed Technology Regions:** Weighted average based on historical production mix

(b) Downward Adjustment Requirements

High-Intensity Baseline Management: The substantial GHG intensities of fossil pathways necessitate immediate downward adjustments to prevent over-crediting:

- **Coal Gasification Regions:** Mandatory adjustment of 10-20% to account for potential efficiency improvements
- **SMR Regions:** Conservative adjustment of 5-10% to reflect best-practice operations
- **CCS Integration:** Anticipatory adjustments for potential blue hydrogen deployment

Dynamic Adjustment Triggers:

- **Technology Deployment:** Large-scale blue hydrogen projects may trigger baseline updates
- **Policy Changes:** Carbon pricing or emissions regulations affecting baseline technology economics
- **Market Shifts:** Significant changes in regional hydrogen production mix

(c) Project Boundary Relevance

Green Hydrogen Positioning: Electrolysis-based hydrogen powered by renewable electricity represents the optimal environmental performance:

- **Emission Intensity:** 0-0.5 $kgCO_2/kgH_2$ compared to 8-15 $kgCO_2/kgH_2$ for fossil alternatives
- **Emission Reduction Potential:** 85-100% reduction compared to fossil baselines
- **Scalability:** Technology readiness and decreasing costs support widespread deployment

Additionality Considerations:

- **Renewable Energy Sourcing:** Must demonstrate additionality of renewable electricity supply
- **Grid Integration:** Limited grid electricity use (≤10%) maintains emission reduction integrity
- **System Integration:** Co-location with renewable generation enhances project additionality

(d) Ambition and Technology Evolution

Progressive Baseline Stringency: Emerging technologies justify increasingly stringent baseline adjustments:

- **2025-2030:** Recognition of methane pyrolysis and advanced electrolysis in regional baselines
- **2030-2035:** Integration of blue hydrogen with high-efficiency CCS in baseline scenarios
- **2035-2040:** Potential inclusion of direct solar hydrogen pathways in technology mix

Innovation Incentives: The methodology framework supports continued innovation by:

- **Technology-Neutral Approach:** Allowing various green hydrogen production methods
- **Performance Standards:** Rewarding genuine emission reductions regardless of specific technology
- **Future-Proofing:** Dynamic baseline mechanisms accommodate technological advancement

Long-term Vision: The pathway analysis supports the methodology's alignment with Paris Agreement goals by establishing clear benchmarks for transitioning from high-carbon fossil hydrogen toward renewable-based production systems, ensuring environmental integrity while promoting technological innovation and deployment at scale