UK Government

UK Low Carbon Hydrogen Standard

Greenhouse Gas Emissions Methodology and Conditions of Standard Compliance

Version 4

January 2026

Contents

Update Notice

<u>LCHS Version 4 (January 2026)</u>

In previous versions of the UK Low Carbon Hydrogen Standard (LCHS), we signalled our intent to update the Standard at regular review points. This is to ensure that the documents remain fit for purpose and reflect our growing understanding of how new technologies work in practice, including how Hydrogen Production interacts with the broader energy system.

We published the original LCHS in July 2022, Version 2 in April 2023, Version 3 in December 2023, and have developed Version 4 since, with significant input from industrial, technical and legal stakeholders. Updates made in Version 4 reflect lessons learned from the application of Version 3 of the LCHS to the first Hydrogen Allocation Round, stakeholder feedback and evolving policy priorities, and focuses on improving the application and detail of the Standard. This includes further simplifying the material classification process for Refinery Off Gas, creating the opportunity for biomethane to be sourced from the gas grid, introducing a new process for evidencing renewable energy use to align more closely with existing processes in the energy sector and allowing gas-splitting hydrogen producers to incorporate the solid-carbon by-product into asphalt. We have also added a new section on stored Feedstocks and Fuels to provide better guidance to producers, and the overall guidance has been restructured, with amendments made throughout to provide further clarity. These updates will further support hydrogen producers with the application of the Standard to their projects.

This version of the LCHS is the version that is published for the purposes of The Hydrogen Production Revenue Support (Directions, Eligibility and Counterparty) Regulations 2023 and replaces any previous versions of the Standard for the purposes of the Regulations. This means that this version of the LCHS will be the one that is used for assessing eligibility under the Regulations.

Since Version 3, the following changes have been made:

Chapter 1:

No significant changes.

Chapter 2:

Multiple new defined terms added with expanded acronyms to ensure there is consistent use of terminology throughout the Standard. Some existing definitions clarified.

References included to any relevant Paragraphs.

Chapter 3:

Updated conditions of Standard Compliance based on new sections for Permissible End Uses of Solid Carbon and revised approach for evidencing Renewable Energy Guarantees of Origin certificates (REGOs).

Chapter 4:

No significant changes.

Chapter 5:

Input/output classification will now be determined by the Delivery Partner through the Data Collection and Monitoring Procedure.

Clarification of emissions to be accounted for from CO_2 capture and entry.

Introduction and clarification of emissions and audit requirements associated with Solid Carbon Sequestration and distribution.

Chapter 6:

No significant changes.

Chapter 7:

Pathways with a Feedstock edited to reflect biomethane update in Annex F.

Chapter 8:

Clarification of reporting for Solid Carbon.

Guidance on REGOs updated to reflect changes in Annex B.

Equivalent evidence to Single Line Diagrams now permissible.

Chapter 9:

No significant changes.

Chapter 10:

No significant changes.

Annex A:

No significant changes.

Annex B:

Overall structure changed to improve readability and clarity.

Updated information on evidence requirements to include alternative Electricity Supply arrangements outside of 'licensed suppliers' e.g., Metered Volume Reallocation Notification Agents.

Clarification of evidence requirements, including allowing evidence equivalent to Single Line Diagrams.

Updated process for Renewable Energy Guarantees of Origin (REGOs) use and requirements.

Clarification on the calculation of Transmission and Distribution Losses.

Annex C:

Updates made relating to the use of stored REGOs for Electricity Storage Systems, in line with changes to Annex B.

New section on Stored Feedstocks and Fuels, detailing the evidencing requirements and permissible chain of custody accounting approaches for Input Storage Systems.

Annex D:

Simplification of Refinery Off Gas classification compliance procedures.

Annex E:

No significant changes.

Annex F:

Expanded to provide detailed requirements for biomethane supply, including evidence obligations, and mass balance principles, treatment of losses and the Renewable Gas Guarantees of Origin (RGGOs) cancellation process.

Annex G:

No significant changes.

Annex H:

Further clarification on measuring solid Inputs and Outputs.

Clarification on emissions accounting for batch Inputs.

Data Annex:

Updated all emission factors and conversion values using the latest data, including projected grid carbon intensity and annual Transmission and Distribution Losses through to 2050.

Corrected key technical parameters such as hydrogen-specific volume constants, adiabatic compression efficiency, and electricity storage round-trip efficiency.

Expanded and refreshed data sources for multiple Inputs (e.g., electrolyser efficiency, steam methane reforming/auto-thermal reforming water Inputs, activated carbon, monoethanolamine, oxygen, salts, and other chemicals).

Added new emission factors for biomethane upstream emissions, propylene glycol, ferric chloride, citric acid, and other Input Materials.

Updated methodology and references for Fossil Waste Counterfactuals, upstream emissions, and indirect land use change values.

Updated confidence ratings and impact scores across Input Materials and corrected rounding errors in previous datasets.

Asphalt added as a Solid Carbon Permissible End Use.

Hydrogen Emissions Calculators (HEC):

New versions (v4.10) of the HECs have been published to incorporate the latest Eligible Hydrogen Production Pathways, latest Data Annex values and the updated GHG Emission Intensity Calculation Methodology.

Fugitive Hydrogen Emissions Risk Reduction Plan and Annual Report Templates:

No changes.

1. Introduction

1.1. The UK Low Carbon Hydrogen Standard ('the Standard') supports the UK's evolving hydrogen policy framework, with further details to be provided in the forthcoming Hydrogen Strategy.

1.2. The Standard defines what constitutes 'low carbon hydrogen' up to the point of production. The intent of the Standard is to ensure UK Hydrogen Production contributes to our GHG emission reduction targets under the Climate Change Act[1].

1.3. As we look to grow the UK's nascent hydrogen economy, we must consider the range of methods that could be used to produce low carbon hydrogen. These could cover a wide variety of Feedstocks, energy sources and technology processes, all with different GHG Emission Intensities and broader sustainability impacts.

1.4. This document (including its Annexes) and the Data Annex set out the requirements of complying with the Standard. It aims to assist Hydrogen Production Facilities in their Final GHG Emission Intensity calculations, providing the means to assess Consignments of Hydrogen Product against the GHG Emission Intensity Threshold, and to assess Hydrogen Production Facilities against the Conditions of Standard Compliance. The Data Annex provides data to support the required GHG emission calculations. This document (including its Annexes) and the Data Annex shall be used in their entirety for schemes that apply the Standard.

1.5. This document (including its Annexes) and the Data Annex may be updated at regular review points, giving rise to a new version of the Standard. This will help to ensure they remain fit for purpose and reflect our growing understanding of how Hydrogen Production methods work in practice, including the interaction between Hydrogen Production and the broader energy system. Updates may also be made to the extent any part of this document (including its Annexes) or the Data Annex are no longer able to operate as intended.

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[1] https://www.legislation.gov.uk/ukpga/2008/27/contents

2. Terminology

2.1.   Across the documents of the Standard, this document is commonly referred to as the Standard Document and contains the Annexes to the Standard. The separate document containing the data annex is referred to as the Data Annex.

2.2.   Across the documents of the Standard, "shall" is to be read as a requirement of the Standard, "should" as a recommendation, and "may" as a permissible option.

2.3.   Terms shall be defined as follows, for all the documents of the Standard:

Activity Flow: The energy rate, mass rate or volumetric rate of an Input or Output.

Activity Flow Data: The rate of Input or Output from a Step, given in units of either energy, mass or volume per time.

Allocation Factor: The percentage of Upstream Emissions and Step Emissions assigned to the Product or Co-Product from a Step, based on Equation 6 and Equation 7.

Balancing Market: The electricity market operated by the Irish System Operator to balance demand and supply of electricity in real time.

Balancing Mechanism: The electricity market operated by the Great Britain (GB) System Operator to balance demand and supply of electricity in real time.

Balancing Mechanism Units / Balancing Market Units (BMU): The units of trade within the Balancing Mechanism in Great Britain or Balancing Market in the island of Ireland. Each BMU accounts for a collection of plant and/or apparatus and is considered the smallest grouping that can be independently controlled.

Balancing and Settlement Code (BSC): A legal document which defines the rules and governance for the Balancing Mechanism and imbalance settlement processes of electricity in Great Britain.

Best Available Techniques (BAT): The most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole.

Bid Offer Acceptance: An instruction issued by the electricity Transmission Network System Operator when they accept a bid and/or offer from a company that has acceded to the Balancing and Settlement Code (BSC) or Trading and Settlement Code (TSC).

This includes a price and capacity that a company has committed to either consuming more electricity or generating less electricity.

Biomass Requirements: The requirement for a biogenic Input to meet the Sustainability Criteria, the Minimum Waste and Residue Requirement, and report on estimated indirect land-use change (ILUC) greenhouse gas (GHG) emissions.

Biomethane Guarantees of Origin Certificate: A documentary instrument issued under a recognised voluntary scheme that evidences the production of biomethane and its associated low carbon attributes.

Biomethane Mass Balance Period: The period over which at least as much biomethane must be evidenced as being physically delivered and tracked to a Hydrogen Production Facility as is claimed for use as an Input to Hydrogen Production at such Hydrogen Production Facility. The Biomethane Mass Balance Period shall not exceed 3 months.

Biomethane Mass Balance System: A defined infrastructure (e.g. pipeline grid or Balancing Zone) where the quantity of certified biomethane entering and exiting the system is tracked and reconciled. Physical separation of biomethane and fossil natural gas is not required, but energy content reconciliation of the biomethane is required. The system must ensure physical delivery, tracking through recognised registries, and cancellation of associated certificates within the Biomethane Mass Balance Period to maintain integrity and prevent double counting.

Biomethane Production Facility: A plant that is producing biomethane, including all ancillary equipment and infrastructure.

Biomethane Supply Chain Losses: The volumetric percentage of biomethane lost between the Biomethane Production Facility and Hydrogen Production Facility accounting for all transport modes.

Buffer Storage: Temporary storage of hydrogen at the Hydrogen Production Facility, prior to any hydrogen Compression and Purification, used solely for operational purposes such as balancing out production system fluctuations.

Carnot Efficiency: The maximum theoretical efficiency that a heat engine may have operating between two given temperatures. It is used in the Energy Allocation methodology when heat or steam is a Co-Product, to convert MJ_{LHV} energy values into MJ_{LHV} useful energy values for steam or heat. Refer to Equation 8 and Paragraph 5.15 for further details.

CO_2 Capture and Network Entry: An Emission Category including emissions associated with purification, compression, temporary storage and transport of CO_2, up to and including entry into a CO_2 T&S Network. Refer to Paragraphs 5.46 - 5.49 for further details.

CO_2 Capture and Sequestration (CCS): The equipment or infrastructure for capturing CO_2 from a process stream in the Hydrogen Production Facility, any purification and compression of the CO_2, any transport including via a CO_2 T&S Network before injection into geological storage.

CO_2 Emission Intensity: The carbon dioxide emissions produced per unit of energy or mass for a given Activity Flow. For Activity Flows containing energy, this is given in grams of carbon dioxide per megajoule (using Lower Heating Values), i.e. gCO_2/MJ_{LHV}. For Activity Flows not containing energy, it is expressed in grams of carbon dioxide per kilogram, i.e. gCO_2/kg.

CO_2 Sequestration: An Emission Category that credits the sequestration of CO_2 in underground geological storage using a CO_2 T&S Network, as further detailed in Paragraphs 5.50 - 5.54**.**

CO_2 T&S Network: A 'transport and storage network' as defined by Chapter 1, 1(9) of the Energy Act 2023[2].

CO_2 T&S Network Operator: A company licensed to provide transport and storage services for the CO_2 T&S Network.

CO_2 T&S Network Delivery Point: The connection point at which carbon dioxide is delivered into the CO_2 T&S Network.

Compression and Purification: An Emission Category including emissions for the theoretical Compression and Purification of the Hydrogen Product to meet the minimum pressure and purity under the Standard, as further detailed in Paragraphs 5.71 - 5.75.

Conditions for Standard Compliance: A list of requirements set out in Paragraph 3.4 that need to be satisfied in order for a Hydrogen Production Facility to have the ability to generate Hydrogen Product compliant with the Standard.

Consignment: An amount of Hydrogen Product to which emissions are allocated. A Consignment can be a Discrete Consignment (see definition below) or a Weighted Average Consignment (see definition below), as the context requires.

Co-Products: The Electricity, Useful Heat or materials (which are not Wastes or Residues, as defined in Chapter 2) that are produced at the same time as a main Product from a Step.

Cross-Border Interconnection Point: A physical or contractual interface between two mass balance systems (e.g. UK and EU gas grids) where biomethane flows are nominated and tracked.

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[2] https://www.legislation.gov.uk/ukpga/2023/52/contents/enacted

Cumulative Allocation Factor: The percentage of GHG emissions from a Step or multiple Steps that will be assigned to the Hydrogen Product, as set out in Paragraphs 5.18 - 5.19.

Cumulative Non-Production Emissions: The total GHG emissions that are generated during consecutive Reporting Units where there is no Hydrogen Product generated.

Data Annex: The document titled as Data Annex: Data for calculating Greenhouse Gas Emissions under the UK Low Carbon Hydrogen Standard.

Data Collection and Monitoring Procedure (DCMP): The agreement between the Hydrogen Production Facility and the Delivery Partner for the establishment of suitable procedures to evidence compliance with the Standard, including for the measurement and sampling of Input and Output flows. Further details are given in Chapter 8 and Annex H.

Default Data: The conservative data provided in the Data Annex by DESNZ for use by pre-operational Hydrogen Production Facilities only, where Projected Data, and/or Typical Data and Non-Typical Data is unavailable for any Emission Sources within the Feedstock Supply, Energy Supply and/or Input Material Emission Categories.

Delivery Partner: A government-appointed organisation to help deliver a government scheme, who is responsible for assessing compliance by Hydrogen Production Facilities with the Standard.

Design Capacity: The maximum volume of electricity in kWh_e that can be discharged after losses from an Electricity Storage System at the start of its lifetime, when fully charged and without any further charging. This may be smaller than the maximum energy storage within the system.

Discrete Consignment: An amount of Hydrogen Product which shares the same Environmental Characteristics (including GHG Emission Intensity) within a Reporting Unit. Discrete Consignments are determined by the Feedstock(s) for Pathways with a Feedstock, or by the energy Input(s) for Pathways without a Feedstock. Refer to Paragraphs 7.3 - 7.9.

Distribution Losses: The losses incurred (expressed as a percentage) from the entry point (could be from a generator, a transmission or Private Network connection point) to the exit point (could be the Hydrogen Producer, a transmission or Private Network connection) of the Distribution Network.

These losses are typically calculated using an initial volume and Line Loss Factors (LLF) in GB or Distribution Loss Adjustment Factors (DLAF) in NI, which can in turn be used to calculate a percentage.

Distribution Loss Adjustment Factor (DLAF): A multiplier used to adjust initial metered volumes for market participants in NI depending on:

- If a market participant is found to be increasing network losses; or

- If a market participant is found to be decreasing network losses.

DLAFs are expressed as a value slightly above or below 1.000 depending on the extent to which a market participant increases or reduces Transmission Losses.

Distribution Network Operator (DNO): An entity that operates an onshore electricity Distribution Network, holding a distribution licence in Great Britain.

Distribution Network: For electricity, the onshore Electricity Supply infrastructure connecting GB's and NI's electricity Transmission Network to lower voltage users. For gas, the UK's natural gas supply infrastructure connecting the gas Transmission Network to lower pressure users.

Distribution System Operator (DSO): An entity that operates an onshore electricity Distribution Network, holding a distribution licence in Northern Ireland.

Downstream Transmission & Distribution (T&D) Losses: The T&D Losses between the Electricity Storage System and the Hydrogen Production Facility.

Electricity Curtailment Avoidance: The electricity consumed from the Transmission or Distribution Network which would have otherwise led to electricity curtailment, as evidenced by a Bid Offer Acceptance. Further details given in Annex B.

Electricity Grid: An interconnected network to deliver electricity which includes both the high-voltage electricity Transmission Network that connects major electricity generators with local electricity Distribution Networks, and the electricity Distribution Networks that connect the electricity Transmission Network to lower voltage consumers.

Electricity Storage System: A rechargeable asset that uses an electrical Input to fill up or "charge" for the purpose of energy storage and then converts this energy storage to an electrical Output to drain or "discharge" energy storage. Uninterruptable power supply and capacitors within the Hydrogen Production Facility are excluded from this definition.

Electricity Supply: A sub-category within Energy Supply that accounts for the emissions associated with the consumption of Input electricity by the Hydrogen Production Facility. Refer to Paragraphs 5.29 - 5.30.

Electricity Supply Party: A party who provides electricity to a Hydrogen Production Facility through associated arrangements with those generators (or Electricity Storage Systems). An Electricity Supply Party is not necessarily required to hold an Electricity Supply license, e.g., Metered Volume Reallocation Notification Agents.

Eligible Biomethane Purchase Agreement (BPA): A contractual arrangement for the sale, purchase and Transfer of Title for biomethane that meets all the evidence requirements for the relevant source of that biomethane as set out in Annex F, but not including any Excluded BPA.

Eligible Hydrogen Production Pathway: A Hydrogen Production Pathway listed in Paragraph 4.2.

Eligible Power Purchase Agreement (PPA): A contractual arrangement for the sale, purchase and Transfer of Title for electricity that meets all the evidence requirements for the relevant source of that electricity as set out in the first row of Table 3 in Annex B, but not including any Excluded PPA.

Emission Category: A grouping of GHG emissions from similar Inputs or Outputs, used for reporting a breakdown of the Hydrogen Product GHG Emission Intensity. These groupings are organised into Feedstock Supply, Energy Supply, Input Materials, Process CO_2, Fugitive non-CO_2, CO_2 Capture and Network Entry, CO_2 Sequestration, Solid Carbon Distribution, Solid Carbon Sequestration, theoretical Compression and Purification, and Fossil Waste/Residue Counterfactual emissions, as relevant. See Chapter 5 for more details.

Emission Source: Any individual Input or Output that has an associated GHG Emission Intensity or GWP. Emissions from multiple sources of the same Input are to be considered together within one Emission Source, as are multiple sources of the same Output.

Energy Allocation: A GHG accounting approach which assigns Upstream and Step Emissions to the Products and Co-Products from that Step, according to their proportion of the Step's total useful Output energy as measured on a Lower Heating Value basis. Refer to Paragraph 5.14 for more details.

Energy Supply: An Emission Category consisting of emissions from Electricity Supply, Steam Supply, Heat Supply and Fuel Supply detailed in Paragraphs 5.25 - 5.27.

Environmental Characteristics: The characteristics of a Discrete Consignment defined in Paragraphs 7.4 - 7.5.

Estimated Data: The Activity Flow Data for an operational Hydrogen Production Facility which is not Measured Data.

Excluded Biomethane Purchase Agreement (BPA): A contractual agreement for the sale, purchase, and Transfer of Title for biomethane that has been produced using hydrogen as a Feedstock in the production process.

Excluded Power Purchase Agreement (PPA): A contractual arrangement for the sale, purchase and Transfer of Title in electricity generated from either:

(a) Any generator that uses hydrogen as a Fuel source to generate electricity.

(b) Any generator with CO_2 Capture and Sequestration that uses fossil natural gas as a Fuel source to generate electricity.

Where electricity generator(s) and Hydrogen Production Facilities are owned by the same legal entity, the exclusion of electricity generated from the two scenarios listed above still applies.

Facility: Same as a Hydrogen Production Facility.

Feedstock: An energy-containing material that undergoes a chemical or biological conversion process to generate another material e.g., biomass converted to biomethane, or natural gas converted to hydrogen.

Feedstock Gas: This includes natural gas, Refinery Off Gas (ROG), biomethane, Waste industrial gases, and other fossil, renewable, or biogenic gases.

Feedstock Supply: An Emission Category comprising emissions from Feedstock extraction, cultivation, collection, harvesting, pre-processing, storage, and transportation Steps detailed in Paragraph s - 5.24.

Final Greenhouse Gas (GHG) Emission Intensity: The calculated GHG Emission Intensity for a Discrete Consignment after any addition of extra emissions from Reporting Units where there is no Hydrogen Product generated. Refer to the methodology to calculate Final GHG Emission Intensity from Raw GHG Emission Intensity given in Paragraphs 7.24 - 7.27.

Forest Criteria: A minimum set of requirements for forest biomass to meet, including consideration of certain protected areas, harvesting, soil, biodiversity, regeneration, and carbon stock accounting. Refer to Annex E. 42 - E. 44 for more details.

Fossil Waste/Residue Counterfactual: An Emission Category that comprises the additional emissions incurred from diversion of a fossil Waste/Residue Feedstock from its prior use and accompanying reduction in fossil CO_2 detailed in Paragraphs 5.76 - 5.81.

Fuel: An energy-containing material that is combusted to produce electricity, heat or steam in Hydrogen Production. e.g., biomass combusted offsite to generate electricity for Hydrogen Production, or diesel combusted onsite in a generator to provide electricity for Hydrogen Production. Note that where a Fuel is the same as a Feedstock (e.g., natural gas used to fire a natural gas reformer), both flows are to be considered together as a Feedstock, not as a Fuel.

Both Feedstock and Fuel Inputs have Lower Heating Values and may contribute to the overall GHG Emission Intensity of Hydrogen Production. Their treatment under the LCHS depends on their role in the process and associated emissions.

Fuel Mix Disclosure (FMD): The requirement on all licensed electricity suppliers in Great Britain to disclose to their customers the mix of Fuels used to generate the electricity supplied annually, under the Electricity (Fuel Mix Disclosure) Regulations 2005 (SI 2005 No. 391). Suppliers shall evidence their Renewable Electricity procurement via submitting REGOs to Ofgem. There are equivalent requirements for suppliers licenced in Northern Ireland.

Fuel Supply: Emissions associated with the production, processing, and delivery of Input Fuels used to provide energy to the Hydrogen Production process. Refer to Paragraphs 5.32 - 5.33 for details.

Fugitive Hydrogen Emissions: Both the unintentional release of hydrogen (e.g., leaks) and the deliberate release through processes (e.g., purging or venting).

Fugitive Hydrogen Emissions Annual Report: The estimated Fugitive Hydrogen Emissions in the past year and actions taken to mitigate these, as defined in Paragraph 10.10 – 10.12.

Fugitive Hydrogen Emissions Risk Reduction Plan: A plan demonstrating how the Hydrogen Production Facility will be operated, and Fugitive Hydrogen Emissions will be monitored and mitigated to ensure that Fugitive Hydrogen Emissions are kept as low as reasonably practical.

Fugitive non-CO_2: An Emission Category that comprises the emissions of Greenhouse Gases other than CO_2 that are released from the Hydrogen Production Facility. Refer to Paragraphs 5.39 - 5.44. for further details.

Gate Closure: A point one hour prior to the start of a Settlement Period, by which BSC parties shall have submitted information to the System Operator regarding their planned production or consumption in the Settlement Period.

Global Warming Potential (GWP): The amount of carbon dioxide (CO_2) for any Greenhouse Gas that would cause an equivalent amount of global warming as the selected GHG over a given time period. This measures the radiative forcing from the emission of one mass unit of a given GHG in the present-day atmosphere integrated over a chosen time horizon, relative to the emissions of one mass unit of carbon dioxide. The units are given as grams of carbon dioxide equivalent per gram (gCO_2e/g).

Greenhouse Gas (GHG): The gases in the atmosphere, both naturally occurring and generated from human activity, that cause global warming by trapping heat in the Earth's atmosphere, land and oceans. Those gases in scope are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen trifluoride (NF_3), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6), as listed in the Data Annex.

Greenhouse Gas (GHG) Emission Intensity: The Greenhouse Gas emissions produced per unit of energy or mass for a given Activity Flow. For Activity Flows

containing energy, this is expressed in units of carbon dioxide equivalents (using GWPs) per megajoule (using Lower Heating Values), i.e. gCO_2e/MJ_{LHV}. For Activity Flows not containing energy, it is expressed in units of carbon dioxide equivalents per kilogram, i.e. gCO_2e/kg.

Greenhouse Gas (GHG) Emission Intensity Calculation Methodology: The methodology used to calculate the total GHG emissions from each Emission Source. Refer to Chapter 5 for details.

Greenhouse Gas (GHG) Emission Intensity Threshold: The maximum GHG Emission Intensity for a Consignment. The final GHG Emission Intensity to be compliant with the Standard maximum of 20.0 gCO_2e/MJ_{LHV} Hydrogen Product, as given in Paragraph 3.3.

Gross Meter: A meter that records Activity Flow Data in one direction only, without subtracting any flows that occur in the opposite direction.

Heat Supply: A sub-category within Energy Supply that compromises the emissions associated with consumption of Input heat by the Hydrogen Production Facility, refer to Paragraph 5.31 for details.

Higher Heating Value: A measure of the energy content of a substance, also known as the Gross Calorific Value, that includes the latent heat of vaporisation of any moisture in the substance and arising from combustion of hydrogen atoms in the substance.

Hydrogen Emissions Calculator (HEC): A tool published by DESNZ alongside the Low Carbon Hydrogen Standard for pre-operational Hydrogen Production Facilities to use to calculate whether their future Hydrogen Production is likely to comply with the GHG Emission Intensity requirements of the Standard. Refer to Paragraph 8.6.

Hydrogen Product: The Output from the Hydrogen Production Facility, containing hydrogen and any impurities, as measured by the hydrogen meter.

Hydrogen Production Facility: A plant that is producing hydrogen, including all ancillary equipment and infrastructure within the scope of the System Boundary (for example, CO_2 capture plant, compression, on-site Hydrogen Storage). Unless otherwise stated, this plant is assumed to be operational.

Hydrogen Production Pathway: A combination of physical supply chain Steps, starting with the Feedstock, and finishing with the Hydrogen Production Facility. Paragraphs 5.1 - 5.3 define where the System Boundary starts for the Feedstock.

Hydrogen Storage: The hydrogen storage at the Hydrogen Production Facility that occurs after Compression and Purification of the Hydrogen Product, excluding Buffer Storage.

Identity Preservation: A chain of custody approach where all material stored within an Input Storage System is kept physically isolated from any other material. The Input Storage System shall only contain material from a single source at any one time, and have the same Environmental Characteristics, including GHG Emission Intensity.

Immaterial Emission Source: An Emission Source that contributes GHG emissions that are below the Materiality Threshold.

Input: A material or energy flow that enters a Step.

Input Materials: Substances or compounds used within the Hydrogen Production process, but which are not Feedstock or Fuel, and either have no Lower Heating Value or are not used for providing energy services.

Input Storage System: An asset in which Feedstocks and Fuels may be stored prior to their use at a Hydrogen Production Facility. An Input Storage System may be an individual container or may comprise multiple tanks/vessels/chambers in one location. Note that this does not include the storage of electricity (which is covered under Electricity Storage System) or Input Materials.

Land Criteria: A minimum set of requirements for certain biomass Feedstocks to meet, to ensure preservation of biodiversity and carbon stocks. Refer to Annex E Paragraphs E. 33 - E. 34. for details.

Ledger-Based Mass Balance: A chain of custody approach for an Input Storage System where Inputs, stored materials and Outputs are recorded in a ledger, with the Input Storage System Operator choosing which Inputs (or parts of Inputs) are recorded as exiting the system and therefore which remain.

Line Loss Factor (LLF): A multiplier used to determine:

- The volume of electricity that is required to be input into a GB Distribution Network (or a GB Private Network) to overcome electricity Distribution Losses and supply a Hydrogen Production Facility, or

- The volume of electricity available on a GB Distribution Network (or a GB Private Network) after electricity Distribution Losses from the point of generation have been accounted for.

LLFs are expressed as a value slightly above 1.000 in the case of a consumer, and slightly below 1.000 in the case of a generator.

Lower Heating Value (LHV): A measure of the energy content of a substance, also known as the Net Calorific Value. Specifically, it is the amount of heat released in the combustion of a specified quantity of the substance. For the purposes of Consignment sizes and Step efficiencies, this LHV measure takes into account the energy content of the substance including the latent heat of vaporisation of any moisture in the substance.

For the purposes of Co-product Energy Allocation, this LHV measure takes into account the energy content of the substance excluding the latent heat of vaporisation of any moisture in the substance.

Material Emission Source: An Emission Source that contributes GHG emissions that are above the Materiality Threshold.

Materiality: An estimation and identification of an Emission Source as either a Material Emission Source that needs to be included within the GHG Emission Intensity Calculation Methodology, or as an Immaterial Emission Source that does not need to be included.

Materiality Threshold: A maximum threshold of 0.2 gCO$_2$e/MJ$_{LHV}$ Hydrogen Product for an Immaterial Emission Source provided the sum of all Immaterial Emissions Sources is also below 1.0 gCO$_2$e/MJ$_{LHV}$ Hydrogen Product. Further details are given in Paragraphs 5.84.

Measured Data: Any Activity Flow Data for a Hydrogen Production Facility that is metered, weighed, sampled or analysed using compositional analysis.

Measurement and Meter Failure: This occurs when the Hydrogen Production Facility fails to record, or report measured or metered data when required. Refer to Annex H. 43. for further details.

Minimum Waste and Residue Requirement: A minimum proportion of 50% (by LHV energy content) of the biohydrogen produced in a calendar month that shall be derived from Inputs classified as biogenic Wastes or biogenic Residues.

Monitoring, Reporting and Verification (MRV): the process of metering, measuring and recording the data required for compliance with the Standard; compiling and reporting this information; and this reported data being subject to review and verification.

Net Meter: A meter that records Activity Flow in a particular direction but subtracting any flows that occur in the opposite direction.

Non-Typical Data: A GHG Emission Intensity value for an Input or Output, that is not sourced from the Data Annex.

Output: A material or energy flow that leaves a Step.

Partial Scope 3 Emissions: A Pathway's indirect GHG emissions other than those covered in Scope 1 and Scope 2, and which include upstream supply chain emissions until the System Boundary but not including any downstream emissions from Hydrogen Product distribution and use.

Pathway: An Eligible Hydrogen Production Pathway.

Precursor Feedstock: An energy containing material that after physical, biological or chemical conversion within the supply chain becomes a Feedstock for Input to a Hydrogen Production Facility. For example, biogas sent to a biomethane upgrading facility, or wood chips sent to a biomass pellet plant.

Primary Balancing Mechanism Units (BMU): The units used under the Balancing and Settlement Code to account for all electricity that flows on or off the combined Transmission Network and Distribution Networks in Great Britain. A Primary BMU is the smallest grouping of generation and/or demand equipment that can be independently metered for settlement, and all electricity generation and demand equipment in GB shall be captured in a Primary BMU.

Private Network: A local Electricity Grid in GB or NI connecting electricity generators and consumers, operated by an organisation other than a DNO, DSO or electricity Transmission Network System Operator, that supplies electricity to a Hydrogen Production Facility. This local Electricity Grid may or may not connect to the wider national Electricity Grid.

Process CO_2: An Emission Category that compromises the amount of CO_2 generated within the Hydrogen Production Facility. Further details are given in Paragraphs 5.37 - 5.38.

Product: A material, electricity or Useful Heat Output that is the primary aim of a Step in the Pathway; or alternatively, a material that has been intentionally modified or contaminated in an attempt to classify it as a Residue or Waste.

Projected Data: The data projected by pre-operational Hydrogen Production Facilities based on the design and expected performance of the Hydrogen Production Facility.

Raw Greenhouse Gas (GHG) Emission Intensity: The GHG Emission Intensity for a Discrete Consignment before any addition of extra emissions from periods without Hydrogen Production. Refer to Paragraph 7.24 - 7.27 for details.

Refinery: An industrial installation where crude oil is thermo-chemically converted into a range of different Fuels and other products.

Refinery Off Gas (ROG): A variable mixture of methane, hydrogen, and other light hydrocarbons plus impurities that arise directly from Refinery conversion unit operations.

Refinery Off Gas (ROG) Refinery: The specific Refinery from which a ROG Stream originated.

Refinery Off Gas (ROG) Stream: The ROG as received at the Hydrogen Production Facility, after any processing and/or separation steps at the Refinery.

Refinery Unit: The process Step at the Refinery responsible for generating the Precursor ROG Stream used for Hydrogen Production prior to any processing/separation.

Regional GHG Emission Intensity: A dataset for the GB Electricity Grid GHG Emission Intensity broken down by area, measuring the gCO_2 emissions per kilowatt hour of electricity consumed.

Renewable Electricity: Electricity generated by a renewable non-fossil energy source, for example, wind, solar, hydropower, tidal, wave, hydrothermal, aerothermal and geothermal sources, as well as biogenic Feedstocks.

Renewable Energy Guarantees of Origin (REGO): The certification scheme which provides transparency to consumers regarding the proportion of electricity that suppliers source from Renewable Electricity generators, as part of their Fuel Mix Disclosure obligations. One REGO certificate is issued per megawatt hour (MWh) of eligible renewable Output to generators of Renewable Electricity.

Renewable Energy Guarantees of Origin (REGO) Percentage: The percentage of the electricity consumed that arises from REGO registered electricity generators.

Renewable Energy Guarantees of Origin (REGO) Year: 1st April to 31st March.

Renewable Electricity Register (RER): A web-based system used by Ofgem to manage several schemes administered on behalf of government, including the REGO scheme.

Reporting Unit: A 30-minute period of time used to calculate and report GHG emissions under the Standard. The first Reporting Unit in each day starts at midnight.

Residue: A substance that is not the end Product sought directly from the Step in the Pathway; the production of which is not a primary aim of the Step; and which has a low economic value (approximately 10% or less) in relation to the Products or Co-Products from the Step.

Residues from Agriculture, Aquaculture, Fisheries or Forestry: Residues that are directly generated by agriculture, aquaculture, fisheries, or forestry. These do not include Residues from related industries or processing.

Round Trip Efficiency: The average percentage of electricity Input into an Electricity Storage System that can be discharged from the Electricity System Storage, after taking into account all internal losses. Refer to Annex C Paragraph C. 12 for further details.

Scope 1 Emissions[3]: A Hydrogen Production Facility's direct GHG emissions.

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[3] Corporate Standard Frequently Asked Questions | GHG Protocol

Scope 2 Emissions: The GHG emissions associated with the generation of electricity, heat, steam, and cooling outside of the Hydrogen Production Facility that are consumed by the Hydrogen Production Facility.

Secondary Balancing Mechanism Units (BMU): The units used under the Balancing and Settlement Code to account for all electricity that flows on or off the combined Transmission Network and Distribution Networks in Great Britain. Secondary BMUs can only be registered by Virtual Lead Parties.

Self-Discharge Loss: The ongoing losses of energy inherent to an Electricity Storage System including when the Electricity Storage System is not in use. Refer to Annex C for further information.

Sequential Mass Balance: A chain of custody approach for an Input Storage System that assumes what Input enters an Input Storage System last is then the first to be removed ('last in first out') or what Input enters an Input Storage System first is then the first to be removed ('first in first out').

Settlement Period: A period of 30 minutes beginning on the hour or the half-hour, over which the Balancing Mechanism or Balancing Market operates to correct any imbalances between generation and consumption on the Electricity Grid.

Single Line Diagram: A symbolic representation of the electrical system, using lines that represent all three phases, indicating any generators (including standby generators), meters, interconnectors, and grid connection points, providing voltages and maximum currents on each line. Other equivalent information may be utilised in lieu of evidencing Single Line Diagrams, where the form and content of this information is deemed satisfactory to the Delivery Partner.

Soil Carbon Criteria: A minimum set of requirements for agricultural Residues/Wastes to demonstrate monitoring or management plans are in place to address the impacts on soil quality and soil carbon from the harvesting of the biomass. Refer to Annex E. 39 - E. 41 for further details.

Solid Carbon: Elemental carbon (plus impurities) in a solid state. Solid Carbon can exist in different structural forms e.g., carbon black, graphite, graphene.

Solid Carbon Distribution: An Emission Category that comprises the emissions from any transport, storage, and further processing of Solid Carbon from the Hydrogen Production Facility, further detailed in Paragraphs 5.54 - 5.62.

Solid Carbon End User Point: The point agreed with the Delivery Partner where it is deemed that Solid Carbon is sequestered in a Solid Carbon Permissible End Use.

Solid Carbon Permissible End Uses: A list of uses for Solid Carbon given in the Data Annex under Solid Carbon Sequestration.

Solid Carbon Sequestration: An Emission Category further detailed in Paragraphs 5.63 - 5.70. that comprises the use of Solid Carbon in those permitted end uses given in the Data Annex under Solid Carbon Sequestration.

Standard: The UK Low Carbon Hydrogen Standard, as set out in this document (including its Annexes) and the Data Annex.

Standard Compliance: This includes adherence to the GHG Emission Intensity Threshold and all the Conditions for Standard Compliance. Refer to Paragraph 3.3.

Standard Document: This document (including its Annexes).

State of Charge (SoC): A measurement of the volume of electricity available in an Electricity Storage System compared with its present capacity, expressed as a percentage.

State of Health (SoH): The State of Health is a measurement of the present capacity of an Electricity Storage System compared with its Design Capacity, expressed as a percentage.

Steam Supply: A sub-category within Energy Supply that compromises the emissions associated with the consumption of Input steam by the Hydrogen Production Facility. See Paragraph 5.30.

Step: Any physical stage in the Pathway from Feedstock through to the Hydrogen Production Facility. Steps include (where relevant) Feedstock production, any intermediate pre-processing, Feedstock storage and transport, as well as the Hydrogen Production Facility generating hydrogen (the final Step in the Pathway).

Step Emissions: The GHG emissions associated with each physical stage in the Pathway.

Stored Electricity Greenhouse Gas (GHG) Emission Intensity: The GHG Emission Intensity of the electricity stored within an Electricity Storage System.

Stored Electricity Greenhouse Gas (GHG) Emission Intensity Tracker: The dataset maintained by the operator of the Electricity Storage System that updates the Stored Electricity GHG Emission Intensity every Reporting Unit.

Stored Input Greenhouse Gas (GHG) Emission Intensity: The GHG Emission Intensity of Feedstocks or Fuels stored within an Input Storage System.

Stored Input Greenhouse Gas (GHG) Emission Intensity Tracker: The dataset maintained by the operator of the Input Storage System that updates the Stored Input GHG Emission Intensity every Reporting Unit.

Stored Renewable Energy Guarantees of Origin (REGO) Percentage: The percentage of the electricity stored within an Electricity Storage System that arises from REGO registered electricity generators.

Stored Renewable Energy Guarantees of Origin (REGO) Percentage Tracker: The dataset maintained by the operator of the Electricity Storage System that updates the Stored REGO Percentage every Reporting Unit.

Supply Chain Losses: The energy-based losses that occur during the transport, handling, and storage of an Input between its point of production and its point of use. This includes losses across all transport modes (e.g., pipeline, truck, ship), intermediate processing steps (e.g., liquefaction, regasification), and storage facilities. See Paragraph F. 10 - F. 17. This definition applies to all Inputs except electricity, for which losses are defined separately under Transmission and Distribution Losses Paragraph B. 26.

Sustainability Criteria: The Land Criteria, Soil Carbon Criteria, and Forest Criteria.

System Boundary: The Steps which should be included in the Hydrogen Product GHG Emission Intensity Calculation Methodology, and at what point an Input or Output to the Pathway is included within the GHG Emission Intensity Calculation Methodology. Refer to Paragraphs 5.1 - 5.3 for further details.

System Operator: An organisation responsible for the Transmission or Distribution of electricity to the Hydrogen Production Facility.

Temporal Correlation: A requirement for a specific generator to evidence they are generating at least as much electricity during each Reporting Unit as is being claimed to be consumed by the Hydrogen Production Facility (or Electricity Storage System if applicable), factoring in any Transmission and Distribution Losses.

Trading and Settlement Code (TSC): A legal document which defines the rules and governance for the Balancing Mechanism and imbalance settlement processes of electricity in the island of Ireland.

Transfer of Title: The contractual process that transfers ownership of:

> (a) Electricity volumes from the electricity generator or party supplying this electricity, to the Hydrogen Production Facility; or

> (b) Biomethane from the biomethane producer or supplier to the Hydrogen Production Facility.

This may include direct contracts or associated arrangements, provided that traceability, delivery, and compliance with relevant supply configuration requirements are maintained.

Transmission Losses: The losses incurred (expressed as a percentage) from the entry point (could be from a generator, a distribution or Private Network connection point) to the exit point (could be the Hydrogen Producer, a distribution or Private Network connection) of the Transmission Network.

These losses are typically calculated using an initial volume and Transmission Loss Multipliers (TLM) in GB or Transmission Loss Adjustment Factors (TLAF) in NI, which can in turn be used to calculate a percentage.

Transmission Loss Adjustment Factor (TLAF): A multiplier used to adjust initial metered volumes from market participants in NI depending on:

- If a market participant is found to be increasing network losses; or

- If a market participant is found to be decreasing network losses.

TLAFs are expressed as a value slightly above or below 1.000 depending on the extent to which a market participant increases or reduces Transmission Losses.

Transmission Loss Multiplier (TLM): A multiplier used to determine:

- The volume of electricity that is required to be input into a GB Transmission Network (or a GB Private Network) to overcome losses and supply a GB Distribution Network (or a Hydrogen Production Facility directly), or

- The resulting volume of electricity on a GB Transmission Network (or a GB Private Network) after losses from the point of generation have been accounted for.

TLMs are expressed as a value slightly above 1.000 in the case of a consumer, and slightly below 1.000 in the case of a generator.

Transmission and Distribution Losses (T&D Losses): The percentage of the generated electricity lost between the point of metered electricity generation and the point of metered electricity consumption (either Hydrogen Production Facility or Electricity Storage System, as appropriate).

Transmission Network: For electricity, the long-distance Electricity Supply infrastructure in GB and in NI, operating at voltages significantly above the electricity Distribution Network. For gas, the long-distance gas transport infrastructure in the UK, operating at pressures significantly above the gas Distribution Network.

Typical Data: The GHG Emission Intensity values given in the Data Annex that shall be used in the GHG Emission Intensity Calculation Methodology for those Inputs and Outputs listed in the Data Annex.

UK Gas Network: The natural gas infrastructure in the UK used for transportation and distribution of gas. This includes the long-distance high-pressure natural gas infrastructure.

Uninterruptible Power Supply (UPS): A type of power system that provides automatic emergency backup electrical power when the typical Input power source fails.

Upstream Emissions: The cumulative GHG emissions from all the Steps within the System Boundary preceding the current Step being evaluated. For example, if the Step being evaluated were the Hydrogen Production Facility, the Upstream Emissions would compromise the whole of the supply chain for the Feedstock.

Upstream Transmission and Distribution (T&D) Losses: The T&D Losses between the electricity generation asset and the Electricity Storage System.

Useful Heat: The heat generated to satisfy an economically justifiable demand for heat.

Useful Steam: The steam generated to satisfy an economically justifiable demand for heat.

Valorise: The export of a material from a Step to customers or use of that material for onsite operations. For hydrogen, this excludes Fugitive Hydrogen Emissions and any Hydrogen Production that is disposed of at the Hydrogen Production Facility, but includes hydrogen sold or sent to onsite Hydrogen Storage.

Virtual Lead Party: An independent agent that controls (potentially on behalf of a third party) power generation and/or electricity demands from a range of assets for the purposes of selling electricity balancing services to the Electricity System Operator.

Virtual Reverse Flow: The nominated movement of gas in the opposite direction to the aggregate physical flow within a pipeline system.

Waste: Any substance or object which the holder discards or intends or is required to discard. This definition excludes substances that have been intentionally modified or contaminated for the purpose of transforming it into a Waste.

Weighted Average Consignment: An optional aggregation of Discrete Consignments of Hydrogen Product at the end of a calendar month that is assigned the weighted average Final GHG Emission Intensity of its constituent Discrete Consignments. Refer to Paragraphs 7.28 - 7.35. for further information.

Weighted Average Segregation: A chain of custody approach for an Input Storage System that assumes that when an Input is added to an Input Storage System, the contents of the Input Storage System are homogeneously mixed and therefore any Output takes on the weighted average characteristics of the tank's current contents. Inputs can come from multiple sources with different GHG Emission Intensities, but all the materials shall be the same Feedstock or Fuel, with the same form, classification

and type (as per Paragraphs 7.4 - 7.5). This accounting approach shall only be applied for the storage of non-biogenic Inputs.

3. Standard Compliance

Application of 'Standard Compliance'

3.1.   The concept of Standard Compliance (or 'complying with the Standard') shall be applied to Consignments rather than a Hydrogen Production Facility. Compliance with the Standard means that the Consignment can be considered to be 'low carbon hydrogen'.

3.2.   Before a Hydrogen Production Facility has started producing Consignments claims of Standard Compliance cannot be made. Until Hydrogen Production begins, only claims of *likely* Standard Compliance may be made (for example, for the purposes of demonstrating eligibility for government subsidy schemes). The Standard Document has been designed to substantiate claims of Standard Compliance, but clarifications are periodically included for the determination of *likely* Standard Compliance ahead of a Facility's first Hydrogen Production.

Definition of 'Standard Compliance'

3.3.   For a Consignment to be considered compliant with the Standard, the Consignment shall:

- Have a Final GHG Emission Intensity that is less than or equal to the GHG Emission Intensity Threshold of 20 grams of carbon dioxide equivalent per megajoule of Hydrogen Product, using Lower Heating Values (20.0 gCO$_2$e/MJ$_{LHV}$ Hydrogen Product).

- Be produced by a Hydrogen Production Facility which satisfies all of the Conditions of Standard Compliance.

3.4.   The Conditions of Standard Compliance are that the Hydrogen Production Facility shall:

- Employ an Eligible Hydrogen Production Pathway (see Chapter 4) for the production of hydrogen.

- For any Solid Carbon Outputs, meet the requirements of Paragraphs 5.63 - 5.70 regarding Solid Carbon Permissible End Use; transfer of liability; and accounting.

- Follow the GHG Emission Intensity Calculation Methodology using Lower Heating Values and the System Boundary applicable to the Pathway Inputs, accounting for each of the Emission Categories in Chapter 5.

- Apply Global Warming Potential values for GHG emissions in all relevant calculations (further details are provided in the Data Annex under Global Warming Potentials (GWP)).

- Calculate the magnitude of each Emission Source in accordance with the Materiality requirements, detailed in Paragraphs 5.82 - 5.89 and account for any Material Emission Sources.

- Meet the Biomass Requirements in Chapter 6 (Sustainability Criteria, Minimum Waste and Residue Requirement and ILUC emission reporting) if a biogenic Feedstock is used or a biogenic energy Input is used for a Pathway without a Feedstock.

- Meet the evidence requirements of Annex B (and/or Annex C) for the relevant Electricity Supply configuration, for all Pathways.

- Every month, report the Final GHG Emission Intensity and Environmental Characteristics for the Hydrogen Product in every Discrete Consignment, creating at least one Discrete Consignment for every Reporting Unit (30 minutes) where Hydrogen Product is generated (see Chapter 7).

- Every month, report the Raw GHG Emission Intensities of each Discrete Consignment split by Emission Category (see Chapter 7).

- Set out before operations, and annually review and update during operations, a Fugitive Hydrogen Emissions Risk Reduction Plan (refer to Chapter 10 for details).

- Every year during operations, provide a Fugitive Hydrogen Emissions Annual Report (refer to Chapter 10 for details).

- Producers shall ensure their supply of Renewable Electricity is backed by sufficient Renewable Energy Guarantees of Origin (REGOs) certificates each year in accordance with Annex B (and Annex C if relevant).

- For Pathways with a Feedstock, producers shall ensure that such Feedstock supply complies with the relevant requirements of Annex D and/or Annex F.

- Have a Data Collection and Monitoring Procedure (DCMP) in place with the Delivery Partner.

3.5. The Standard also sets evidence requirements specific to certain Inputs and Outputs of a Hydrogen Production Facility which are detailed in this document and its associated Annexes. Some of these requirements may not strictly need to be satisfied to achieve Standard Compliance but may be necessary to evidence that one or many of the above requirements are adequately met.

Non-compliant Consignments

3.6.   Failure of a Consignment to meet the GHG Emission Intensity Threshold or any one of the Conditions of Standard Compliance shall result in the Consignment being declared non-compliant with the Standard.

3.7.   A Discrete Consignment which does not meet the GHG Emission Intensity Threshold but does satisfy all the Conditions of Standard Compliance may be considered within a Weighted Average Consignment (Refer to Chapter 7 for details). Any Discrete Consignment which does not meet all the Conditions of Standard Compliance shall not be included within a Weighted Average Consignment.

4. Eligible Hydrogen Production Pathways

4.1.   There are numerous Pathways to produce hydrogen from various primary energy sources. The Standard Document (including its Annexes) and the Data Annex have been designed to be applied to UK-based Hydrogen Production Facilities and Eligible Hydrogen Production Pathways only.

4.2.   The following Eligible Hydrogen Production Pathways are currently considered within scope of the Standard and therefore eligible to comply (further details are given in Annex A):

- Electrolysis.

- Fossil gas reforming with CCS.

- Biogenic gas reforming.

- Biomass gasification.

- Waste gasification.

- Gas splitting producing Solid Carbon.

4.3.   Each of the listed Eligible Hydrogen Production Pathways has the potential to produce hydrogen which complies with the Standard. Inclusion on this list does not guarantee the hydrogen produced will comply with the Standard – Hydrogen Production Facilities will need to be designed and operate in an appropriate way to ensure the Standard Compliance is achieved in practice and on an ongoing basis.

Adding new pathways to the scope of the Standard

4.4.   Other Pathways may also be able to meet the requirements of the Standard. Before these Pathways can be said to produce hydrogen which complies with the Standard, they need to be included in the list of Eligible Hydrogen Production Pathways above.

4.5.   Stakeholders wishing to have a new Pathway (or new use of Solid Carbon) added to this list are invited to submit the following evidence via uklchs@energysecurity.gov.uk to the Department for Energy Security & Net Zero (DESNZ):

- The expected GHG Emission Intensity of Hydrogen Product generated from this Pathway under a range of different scenarios with reasonable assumptions. This should use the Standard's GHG Emission Intensity Calculation Methodology (see

Chapter 5) as closely as practicably possible, highlighting where a new or different approach is adopted.

- The ability for any biogenic Inputs to meet the Biomass Requirements set out in the Standard, highlighting any risks of non-compliance.

- The strategic case for including the Pathway (or Solid Carbon use) in the Standard, highlighting its ability to make a direct contribution to GHG emission reduction targets under the Climate Change Act[4]. This should consider:

- The ability for the Pathway to be further decarbonised over time (for example, scope for future innovation).

- The opportunities and risks it poses to wider decarbonisation efforts (for example, the impact of the Pathway on the wider energy system, the storage potential or emission impact of Outputs from the Pathway).

- If applicable, the proposed use of Solid Carbon including its form; purity; any manufactured Product it is incorporated into; the use and lifetime of this Product; its end-of-life fate; and any losses of Solid Carbon.

- Other relevant environmental impacts (for example, resource and water impacts; particulate emissions and other pollutants; and fit with resource or Waste policies).

4.6. DESNZ will scrutinise the evidence provided and aim to respond promptly to the submission. This initial response will set out the next steps before a decision can be confirmed, which will vary according to the complexity of the information that needs to be considered. Further or amended evidence submissions or modelling may be requested. The initial response will not provide a final decision but will provide a likely timescale over which a decision can be expected provided that the next steps are followed.

4.7. The decision will be communicated with a justification to the party which has submitted evidence. If a decision is made to include the Pathway as an Eligible Hydrogen Production Pathway, DESNZ may develop further detail or new requirements for the Pathway in an updated version of the Standard Document and Data Annex. The decision will only come into effect once the updated version of the Standard is published, with the new Pathway being listed in Paragraph 4.2.

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[4] https://www.legislation.gov.uk/ukpga/2008/27/contents

5. GHG Emission Intensity Calculation Methodology

System Boundary

5.1. The GHG Emission Intensity Calculation Methodology shall follow a 'point of production' System Boundary. This only covers Scope 1 Emissions, Scope 2 Emissions, and Partial Scope 3 Emissions of the Hydrogen Production Facility as set out in the Emission Categories in Equation 1. It excludes any emissions related to the distribution or use of Hydrogen Product and excludes any emissions prior to the collection of a Waste or Residue Feedstock.

5.2. The GHG emissions from the construction; manufacturing; decommissioning of capital goods (such as production equipment, upstream pre-processing equipment, vehicles, and storage assets); business travel; employee commuting; and upstream leased assets are not within scope of the Standard.

5.3. GHG emissions associated with hydrogen processes after the Hydrogen Production Facility gate (for example, off-site Hydrogen Storage, off-site liquefaction, and off-site hydrogenation into a hydrogen carrier) are not within scope of the Standard. However, if processes are located onsite at the Hydrogen Production Facility, and Inputs or Outputs to these processes are not separately metered (or measured) from the Hydrogen Production Facility, the GHG emissions associated with operating these processes shall be accounted for within the Standard. For example, the GHG emissions associated with operating any Buffer Storage or any onsite Hydrogen Storage after purification and compression, where the Hydrogen Production Facility does not separately meter the electricity Input to these processes, are considered within scope and shall be accounted for.

Global Warming Potential (GWP)

5.4. All GHGs shall be converted into a common metric of grams of carbon dioxide equivalent within the GHG Emission Intensity Calculation Methodology. To do so, the emission of each Greenhouse Gas measured in grams shall be multiplied by the relevant GWP value (gCO_2e/g) taken from the Data Annex under Global Warming Potentials (GWP). The GWP values may also include distinct accounting of emissions of fossil CO_2 and biogenic CO_2.

GHG Emission Intensity Calculation

5.5.   This section breaks down the Emission Categories that shall be accounted for and reported under the Standard by all Hydrogen Production Facilities. It provides detail on the emissions included within each category and how these shall be accounted for, as applicable to the Hydrogen Production Facility in question.

5.6.   GHG emissions for any Input or Output shall be calculated using the Activity Flow Data multiplied by the corresponding GHG Emission Intensity (or GWP) for that Input or Output, subject to any unit conversions. Refer to the measuring and metering methodology outlined in Annex H to calculate Activity Flow Data.

5.7.   Following the System Boundary, Hydrogen Production Facilities shall apply the following Equation 1 for the purpose of calculating the total GHG emissions to be assigned to a Discrete Consignment (see further details in Chapter 7):

Equation 1

$$E_{Total} = E_{Feedstock\ Supply} + E_{Energy\ Supply} + E_{Input\ Materials} + E_{Process\ CO_2} + E_{Fugitive\ non\text{-}CO_2} + E_{CO_2\ Capture\ and\ Network\ Entry} - E_{CO_2\ Sequestration} + E_{Solid\ C\ Distribution} - E_{Solid\ C\ Sequestration} + E_{Compression\ and\ Purification} + E_{Fossil\ Waste/Residue\ Counterfactual}$$

- Where E_{Total} is the total GHG emissions in gCO2e over the Reporting Unit for the Discrete Consignment, and each term on the right-hand side of Equation 1 represents an Emission Category within the scope of the Standard. Hydrogen Production Facilities shall apply the following Equation 2 for the purpose of calculating the Raw GHG Emission Intensity of the Discrete Consignment:

Equation 2

$$EI_{Raw} = E_{Total}/P$$

- Where P is the total quantity of Hydrogen Product produced over the Reporting Unit for the Discrete Consignment, in MJ$_{LHV}$, and EI$_{Raw}$ is the Raw GHG Emission Intensity per unit of Hydrogen Product, in gCO2e/MJ$_{LHV}$. EI$_{Raw}$ shall be reported to the nearest 0.1 gCO2e/MJ$_{LHV}$.

5.8.   For any calculation relating to P or Step efficiencies (MJ$_{Step\ main\ Output}$/MJ$_{Step\ main\ Input}$, used to calculate the emission contribution of upstream supply chain Steps), these metrics shall use Lower Heating Values (LHV) calculated with Equation 3:

Equation 3

$$Flow\ (MJ_{LHV}) = Mass\ of\ flow\ (kg_{as\ received}) \times Flow\ LHV\ (MJ/kg_{dry}) \times (1 - moisture\ content_{as\ received}\ (\%))$$

- Dry material is at 0% moisture content, and the moisture content shall be the kg of water present in 1 kg of as received material. If not required to be measured, as in Annex H. 9 - H. 10, references for LHV values in MJ/kg$_{dry}$ may be used from the Data Annex under Sources of Data for Lower Heating Values. Note this formula differs from the LHV definition used for Co-Product Energy Allocation in Paragraphs 5.14 - 5.20.

5.9. The whole of the Hydrogen Product shall be considered under the Standard, including any impurities, and not just the pure hydrogen component. Hydrogen Production Facilities shall calculate the energy within the Hydrogen Product using Equation 4.

Equation 4

$$Hydrogen\ Product\ (MJ_{LHV}) =$$
$$Mass\ of\ Hydrogen\ Product\ (kg) \times Hydrogen\ Product\ LHV\ (MJ/kg)$$

The LHV of the Hydrogen Product shall include the impact of any impurities using Equation 5.

Equation 5

$$Hydrogen\ Product\ LHV\ (MJ/kg)$$
$$= \sum_i (LHV\ of\ pure\ species_i\ (MJ/kg)$$
$$\times Mass\ \%\ of\ each\ species_i\ in\ Hydrogen\ Product)$$

Material classification

5.10. Pathways typically take in and/or result in various Waste materials, Residue materials, Products and Co-Products. For a Step in the Pathway (including the Hydrogen Production Facility), DESNZ, and/or the Delivery Partner through the DCMP may agree the appropriate Product, Co-Product, Residue, or Waste classification for an Input Feedstock/Fuel, or an Output material, and may set certain requirements or definitions for a particular material classification to be achieved. In making this decision, consideration shall be given to:

- The definitions of Product, Co-Product, Residue, and Waste in Chapter 2.

- Existing classifications in other relevant UK policy.

- The Waste hierarchy[5].

- The current and expected use of the material.

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[5] https://www.gov.uk/government/publications/guidance-on-applying-the-Waste-hierarchy

- The economic value of the material in relation to the Products and Co-Products from the process in which it is generated, on both a £/tonne basis and/or a £/month basis.

- Any other quality or composition requirements.

5.11. In addition, Hydrogen Production Facilities may also need to submit monthly evidence to the Delivery Partner that these definitions and requirements are met on an ongoing basis. Failure to follow the material classification decision shall result in the Hydrogen Production Facility having to recalculate their GHG Emission Intensity using the correct material classification, and the Hydrogen Product Consignments impacted by this misclassification being non-compliant with the Standard until the corrections are made.

LHV Energy Allocation Method of GHG emissions between Products & Co-Products

5.12. The total emissions allocated to Outputs of any Step in a Pathway shall be split only between the Products and Co-Products of that Step. By contrast, Waste or Residue Outputs from any Step in a Pathway shall have no emissions allocated to them. Similarly, Residue and Waste Feedstocks/Fuels start from nil GHG emissions at the point of collection at the beginning of their supply chain.

5.13. The classification of an Output material can have a significant impact on the Hydrogen Product GHG Emission Intensity, as Co-Product materials shall be allocated some of the emissions from the Step and previous Steps reducing the emissions burden on the final Hydrogen Product.

5.14. The following LHV Energy Allocation Method allocates emissions to Co-Products from a Step in the Pathway using Equation 6.

Equation 6

$$Allocation\ Factor\ for\ (Co\text{-})Product_j$$
$$= \frac{Energy\ of\ (Co\text{-})Product_j\ (MJ_{LHV})}{Energy\ of\ Hydrogen\ Product\ (MJ_{LHV}) + \sum Energy\ of\ all\ Co\text{-}Products\ (MJ_{LHV})}$$

- The MJ_{LHV} energy content of Co-Products and Products in both the numerator and denominator of Equation 6 shall be determined based on Equation 7:

Equation 7

$$Energy\ of\ (Co\text{-})Product\ (MJ_{LHV}) = Mass\ of\ (Co\text{-})Product\ (kg_{as\ received})$$
$$\times MAX\left\{0, \begin{bmatrix}(Co\text{-})Product\ LHV\ (MJ/kg_{dry}) \times (1 - moisture\ content_{as\ received}\ (\%)) \\ -2.441 \times moisture\ content_{as\ received}\ (\%)\end{bmatrix}\right\}$$

- Dry is at 0% moisture content, and the % moisture content is the kg of water present in 1 kg of as received Product or Co-Product. Equation 7 removes the latent heat of

vaporisation of water at 25°C (2.441 MJ$_{LHV}$/kg). Additionally, Equation 7 uses zero as a lower bound to stop very wet Products or Co-Products having a negative energy content. Note that Equation 7 is different from Equation 3 used for Step efficiencies and *P* in Paragraph 5.8.

5.15. Hydrogen Production Facilities with heat or steam Co-Products shall apply the Carnot Efficiency to any heat or steam Co-Products, so that only the useful energy content is included in Equation 6 (in both the allocation numerator for that Co-Product and in the allocation denominator for the sum of all Products and Co-Products). The useful part of the heat or steam Co-Product is found by multiplying its energy content with the Carnot Efficiency, C_h, calculated with Equation 8:

Equation 8

$$C_h = \frac{T_h - T_0}{T_h}$$

- T_h is Temperature, measured in absolute temperature (Kelvin) of the Useful Heat or Useful Steam at the point of delivery, taken as an average temperature within the month.

- T_0 is Temperature of surroundings, set at 273.15 Kelvin (equal to 0°C).

5.16. Pathways produce Hydrogen Product as the main Output but might not Valorise other Outputs such as heat or oxygen – these other Outputs may then be classified as Wastes or Residues, not Co-Products. Should other Outputs be classified as Co-Products, GHG emissions shall be allocated to these Co-Products using the LHV Energy Allocation Method above. This LHV Energy Allocation Method shall be applied even in cases where valorised Co-Products have no LHV energy content under Equation 7 (e.g., oxygen), which leads to no GHG emissions being allocated to these Co-Products.

Example: An illustration of how 1,000 kgCO2e of emissions might be allocated to Hydrogen Product and various other Outputs from a theoretical process is presented below in Table 1.

Table 1: Illustrative example for allocating 1,000 kgCO₂e of GHG emissions

Output	Output Quantity	LHV dry (MJ/kg)	Useful Output MJ$_{LHV}$)	Allocation (% of useful Output)	Emissions allocated (kgCO₂e)	Emissions (gCO₂e/MJ$_{LHV}$ useful Output)
Hydrogen Product (dry)	834 kg	119.9	100,000	72.8%	728	7.3
Co-Product electricity	10,000 MJ$_e$	NA	10,000	7.3%	73	7.3
Co-Product steam at 200°C	10,000 MJ$_{LHV}$	NA	4,227	3.1%	31	7.3
Co-Product oxygen	100 kg	0	0	0%	0	0
Co-Product methane (dry)	400 kg	50	20,000	14.6%	146	7.3
Co-Product solid at 50% moisture	400 kg	18	3,112	2.3%	23	7.3
Co-Product sludge at 90% moisture	100 kg	18	0	0%	0	0
Waste solid (dry)	100 kg	5	500	0%	0	0

5.17. A Pathway from Feedstock to Hydrogen Product can have multiple Steps with each Step potentially generating Products and Co-Products. The Allocation Factor for each Step shall be calculated individually using the above LHV Energy Allocation Method. Taking each Step in turn:

- The Allocation Factor for the Hydrogen Production Step, AF$_{production}$, is calculated in Equation 9 as the MJ$_{LHV}$ of Hydrogen Product divided by the MJ$_{LHV}$ sum of all Products and Co-Products from the Hydrogen Production Facility, using the Equation 7 energy content definitions.

Equation 9

$$AF_{production} = \frac{Hydrogen\ Product\ (MJ_{LHV})}{Hydrogen\ Product\ (MJ_{LHV}) + \sum Co\text{-}Products\ (MJ_{LHV})}$$

- The Allocation Factor for the Hydrogen Production Step, AF$_{production}$, shall be applied to the Energy Supply, Input Materials, Process CO_2, Fugitive non-CO_2, CO_2 Capture and Network Entry, CO_2 Sequestration, Solid Carbon Distribution, and

Solid Carbon Sequestration Emission Categories. No Allocation Factor is applied to the Compression and Purification Emission Category.

- Each upstream Step in the supply chain will have one intermediate Product or Co-Product that will ultimately end up as Hydrogen Product. Any other Products or Co-Products from that upstream Step will not form hydrogen but instead exit the System Boundary taking some emissions with them. The Allocation Factor for an upstream $Step_i$ in the supply chain, AF_i, shall be calculated with Equation 10 as the MJ_{LHV} of intermediate Product or Co-Product of interest to the Pathway divided by the sum of the MJ_{LHV} of all Products and Co-Products from that $Step_i$ (using the Equation 7 energy content definition).

Equation 10

$$AF_i = \frac{Step_i\ Intermediate\ (Co\text{-})Product\ of\ interest\ (MJ_{LHV})}{Step_i\ Product\ (MJ_{LHV}) + \sum Step_i\ Co\text{-}Products\ (MJ_{LHV})}$$

5.18. A Cumulative Allocation Factor for the whole Pathway from Feedstock to Hydrogen Product, $CAF_{Pathway}$, can then be calculated using Equation 11 by multiplying all of the intermediate Product and Co-Product Allocation Factors and the final $AF_{production}$ Allocation Factor together. This $CAF_{Pathway}$ value is used in Equation 11:

Equation 11

$$CAF_{pathway} = AF_{Production} \times \prod_{\substack{n=Starting\\Step}}^{\substack{Step\ before\\Production}} AF_n$$

5.19. Cumulative Allocation Factors can also be generated for each Step in the supply chain, $CAF_{Step\ i}$, using Equation 12 starting with the Hydrogen Production Facility and multiplying Allocation Factors back up the supply chain for the Feedstock until reaching and including the Allocation Factor from the Step of interest (Step i in Equation 12 but not earlier Steps further upstream).

Equation 12

$$CAF_{Step\ i} = AF_{Production} \times \prod_{n=\ Step\ i}^{\substack{Step\ before\\Production}} AF_n$$

5.20. This $CAF_{Step\ i}$ value is multiplied by the GHG emissions generated as a result of that $Step_i$, and this is repeated for all Steps upstream of the Hydrogen Production Facility. The total sum of these cumulatively allocated upstream Step Emissions is equal to the Feedstock Supply GHG emissions, as shown in Equation 13.

Example: A Pathway with upstream Waste pre-processing has the Hydrogen Production Step given in Table 1 above, so the Hydrogen Production Facility Step Allocation Factor ($AF_{Production}$) is 72.8%.

350,000 MJ_{LHV} of raw Waste is collected and transported, then in the upstream pre-processing Step converted into 270,000 MJ_{LHV} of processed Waste; 30,000 MJ_e of Co-Product electricity; and 50,000 MJ of rejected low-grade heat (this rejected heat is not deemed to be a co-product and so is not allocated any emissions). The processed Waste is the intermediate Product of interest, and the Allocation Factor for this Step (AF_i) is $\frac{270,000 \text{ MJ}_{LHV}}{270,000 \text{ MJ}_{LHV} + 30,000 \text{ MJ}_{LHV}} = 90\%$. The processed Waste is then transported to the Hydrogen Production Facility.

The following Cumulative Allocation Factors then apply to each Step:

$CAF_{Hydrogen\ Production\ Step}$ = $AF_{Production}$ = 72.8%
$CAF_{Processed\ Waste\ transport\ Step}$ = 72.8%
$CAF_{Waste\ pre-processing\ Step}$ = 72.8% × 90% = 65.5%
$CAF_{Raw\ Waste\ transport\ Step}$ = 72.8% × 90% = 65.5%
$CAF_{Raw\ Waste\ collection\ Step}$ = 72.8% × 90% = 65.5%

The Cumulative Allocation Factor for the whole Pathway from Feedstock to Hydrogen Product ($CAF_{Pathway}$) is 72.8% × 90% = 65.5%.

E_{Total} would be calculated as:

65.5% of any Fossil Waste/Residue Counterfactual emissions
65.5% of the raw Waste collection, raw Waste transport, and pre-processing emissions (part of Feedstock Supply)
72.8% of the processed Waste transport emissions (also part of Feedstock Supply)
72.8% of the Hydrogen Production Step Emissions for all the remaining Emission Categories (excluding the Compression and Purification Emission Category).
100% of any Compression and Purification emissions.

Feedstock Supply

5.21. Feedstock Supply emissions ($E_{Feedstock\ Supply}$) shall be calculated for each Reporting Unit with Equation 13:

Equation 13

$$E_{Feedstock\ Supply} = \sum_{\substack{Feedstock \\ Supply\ Step\ i}} \left(E_{Feedstock\ Supply\ emissions,i} \times CAF_i \right)$$

- Where $E_{Feedstock\ Supply\ emissions}$ are the GHG emissions during the Reporting Unit arising from Feedstock extraction, cultivation, harvesting, collection, pre-processing, storage, and transport Steps for the particular Feedstock in scope of the Discrete Consignment, calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities or GWPs). CAF_i is the Cumulative Allocation Factor for each individual supply chain Step.[6]

5.22. The GHG emissions in this Emission Category will vary according to the Feedstock used due to the different Steps present in each Pathway:

- Fossil gas Feedstocks: including GHG emissions from exploration, extraction, flaring/venting, pre-processing, compression, storage, transport, liquefaction, and regasification. Facilities shall calculate these emissions on the basis of the requirements set out in Annex D.

- Biomass Feedstocks: including GHG emissions from cultivation, harvesting, pre-processing, storage, and transport; as well as biomethane production and transport where relevant. Emissions associated with direct land-use change shall be included in Feedstock Supply (using e_i from Annex E. 11 - E. 25 multiplied by the MJ_{LHV} of each crop cultivated). Indirect land use change emissions shall be excluded but reported separately as per Annex E. 26 - E. 29. Impacts related to avoided biogenic emissions (for example, avoided landfill methane emissions) shall not be included.

- Waste and Residue Feedstocks (with fossil and/or biogenic content): are assigned nil emissions up to the point of collection so only including GHG emissions from collection, pre-processing, storage, and transport until arrival at the Hydrogen Production Facility. Fossil Waste/Residue Feedstocks shall follow the requirements of, and biogenic Waste/Residue Feedstocks shall follow the requirements of Annex E (as well as Annex F if the Pathway involves biomethane Feedstock).

Additional Feedstocks may be considered on a case-by-case basis by DESNZ. Emissions for these Feedstocks shall be fully accounted for following the same methodology for Feedstock Supply emissions as given above where possible.

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[6] The index i is used to denote Steps within the Feedstock supply chain, and each Step may contain a number of different Emission Sources. The index j in other Emission Category formulae is used to denote different Emission Sources at the Hydrogen Production Facility. The index k is used to denote GHG emissions or credits relating to captured CO_2 or Solid Carbon that are downstream of the Hydrogen Production Facility. This choice of index notation has no impact on the results.

5.23. If a Hydrogen Production Facility uses an Input (for example, natural gas) both as the Feedstock and as a Fuel, then these Inputs shall be combined and considered only as a Feedstock, and the emissions related to that Fuel Input shall only be accounted for under this Feedstock Supply category.

5.24. Any Feedstock arriving at the Hydrogen Production Facility with a negative GHG Emission Intensity (for example, due to upstream pre-processing with CCS or direct land use change benefits from biomass cultivation) shall be recorded as having a nil GHG Emission Intensity within this Emission Category. Similarly, any negative GHG Emission Intensity energy or Precursor Feedstocks used in the upstream production and supply of Feedstocks shall also be reported as having a nil GHG Emission Intensity at the point of arriving at the upstream processing facility when calculating the Feedstock Supply category emissions. This approach ensures separate accounting of GHG removals and consistency with other UK policy but will remain under review as policy on GHG removals develops.

5.25. Electrolysis Pathways shall not account for any emissions within the Feedstock Supply category as Input electricity is considered within the Energy Supply Emission Category and Input water is considered within the Input Materials Emission Category. If an electrolysis Facility is supplied with electricity, heat, or steam generated from fossil or biogenic Inputs then the emissions from the Steps set out in Paragraph 5.21 - 5.22 shall be accounted for within the Energy Supply Emission Category and not within this Feedstock Supply category.

Energy Supply

5.26. Energy Supply ($E_{\text{Energy Supply}}$) emissions in gCO_2e during the Reporting Unit are broken down into four sub-categories: Electricity Supply, Steam Supply, Heat Supply, and Fuel Supply as defined in Equation 14, with further details given below.

Equation 14

$$E_{energy\,supply} = E_{Electricity\,Supply} + E_{steam\,supply} + E_{heat\,supply} + E_{fuel\,supply}$$

5.27. $AF_{production}$ (as defined in Equation 9, and used in below Equation 15) is the Allocation Factor for the Hydrogen Production Step.

5.28. Any Input energy source with a negative GHG Emission Intensity (for example, biofuel produced with CCS) shall be recorded as having a nil GHG Emission Intensity under the Standard.

Electricity Supply

5.29. Electricity Supply emissions ($E_{\text{Electricity Supply}}$) shall be calculated for each Reporting Unit using Equation 15:

Equation 15

$$E_{Electricity\ Supply} = \sum_{Electricity\ source\ j} E_{Electricity\ Supply\ emissions,j} \times AF_{production}$$

- Where $E_{Electricity\ Supply\ emissions}$ are the GHG emissions during the Reporting Unit associated with supply of electricity within the scope of the Discrete Consignment to the Hydrogen Production Facility calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities). Full details on the methodology, reporting requirements, and evidence required to calculate Input electricity GHG Emission Intensities are included in Annex B and Annex G.

5.30. Electricity supplies and their associated GHG Emission Intensities shall be assessed in accordance with the four configurations listed below, with further details and evidence requirements for each of these configurations given in Annex B:

- **Electricity sourced from specific generators in GB or NI** via Eligible PPAs (or equivalent where the generator and Hydrogen Production Facility are owned by the same legal entity). The electricity generation GHG Emission Intensity from the Data Annex under the Energy Supply section shall be used. If a generator is not listed in the Data Annex, the methodology in Annex G shall be applied. Transmission and Distribution (T&D) losses between generators and the Facility shall be accounted for as per Annex B.

- **Electricity sourced from a Private Network in GB or NI and not linked to a specific generator**, excluding grid import to the Private Network. The electricity generation GHG Emission Intensities from the Data Annex under the Energy Supply section shall be used to calculate a Private Network weighted average generation GHG Emission Intensity. If Private Network generators are not listed in the Data Annex, the methodology in Annex G shall be applied. T&D losses between Private Network generators and the Facility shall be accounted for as per Annex B.

- **Electricity sourced from the GB or NI Electricity Grid and not linked to a specific generator**. The delivered GHG Emission Intensity from the Data Annex under the Energy Supply section shall be used.

- **Electricity Curtailment Avoidance.** The delivered GHG Emission Intensity from the Data Annex Paragraphs under Electricity Curtailment Avoidance shall be used.

Steam Supply

5.31. Steam Supply emissions ($E_{Steam\ Supply}$) shall be calculated for each Reporting Unit using Equation 16:

Equation 16

$$E_{steam\,supply} = \sum_{Steam\,source\,j} E_{steam\,supply\,emissions,j} \times AF_{production}$$

- Where $E_{steam\,supply\,emissions}$ are the GHG emissions during the Reporting Unit associated with supply of steam to the Hydrogen Production Facility, calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities). This covers all cases where steam is not generated onsite and not accounted for within other Emission Categories. The Steam Supply GHG Emission Intensity in gCO_2e/MJ_{steam} shall be calculated using the methodology given Annex G accounting for any losses between generation and the Facility.

Heat Supply

5.32. Heat Supply emissions ($E_{Heat\,Supply}$) shall be calculated for each Reporting Unit using Equation 17:

Equation 17

$$E_{heat\,supply} = \sum_{Heat\,source\,j} E_{heat\,supply\,emissions,j} \times AF_{production}$$

- Where $E_{Heat\,Supply\,emissions}$ are the GHG emissions during the Reporting Unit associated with supply of heat (not as steam) to the Hydrogen Production Facility, calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities). This covers all cases where heat is not generated onsite and not accounted for within other Emission Categories. The Heat Supply GHG Emission Intensity in gCO_2e/MJ_{heat} shall be calculated using the methodology given in Annex G accounting for any losses between generation and the Facility.

Fuel Supply

5.33. Fuel Supply emissions ($E_{Fuel\,supply}$) shall be calculated for each Reporting Unit using Equation 18:

Equation 18

$$E_{fuel\,supply} = \sum_{Fuel\,source\,j} E_{fuel\,supply\,emissions,j} \times AF_{production}$$

- Where $E_{Fuel\,Supply\,emissions}$ are the GHG emissions during the Reporting Unit associated with the production and supply of any Input Fuels to the Hydrogen Production Facility, calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities). Note that emissions arising from the combustion/use of Fuels onsite shall be considered under the Process CO_2 and/or the Fugitive non-CO_2 Emission Categories below and not in this Emission Category.

If the Fuel used is the same as the Pathway Feedstock, then the sourcing and supply emissions related to that Fuel shall be accounted for under the Feedstock Supply Emission Category and not included in this Fuel Supply category. These Fuels include (but are not limited to) coal, oil, diesel, natural gas, biomethane, biomass, and wastes, and exclude any Input Materials.

5.34. If an Input Fuel is listed in the Data Annex, the corresponding delivered GHG Emission Intensity value in the Data Annex under the Fuel Supply section shall be used. If a value is not available in the Data Annex, then Facilities shall follow the GHG Emission Intensity Calculation Methodology under the Standard but as applied to the Fuel of interest instead of Hydrogen Production. Once a Fuel production GHG Emission Intensity has been derived, emissions for the Fuel Supply chain (including any fugitive losses) from the Fuel production plant to the Hydrogen Production Facility shall be added, to derive a total production & supply GHG Emission Intensity for the Input Fuel (that excludes combustion/use at the Hydrogen Production Facility). For biofuels, this is approach follows the GHG methodology set out in the latest version of the Renewable Transport Fuel Obligation (RTFO), but excluding several RTFO terms (emissions savings from soil carbon accumulation via improved agricultural management; degraded land bonus; any manure credit; CO_2 capture and replacement; vehicle refuelling; and Fuel in use).

Input Materials

5.35. Input Materials emissions ($E_{\text{Input Materials}}$) shall be calculated for each Reporting Unit using Equation 19:

Equation 19

$$E_{Input\,materials} = \sum_{Input\,material\,j} E_{Input\,material\,emissions,j} \times AF_{production}$$

- $E_{\text{Input Materials emissions}}$ refers to GHG emissions associated with the production and supply of Input Materials to the Hydrogen Production Facility calculated in gCO_2e (using Activity Flow Data multiplied by associated GHG Emission Intensities).

- $AF_{\text{production}}$ is the Allocation Factor for the Hydrogen Production Step. GHG emissions arising from the conversion/use of Input Materials onsite shall be considered under the Process CO_2 and/or the Fugitive non-CO_2 Emission Categories below and not in this Emission Category. The purpose of Input Materials is not to provide energy to the process, so could include for example, water, oxygen, salts, catalysts, solvents, and acids. Only materials generated offsite and brought across the System Boundary into the Hydrogen Production Facility shall be accounted for within this Emission Category. Other flows that cross the System Boundary to generate any materials onsite shall be accounted for within their corresponding Emission Categories.

5.36. If the Input Material is listed in the Data Annex under Input Materials, the corresponding GHG Emission Intensity in the Data Annex under Input Materials shall be used. If a value is not available in the Data Annex under Input Materials, the Facility shall reference alternative reputable sources with a justification for their applicability such as UK government conversion factors or peer reviewed academic literature for the proposed GHG Emission Intensity of these Input Materials.

5.37. To ensure separate accounting of Greenhouse Gas removals any Input Material with a negative GHG Emission Intensity (for example, a biogenic material produced with CCS) shall be recorded as having a nil GHG Emission Intensity under the Standard.

Process CO_2 emissions

5.38. Process CO_2 emissions ($E_{Process\ CO_2}$) shall be calculated for each Reporting Unit using Equation 20:

Equation 20

$$E_{Process\ CO_2} = \sum_{CO_2\ source\ j} E_{Process\ CO_2\ emissions,j} \times AF_{production}$$

- Where $E_{Process\ CO_2\ emissions}$ is the amount of fossil-derived carbon dioxide generated within Hydrogen Production Facility due to conversion/use of fossil Feedstocks, fossil Fuels, and fossil Input Materials, calculated in gCO_2 (using Activity Flow Data multiplied by associated combustion CO_2 Emission Intensities). This Emission Category may account for any fossil CO_2 generated and biogenic CO_2 generated separately using the GWP values in the Data Annex under Global Warming Potentials (GWP). All values are given prior to any CO_2 capture which is considered separately in other Emission Categories. $AF_{production}$ is the Allocation Factor for the Hydrogen Production Step.

5.39. The Hydrogen Production Facility shall use the methodology provided in Paragraphs H. 11 - H. 12 to account for Process CO_2 emissions arising from the conversion of fossil Inputs. For fossil Feedstocks, carbon contents shall be calculated following Paragraph H. 13. For the conversion of Fuels onsite, the Hydrogen Production Facility shall use the carbon contents set out in the Data Annex under Process CO_2 emissions if the Fuel is listed. If carbon contents are not provided in the Data Annex under Process CO_2 emissions for a given Fuel and/or there is conversion of Input Materials involving fossil carbon, the Facility shall reference alternative reputable sources with a justification for their applicability such as UK government conversion factors or peer reviewed academic literature.

Fugitive non-CO_2

5.40. Fugitive non-CO_2 GHG emissions ($E_{Fugitive\ non-CO_2}$) shall be calculated for each Reporting Unit using Equation 21:

Equation 21

$$E_{\textit{Fugitive non-CO}_2} = \sum_{\textit{Fugitive source } j} E_{\textit{Fugitive non-CO}_2 \textit{ emissions,j}} \times AF_{\textit{production}}$$

- Where $E_{\textit{Fugitive non-CO}_2 \textit{ emissions}}$ are the operational emissions of greenhouses gases, other than CO_2, released as fugitive emissions from the Hydrogen Production Facility, calculated in gCO_2e (using Activity Flow Data multiplied by associated GWPs). The GWP values given in the Data Annex under Global Warming Potentials (GWP) shall be applied. AF_production is the Allocation Factor for the Hydrogen Production Step.

5.41. This Emission Category includes all operational losses such as leakages and accidental losses as well as other losses due to poor management of Facility operations, venting, or incomplete flaring of Waste streams. For example, pass-through of unconverted methane; onsite boiler N_2O emissions; release of hydrofluorocarbons (HFCs) used in industrial refrigeration and/or cooling systems; and leakage of sulphur hexafluoride (SF_6) used in electrical switchgear.

5.42. These fugitive emissions shall be calculated and evidenced by Hydrogen Production Facilities through measured or estimated leakage rates applying the approach given in Paragraph H. 48.

5.43. The Environmental Permitting Regulations 2016 (England and Wales), the Pollution Prevention and Control (Industrial Emissions) Regulations NI 2013, and the Pollution Prevention and Control (Scotland) Regulations 2012 require the use of Best Available Techniques in design, operation, and maintenance which would include preventing or minimising fugitive emissions. Therefore, Hydrogen Production Facilities should already be recording their levels of fugitive emissions and looking to reduce these through their facilities.

5.44. For most Hydrogen Production Facilities, Fuels or Feedstocks are provided by a third party so any fugitive non-CO2 emissions associated with the collection, pre-processing, and transport of these Fuels or Feedstocks will likely already be covered by either the Energy Supply or Feedstock Supply Emission Categories depending on the Pathway.

5.45. Evidence shows that hydrogen behaves as an indirect Greenhouse Gas and therefore reducing the amount of hydrogen vented into the atmosphere from the Hydrogen Production Facility (including during onsite Hydrogen Storage) is important. While hydrogen fugitive emissions are not currently required to be accounted for within the GHG Emission Intensity Calculation Methodology, Hydrogen Production Facilities shall minimise and separately report on these Fugitive Hydrogen Emissions as set out in Chapter 10.

CO$_2$ Capture and Network Entry

5.46. Emissions for CO$_2$ capture and entry into the CO$_2$ T&S Network ($E_{CO_2 \text{ Capture and Network Entry}}$) shall be calculated for each Reporting Unit using Equation 22:

Equation 22

$$E_{CO_2 \text{ Capture and Network Entry}} = \sum_{Source\,j} E_{CO_2 \text{ Capture and Network Entry},j} \times AF_{production}$$

- Where $E_{CO_2 \text{ Capture and Network Entry}}$ includes GHG emissions impacts from CO$_2$ capture at the Hydrogen Production Facility, any CO$_2$ purification, compression, temporary storage, and transport, up to and including the CO$_2$ T&S Network Delivery Point, calculated in gCO$_2$e. These emissions shall be allocated using $AF_{production}$ (see Equation 9).

5.47. This Emission Category excludes those emissions already accounted within Energy Supply, Input Materials, Process CO$_2$ emissions, or Fugitive non-CO$_2$ Emission Categories. Therefore, if the CO2 capture equipment is not part of the Hydrogen Production Facility (e.g., the CO2 capture equipment is owned and operated by an adjacent third party with separate meters etc), the emissions related to CO$_2$ capture shall be accounted for in this Emission Category. The full lifecycle GHG Emission Intensities (production, supply, use and disposal) of any Inputs used within this Emission Category shall be applied to the Activity Flow Data for these Inputs. Note that any emissions incurred in operating these CO$_2$ supply chain steps (e.g., Input electricity, heat, chemicals) shall still be fully accounted for even if some of the captured CO$_2$ is vented or lost to atmosphere, there is no allocation of Input emissions permitted to vented or lost CO2. Producers are not required to separately meter energy used for CO$_2$ capture; energy Inputs shall continue to be reported under the Energy Supply category for the Facility as a whole, while this category accounts for the associated GHG emissions from capture-related activities.

5.48. Transport of CO$_2$ prior to the CO$_2$ T&S Network Delivery Point could include transport modes such as trucks or trains and therefore may involve emissions from the supply and combustion of transport Fuels that are not already accounted for within the Energy Supply Emission Category. Similarly, compressors for inputting CO2 into temporary storage or into the CO2 T&S Network may also involve use of Fuels or electricity that are not already accounted for elsewhere and need to be included within this Emission Category.

5.49. Any fugitive CO$_2$ emissions arising from the capture, temporary storage, compression, and transport of CO$_2$ prior to entering the CO$_2$ T&S Network shall be accounted for by a reduction in CO$_2$ Sequestration Emission Category and shall not be accounted for in this Emission Category.

CO$_2$ Sequestration

5.50. The emissions credit resulting from CO$_2$ Sequestration ($E_{CO_2\,Sequestration}$) shall be calculated for each Reporting Unit using Equation 23:

Equation 23

$$E_{CO_2\,Sequestration} = \sum_{Network\,j} E_{CO_2\,Sequestration\,emissions,j} \times AF_{production}$$

- Where $E_{CO_2\,Sequestration\,emissions}$ are CO$_2$ emissions captured and permanently sequestered in underground geological storage, calculated in gCO$_2$. $AF_{production}$ is the Allocation Factor for the Hydrogen Production Step. For CO$_2$ to be claimed under this Emission Category, the following conditions shall be met:

  o CO$_2$ shall be captured and injected into a CO$_2$ T&S Network and stored permanently in underground geological storage. CO$_2$ capture and utilisation or replacement (through a displacement or change in fossil Fuel use that avoids emissions) do not meet this condition.

  o Evidence shall be provided by the Hydrogen Production Facility of a connection to the CO$_2$ T&S Network operated by a licensed CO$_2$ T&S Network Operator. This could include a connection agreement between the Hydrogen Production Facility and the CO$_2$ T&S Network Operator.

  o The responsibility for the CO$_2$ shall be transferred to a CO$_2$ T&S Network Operator at the CO$_2$ T&S Network Delivery Point. Any CO$_2$ leakage or venting after the responsibility has been transferred (e.g., from geological stores) is not accounted for under the Standard.

  o Any credit accounted for under this Emission Category shall not be credited or claimed elsewhere (for example, as a carbon credit in other policies or voluntary markets). If credited elsewhere, the CO$_2$ Sequestration benefit can no longer be included within the GHG Emission Intensity Calculation Methodology.

  o Any credit accounted for under this Emission Category shall be directly related to processes within the System Boundary. Carbon offsets (or similar) from other processes cannot be claimed under the Standard.

5.51. For the application of GWP values to this Emission Category, Hydrogen Production Facilities shall refer to the Data Annex under CO$_2$ Sequestration.

5.52. All GHG emissions associated with transporting and injecting the CO$_2$ into the CO$_2$ T&S Network shall be accounted for across the earlier CO$_2$ Capture and Network Entry Emission Category.

5.53. For some Pathways, a reduction in this CO_2 Sequestration Emission Category could produce non-compliant hydrogen that has a GHG Emission Intensity significantly above the GHG Emission Intensity Threshold. Example reasons include:

- A Hydrogen Production Facility's CO_2 capture equipment stops working or CO_2 capture rates are reduced (resulting in full or partial venting of CO_2 onsite).

- There is a CO_2 T&S Network outage, and the Hydrogen Production Facility cannot inject captured CO_2 into the Network (and instead has to vent).

- There are leaks or fugitive CO_2 emissions occurring prior to injection into the Network.

In all these cases the additional resulting CO_2 emissions shall be accounted for as a reduction in the CO_2 Sequestration Emission Category, not as additional GHG emissions under a different Emission Category.

5.54. For some Pathways, the CO_2 Sequestration credit may be large enough to result in the GHG Emission Intensity for the Hydrogen Product becoming negative. Negative GHG Emission Intensity hydrogen is permitted under the Standard provided this has resulted from Emission Category formulae that use a minus sign (currently $E_{CO2\ Sequestration}$, $E_{Solid\ C\ Sequestration}$, $E_{fossil\ counterfactual\ CO2\ emitted}$ terms) rather than resulting from negative GHG Emission Intensity Inputs.

Solid Carbon Distribution

5.55. The emissions resulting from Solid Carbon Distribution ($E_{Solid\ C\ Distribution}$) shall be calculated for each Reporting Unit using Equation 24:

Equation 24

$$E_{Solid\ C\ Distribution} = \sum_{Source\ j} E_{Solid\ C\ Distribution\ emissions, j} \times AF_{production}$$

5.56. Where $E_{Solid\ C\ Distribution\ emissions}$ are the GHG emissions associated with the distribution of Solid Carbon from the Hydrogen Production Facility to a Solid Carbon Permissible End Use, calculated in gCO_2e. $AF_{production}$ is the Allocation Factor for the Hydrogen Production Step. This Emission Category may include purification, densification, collection, transport and/or temporary storage of the Solid Carbon, all within the UK.

5.57. This Emission Category excludes those emissions already accounted within Energy Supply, Input Materials, Process CO_2 emissions, or Fugitive non-CO_2 Emission Categories (for example, if a Solid Carbon pelleting unit is onsite at the Hydrogen Production Facility and its Inputs are already accounted for).

5.58. Where Inputs are used in these Solid Carbon Distribution steps (such as electricity, Fuels, binder, water), the full lifecycle GHG Emission Intensities (production, supply, use and disposal) of these Inputs shall be applied to the Activity Flow Data for these Inputs. If an Input is listed in the Data Annex, the corresponding delivery and use GHG Emission Intensity values in the Data Annex shall be combined and used. If a value is not available in the Data Annex for an Input, then Non-Typical Data shall be used.

5.59. All Solid Carbon Distribution emissions shall be accounted for under this Emission Category up to and including the Solid Carbon End User Point, even where ownership of the Solid Carbon is transferred to a third-party during Distribution. Where actual Distribution emissions data is not yet available, the Activity Flow Data shall be treated as Estimated Data and subsequently adjusted and reconciled through agreement with the Delivery Partner when Measured Data become available.

5.60. Any losses of Solid Carbon (e.g., spillages, erosion, fires) during the distribution of Solid Carbon Output prior to the Solid Carbon End User Point shall be accounted in this Emission Category, using the Solid Carbon Loss Factor values set out in the Data Annex under Solid Carbon Distribution. If the loss of Solid Carbon is known to be as release of gases other than CO_2 (e.g., methane, CO), these fugitive emissions should be added to this Emission Category with the relevant GWPs. Note that the fossil Solid Carbon Loss Factor is only to be applied to fossil Solid Carbon (and associated fossil Hydrogen Product Consignments), and the biogenic Solid Carbon Loss Factor is only be applied to biogenic Solid Carbon (and associated biogenic Hydrogen Product Consignments). The method for allocating these Distribution emissions across the relevant Discrete Consignments within each month shall be agreed through the DCMP with the Delivery Partner. Equation 81 and Equation 82 can be used to calculate the biogenic/fossil proportions.

5.61. For the purposes of quantifying emissions for Solid Carbon Distribution, the Hydrogen Production Facility shall collect and maintain appropriate evidence relating to Inputs, losses and activities within the Solid Carbon Distribution steps. This evidence shall include but is not limited to:

- Documentation of any purification and/or densification, including invoices or purchase records for any Input energy or materials (e.g., binder, water) not already accounted for under other Emissions Categories.

- Records of transport mode utilised (e.g., pipeline, truck), including any losses and Fuel consumption where applicable.

- Documentation of temporary storage duration, including any losses and energy use where applicable.

5.62. The Hydrogen Production Facility shall allocate the total estimated Solid Carbon Distribution GHG emissions across both Consignments where the associated Solid Carbon Output was and was not used in a Permissible End Use. The method for

allocation and associated time period shall be agreed through the DCMP with the Delivery Partner.

Solid Carbon Sequestration

5.63. The emissions credit resulting from Solid Carbon Sequestration ($E_{Solid\,C\,Sequestration}$) shall be calculated for each Reporting Unit using Equation 25.

Equation 25

$$E_{Solid\,C\,Sequestration} = \sum_{Permissible\,use\,j} E_{Solid\,C\,Sequestration\,emissions,j} \times AF_{production}$$

- Where $E_{Solid\,C\,Sequestration\,emissions}$ are the equivalent CO_2 emissions captured and sequestered via those Solid Carbon Permissible End Uses given in the Data Annex under Solid Carbon Sequestration, calculated in gCO_2e. $AF_{production}$ is the Allocation Factor for the Hydrogen Production Facility.

5.64. For an emissions credit to be claimed under this Emission Category, the following conditions are required to be met:

- The Hydrogen Production Facility provides verifiable evidence that the Solid Carbon generated by Hydrogen Production has been sequestered in a Solid Carbon Permissible End Use, within the UK. If sequestered in a Solid Carbon Permissible End Use within the UK, the Standard does not then restrict the subsequent export of manufactured construction products that contain the sequestered Solid Carbon.

- Where Solid Carbon Output is not used in a Solid Carbon Permissible End Use, the associated Discrete Consignments shall be deemed non-compliant with the Standard in accordance to Paragraph 5.67 below.

- Similarly, Solid Carbon that has been sequestered or incorporated in a Solid Carbon Permissible End Use will not be compliant with the Standard if it is removed from a Solid Carbon Permissible End Use or transferred to an alternative Solid Carbon Permissible End Use.

- Temporary storage between the Hydrogen Production Facility and the Permissible End Use is permitted, but only up to a duration limit as agreed through the DCMP with the Delivery Partner. Any storage duration beyond the agreed duration limit will result in that quantity of Solid Carbon being treated as if used in a non-Permissible End Use. The duration of any temporary storage shall be evidenced through monthly gross mass flows into and out of the temporary storage facility.

- The Hydrogen Production Facility maintains and provides a verifiable audit trail documenting the transfer of Solid Carbon from the Hydrogen Production Facility to

the Solid Carbon Permissible End Use, and retention in the Solid Carbon Permissible End Use. This audit trail shall include records of quantities, dates of transfer, and recipient details sufficient to demonstrate the secure and compliant use of Solid Carbon Output within a Solid Carbon Permissible End Use.

- Any emissions accounted for under this Emission Category shall not be credited or claimed elsewhere (for example, as a carbon credit in other policies or voluntary markets). If credited elsewhere, any emissions sequestration benefit can no longer be included in the overall emissions calculation for the purposes of the Standard.

- Any emissions credit accounted for under this Emission Category are directly related to processes within the System Boundary. Carbon offsets (or similar) from other processes shall not be claimed under the Standard.

Where there are potential time delays in the submission of verifiable evidence, it may be agreed through the DCMP with the Delivery Partner that emission credits are awarded provisionally, ahead of receiving this evidence, and subsequently reconciled once the evidence is provided.

5.65. If the conditions above are met, Solid Carbon being claimed under this Emission Category shall use the sequestration credit values given in the Data Annex under Solid Carbon Sequestration. Note that fossil sequestration credits are only to be applied to fossil Solid Carbon (and associated fossil Hydrogen Product Consignments), and biogenic sequestration credits are only to be applied to biogenic Solid Carbon (and associated biogenic Hydrogen Product Consignments). The biogenic and fossil proportions can be calculated using Equation 81 and Equation 82.

5.66. For Solid Carbon Output that that is produced, the Hydrogen Production Facility shall allocate the Solid Carbon Sequestration GHG emissions associated with the fossil or biogenic Solid Carbon across the respective fossil or biogenic Hydrogen Product generated. The method for allocation and associated time period shall be agreed through the DCMP with the Delivery Partner.

5.67. Where it is identified that a quantity of Solid Carbon Output has not been used in a Solid Carbon Permissible End Use, or has been subsequently removed from one, the Delivery Partner shall be notified. The method for determining the corresponding quantity of Discrete Consignments to be deemed non-compliant under the Standard shall be agreed through the DCMP with the Delivery Partner. This method should reasonably reflect the relationship between the mass of non-permissible Solid Carbon and a mass of Hydrogen Product produced over a representative preceding period, taking into account relevant operational data such as production ratios and Feedstock compositions.

5.68. Any emissions occurring beyond the Solid Carbon End User Point (for example, from the transport, storage, processing, or loss of Solid Carbon) are considered outside the

System Boundary of the Standard to calculate GHG Emission Intensity for Consignments of hydrogen.

5.69. Distribution and Sequestration of Solid Carbon is assumed to remain within the Standard's System Boundary, so Solid Carbon shall not be classified as a Co-Product of the Hydrogen Production Facility. Therefore, Solid Carbon will not be part of the $AF_{production}$ calculations and will not be allocated a share of the Hydrogen Production Facility's emissions.

5.70. For some Pathways using biogenic Feedstocks, the Solid Carbon Sequestration credit may be large enough to result in the overall GHG Emission Intensity for the Hydrogen Product becoming negative. This is permitted under the Standard as this has resulted from an Emission Category with a minus sign, rather than resulting from negative GHG Emission Intensity Inputs.

Compression and Purification

5.71. The pressure and purity of the Hydrogen Product is normally influenced by offtaker and/or end use requirements. Hydrogen Production Facilities shall account for the energy used (e.g., any electricity for compression) to reach their stated Output pressure and purity within the Energy Supply Emission Category above.

5.72. Any fugitive CO_2 produced during Compression and Purification (e.g., from tail gases) shall already be accounted for within the Process CO_2 Emission Category above. Any other GHG emissions released shall already be accounted for within the Fugitive non-CO_2 Emission Category above. Any CO_2 captured and sequestered shall already be accounted for within the CO_2 Sequestration Emission Category above.

5.73. However, the Standard sets a theoretical minimum pressure level of 3MPa and a theoretical minimum purity of 99.9% by volume. Therefore, there is a requirement to calculate the GHG emissions from theoretical Compression and Purification of the Hydrogen Product only in two specific cases:

- Hydrogen Production Facilities outputting Hydrogen Product below the theoretical minimum 3MPa pressure and/or below the theoretical minimum 99.9% purity by volume. In these cases, Facilities shall account for the additional emissions associated with theoretical compression and/or purification to reach the theoretical minimum pressure and purity within the Standard. The data and methodology required for these theoretical calculations are provided in the Data Annex under Compression and Purification of hydrogen.

- Pre-operational Hydrogen Production Facilities using Default Data for the Energy Supply Emission Category (instead of Projected Activity Flow Data) but that are planning to Output Hydrogen Product above the theoretical minimum of 3MPa pressure and/or above the theoretical minimum of 99.9% purity by volume. The Default Data only accounts for compression to 3MPa and purification to 99.9%

purity by volume so the calculation methodology in the Data Annex under Compression and Purification of hydrogen shall be used, starting from 3MPa and 99.9% purity by volume, to calculate the additional GHG emissions to reach the planned pressure and purity Output.

5.74. If one of these two cases apply, theoretical Compression and Purification emissions ($E_{\text{Compression and Purification}}$) shall be calculated for each Reporting Unit using Equation 26.

Equation 26

$$E_{\text{Compression and Purification}} = P \times (EI_{\text{Compression}} + EI_{\text{Purification}})$$

- Where $E_{\text{Compression and Purification}}$ is the GHG emissions from theoretical Compression and Purification, calculated in gCO_2e. P is the total quantity of Hydrogen Product, in MJ_{LHV}, produced over the Reporting Unit for the Discrete Consignment (see Equation 2). $EI_{Compression}$ and $EI_{Purification}$ are defined in the Data Annex under Compression and Purification of Hydrogen and given in gCO_2e/MJ_{LHV}.

5.75. This Emission Category shall always be non-negative given the GHG Emission Intensity of any Input energy source cannot be reported as negative under the Standard. If neither of the specific cases from Paragraph 5.76 apply $E_{\text{Compression and Purification}}$ is taken as nil.

Fossil Waste/Residue Counterfactual

5.76. Utilising Fossil Waste/Residue Feedstock for Hydrogen Production diverts this Feedstock away from its existing counterfactual use/fate (for example, incineration to generate electricity or heat). The utility that is no longer generated in the counterfactual is now required to be provided from another source (for example, UK grid electricity or natural gas from the UK gas grid). These additional GHG emissions shall be attributed to the Pathway. However, diversion of the Feedstock also results in the counterfactual no longer releasing fossil Feedstock CO_2 emissions to atmosphere – CO_2 emission savings which shall also be attributed to the Pathway. This Emission Category therefore considers the impact of these changes in GHG emissions as illustrated in Figure 1.
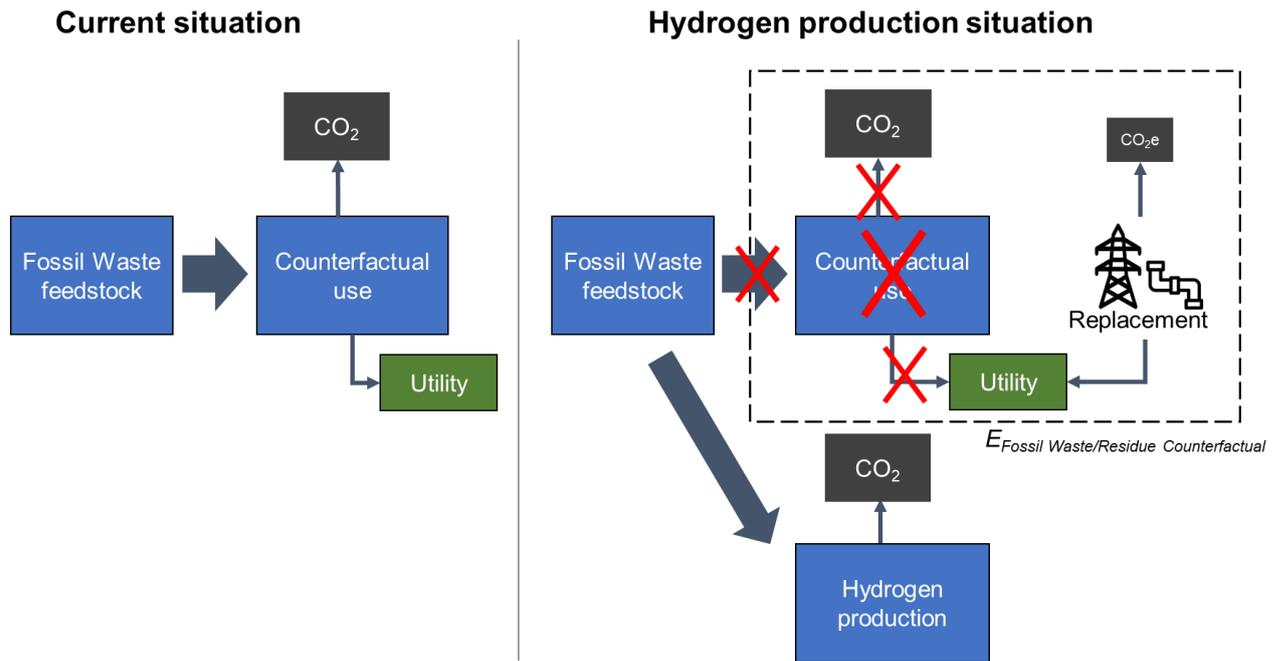
Figure 1: Illustration of the emissions changes from a Fossil Waste Feedstock being diverted from a counterfactual use

5.77. Counterfactual emissions shall only apply to Waste fossil Feedstocks and Residue fossil Feedstocks being used under the Standard. For Waste/Residue Feedstocks with a mix of biogenic and fossil fractions, such as refuse derived Fuel (RDF) Feedstocks, the counterfactual is only applied to the fossil fraction of the Waste/Residue Feedstock and not to the biogenic fraction. No counterfactual emissions shall be applied to biomass Feedstocks or to fossil Feedstocks that are not Wastes/Residues. Counterfactual emissions (in gCO$_2$e) shall be calculated using Equation 27 and Equation 28 below:

Equation 27

$$E_{Fossil\ Waste/Residue\ Counterfactual} = (E_{displaced\ utility} - E_{fossil\ counterfactual\ CO_2\ emitted}) \times CAF_{Pathway}$$

Equation 28

$$E_{displaced\ utility} = MJ_{Feedstock} \times Eff_{counterfactual} \times CI_{energy}$$

Where:

- $E_{\text{Fossil Waste/Residue Counterfactual}}$ is the GHG Emissions (in gCO$_2$e) from replacing the displaced utility that was generated by the counterfactual use, less the Waste/Residue fossil Feedstock CO$_2$ emissions released to atmosphere in the counterfactual use.

- $E_{\text{displaced utility}}$ is the GHG Emissions (in gCO_2e) arising from replacement of the displaced utility when a Waste/Residue fossil Feedstock is diverted to Hydrogen Production.

- $E_{\text{fossil counterfactual CO2 emitted}}$ is the Waste/Residue fossil Feedstock CO_2 emissions that would be released to the atmosphere in the counterfactual (in gCO_2e). Note this excludes other non-CO_2 emissions and excludes other sources of fossil CO_2 generated in the counterfactual that are not from the Waste/Residue fossil Feedstock carbon itself.

- $\text{Eff}_{\text{counterfactual}}$ is the LHV efficiency of converting Waste/Residue fossil Feedstock into electricity, Useful Heat, Useful Steam, and/or other energy vectors in the counterfactual use (in MJ_{LHV} energy/MJ_{LHV} Feedstock).

- $\text{CI}_{\text{energy}}$ is the GHG Emission Intensity of the displaced energy in the counterfactual (in gCO_2e/MJ_{LHV} energy).

- $\text{CAF}_{\text{Pathway}}$ is the Cumulative Allocation Factor for the whole Pathway from Waste/Residue fossil Feedstock to hydrogen (see Paragraphs 5.18 - 5.20)

- $\text{MJ}_{\text{Feedstock}}$ is the total amount of Waste/Residue fossil Feedstock diverted to Hydrogen Production from the counterfactual use (in MJ_{LHV} using the LHV formula on Paragraph 5.8).

5.78. If the Hydrogen Production Facility sequesters fossil CO_2 from the Feedstock that would have otherwise been released to the atmosphere in the counterfactual, then this can lead to emission savings compared to the counterfactual. This sequestered CO_2 will be accounted for separately within the CO_2 Sequestration Emission Category and has no impact on $E_{\text{displaced utility}}$ or $E_{\text{fossil counterfactual CO2 emitted}}$.

5.79. The CO_2 generated from the Waste/Residue fossil Feedstock during Hydrogen Production, along with other onsite sources of fossil CO_2 (e.g., from the combustion of natural gas or diesel Fuels), shall still be accounted for within the Process CO_2 Emission Category.

5.80. Certain Fossil Waste/Residue Feedstocks already have a defined counterfactual which shall be used. These are given in the Data Annex under Fossil Waste/Residue Counterfactual. For other Waste/Residue fossil Feedstocks not listed in the Data Annex, the Hydrogen Production Facility shall provide evidence regarding:

- The form and composition of the Feedstock; the ability to store and transport the Feedstock; the number of producers of the Feedstock; and the market for trade of the Feedstock.

- The current and expected uses of the Feedstock and the utility that would be displaced (both for the specific Feedstock tonnages proposed for Hydrogen Production and the wider use of the Feedstock across the UK).

- The energy sources that are most likely to replace this displaced utility (both for the specific Feedstock tonnages proposed for Hydrogen Production and the wider use of the Feedstock across the UK).

- DESNZ will review this evidence and determine an appropriate counterfactual and if necessary, may update the Data Annex to provide more details of the new counterfactual. DESNZ will also determine if a counterfactual applies to all Hydrogen Production Facilities using the Feedstock or if a counterfactual only applies to one particular Hydrogen Production Facility.

5.81. DESNZ will continually monitor the appropriateness of the counterfactuals provided in the Data Annex under Fossil Waste/Residue Counterfactual, including alignment with other relevant policy and the opportunities or risks that may be posed to system-wide environmental and decarbonisation efforts. If necessary, DESNZ will update the counterfactuals or counterfactual methodology at a future review point.

Example (noting that this purely illustrative example does not indicate the appropriate counterfactual to be used):

100 MJ_{LHV} of the fossil fraction of RDF is used in a gasification Facility to produce 50 MJ_{LHV} of hydrogen.

The counterfactual is an unabated energy from Waste power plant with 22% net electrical efficiency that would have released 9,300 gCO_2 to atmosphere from combustion of the 100 MJ_{LHV} of Fossil Waste Feedstock.

In this example, grid average electricity is assumed to replace this missing generation with a GHG Emission Intensity of 35 gCO_2e/MJ_e. The Cumulative Allocation Factor for the whole Pathway is 65.5% from a Hydrogen Production Facility Allocation Factor of 72.8%, and a pre-processing Step Allocation Factor of 90% (Co-Products are generated both during the pre-processing Step and at the Hydrogen Production Facility). It is assumed the pre-processed Waste Feedstock retains 85% of the original Waste Feedstock carbon.

$E_{\text{Fossil Waste/Residue Counterfactual}}$ would be = $(100\ MJ_{LHV} \times 35\ gCO_2/MJ_{LHV} \times 22\% - 9{,}300 gCO_2) \times 65.5\% = (770\ gCO_2e - 9{,}300\ gCO_2) \times 65.5\% = -5{,}587\ gCO_2e$. The contribution of $E_{\text{Fossil Waste/Residue Counterfactual}}$ to the Final GHG Emission Intensity would be $\frac{-5{,}587\ gCO_2e}{50\ MJ_{LHV}} = -111.7\ gCO_2e/MJ_{LHV}$.

However, the Hydrogen Production Facility Process CO_2 emissions will be approaching $9{,}300\ gCO_2 \times 85\% = 7{,}905\ gCO_2$ due to fossil CO_2 generated from the conversion of the pre-processed Waste Feedstock prior to any CO_2 capture and emissions allocation to Co-Products

at the Facility. $E_{\text{Process CO}_2}$ would be 7,905 $gCO_2 \times 72.8\% = 5,755$ gCO_2e. The contribution of $E_{\text{Process CO}_2}$ to the Final GHG Emission Intensity would be $\frac{5,755 \text{ gCO2e}}{50 \text{ MJ}_{\text{LHV}}} = +115.1$ gCO_2e/MJ_{LHV}.

$E_{\text{Feedstock Supply}}$ would also have emissions to account for the release of 15% of the Feedstock fossil carbon during pre-processing.

Therefore, the net result for the fossil fraction of RDF, where both the Hydrogen Production and Fossil Waste Feedstock counterfactual are unabated, is strongly influenced by the efficiency of the counterfactual and the displaced GHG Emission Intensity.

Example: (noting that this purely illustrative example does not indicate the appropriate counterfactual to be used):

100 MJ_{LHV} of fossil plastic is used in a gasification Hydrogen Production Facility to produce 55 MJ_{LHV} of hydrogen.
The counterfactual is an unabated furnace for cement kiln heating that would have released 10,300 gCO_2 to atmosphere from the combustion of the 100 MJ_{LHV} of Fossil Waste Feedstock. Grid natural gas is assumed to replace this missing heating Fuel with a GHG Emission Intensity of 6.2 gCO_2e/MJ_{LHV} for supply and 55.6 gCO_2e/MJ_{LHV} for combustion.
For simplicity, there is no difference assumed between furnace heating efficiencies when using natural gas or Waste plastic, and there are no Co-Products or pre-processing in this Pathway.

$E_{\text{Fossil Waste/Residue Counterfactual}}$ would be = $(100 \text{ MJ}_{\text{LHV}} \times (6.2 \text{ gCO}_2e/MJ_{\text{LHV}} + 55.6 \text{ gCO}_2e/MJ_{\text{LHV}}) - 10,300 \text{ gCO}_2) \times 100\% = 6,180 \text{ gCO}_2 - 10,300 \text{ gCO}_2 = -4,120 \text{ gCO}_2e$. The contribution of $E_{\text{Fossil Waste/Residue Counterfactual}}$ to the Final GHG Emission Intensity would be $\frac{-4,120 \text{ gCO2e}}{55 \text{ MJ}_{\text{LHV}}} = -74.9 \text{ gCO}_2e/MJ_{\text{LHV}}$.

$E_{\text{Process CO}_2}$ would be = 10,300 $gCO_2e \times 100\% = 10,300$ gCO_2e. The contribution of $E_{\text{Process CO}_2}$ to the Final GHG Emission Intensity would be $\frac{10,300 \text{ gCO2e}}{55 \text{ MJ}_{\text{LHV}}} = +187.3 \text{ gCO}_2e/MJ_{\text{LHV}}$.

The net result for the fossil plastic used is that the hydrogen will not be compliant with the Standard due to the high emissions of the displaced heating in the counterfactual, unless significant CCS were implemented by the Hydrogen Production Facility.

Materiality

5.82. In any Pathway, there will be a number of minor Emission Sources which can be costly to measure, report, and verify while their impact on the overall GHG Emission Intensity of the hydrogen is insignificant. Life-cycle analyses typically define a 'Materiality' level below which Emission Sources may be categorised as Immaterial Emission Sources and excluded from the GHG Emission Intensity Calculation Methodology. These Materiality limits are set to ensure confidence in the overall reported GHG Emission

Intensities whilst also avoiding unnecessary administrative burdens of reporting and evidencing Immaterial Emission Sources.

5.83. The Materiality Threshold for an Emission Source is 1% of the GHG Emission Intensity Threshold so a value of 0.2 gCO_2e/MJ_{LHV} Hydrogen Product. No more than a total of 5% of the GHG Emission Intensity Threshold (so a value of 1.0 gCO_2e/MJ_{LHV}) shall be excluded as being Immaterial Emission Sources.

5.84. Therefore, if a single Emission Source contributes <0.2 gCO_2e/MJ_{LHV} Hydrogen Product and in total all the Immaterial Emission Sources contribute <1.0 gCO_2e/MJ_{LHV} Hydrogen Product, the single Emission Source in question may be considered as an Immaterial Emission Source and excluded from the GHG Emission Intensity Calculation Methodology. Where an individual Emission Source is <0.2 gCO_2e/MJ_{LHV} Hydrogen Product but deeming it to be an Immaterial Emission Source would lead to a total of >1.0 gCO_2e/MJ_{LHV} Hydrogen Product being considered as Immaterial Emission Sources, this specific Emission Source shall be considered as a Material Emission Source and included in the GHG Emission Intensity Calculation Methodology.

5.85. Immaterial Emission Sources shall be agreed with the Delivery Partner based on the Hydrogen Production Facility's initial calculations. Once a Hydrogen Production Facility has first begun operations Materiality shall be assessed for each calendar month at the end of that month. For each Emission Source, the Facility shall assess Materiality using the sum of the GHG emissions from the Emission Source during that month divided by the month's total generation of Hydrogen Product and shall confirm the status of each Emission Source with respect to the Materiality Threshold. Changes between months in the usage rate of Inputs or the use of new Inputs may lead to some Emission Sources that were reported in previous months as Immaterial Emission Sources becoming Material Emission Sources (or vice versa).

5.86. Emissions from similar Input sources shall be considered together to avoid Hydrogen Production Facilities making multiple claims of Immaterial Emission Sources which if aggregated would result in Material Emission Sources (above the Materiality Threshold). Electricity Inputs shall be considered together within groups of similar generation types for the purposes of assessing Materiality: for example, wind/solar, nuclear, electricity from biogenic sources, energy from Waste, grid average, and Electricity Storage System.

Example: If five different grades of fossil diesel are used, each of which are individually Immaterial Emission Sources, the Hydrogen Production Facility shall aggregate these similar Inputs to assess whether the total fossil diesel usage is a Material Emission Source or an Immaterial Emission Source.

Example 2: A Hydrogen Production Facility could set up dozens of PPAs with bio-electricity generators, each only contributing 0.1 gCO_2e/MJ_{LHV} hydrogen, but the Hydrogen Production

Facility shall aggregate these similar Inputs to determine the Materiality of all the bio-electricity Inputs.

5.87. Any emissions credits from direct land use change with the $E_{Feedstock\ Supply}$ Emission Category, or the $E_{CO_2\ Sequestration}$ and $E_{Solid\ Carbon\ Sequestration}$ Emission Categories, shall be deemed Material Emission Sources, regardless of their magnitude. Similarly, the negative term $E_{Fossil\ counterfactual\ CO_2\ emitted}$ within the Fossil Waste/Residue Counterfactual Emission Category shall be deemed a Material Emission Source, regardless of its magnitude.

5.88. Designation of an Emission Source as an Immaterial Emission Source in GHG emission terms shall not impact on or negate other compliance, evidence, or technical requirements of the Standard.

Example: Wind electricity (with a nil GHG Emission Intensity) or biomass-derived electricity with CCS (that has negative GHG Emission Intensity but is declared as having nil GHG Emission Intensity under the Standard) will still need to meet the evidence requirements of Annex B and any relevant Biomass Requirements in Annex E respectively.

5.89. The Materiality assessment shall be included within the scope of any third-party audits to check that Emission Sources have been appropriately excluded. More scrutiny should be paid to those Emission Sources likely to be closer to the Materiality Threshold.

Examples of potentially Immaterial and Material Emission Sources:

For electrolysis Pathways, typical Hydrogen Production Facilities might expect that Emission Sources such as mains water Input, minor chemicals such as acids and alkalis used in water treatment, along with nitrogen supplied for purging, to each be Immaterial Emission Sources (<0.2 gCO_2e/MJ_{LHV} hydrogen) but this will vary by Facility and needs to be confirmed each month in ongoing reporting. Inputs such as diesel used for back-up generators may well be Material Emission Sources in a given calendar month.

For natural gas reforming Pathways, typical Hydrogen Production Facilities might expect that Emission Sources such as mains water Input and minor chemicals are likely to be classified as Immaterial Emission Sources, but this will also vary by Hydrogen Production Facility and needs to be confirmed each month. Inputs and Outputs such as amine solution make-up used for CO_2 capture; oxygen deliveries (if not generated onsite); grid electricity; and fugitive emissions of methane may be Material Emission Sources. It is expected that natural gas supply and Process CO_2 emissions will always be Material Emission Sources for natural gas reforming Pathways.

6. Biomass Requirements

6.1.   Hydrogen derived from biogenic Inputs shall satisfy the Standard's Biomass Requirements as part of demonstrating compliance with the Standard (see 'Standard Compliance' in Chapter 3). These Biomass Requirements encompass the Sustainability Criteria, the Minimum Waste and Residue Requirement, and the reporting of indirect land use change emissions. These requirements apply to Hydrogen Production Facilities that use biogenic Feedstocks or biogenic energy Inputs (electricity, heat, steam, and Fuels).

6.2.   The Biomass Requirements currently do not apply to the use of biochemical Inputs (biogenic Inputs not used for energy purposes in the Hydrogen Production Facility). These Biomass Requirements also currently do not apply to the use of non-Feedstock biogenic Inputs within the Pathway's Feedstock Supply chain prior to the Hydrogen Production Facility (e.g., biodiesel used in trucks transporting Feedstock, biomass heating Fuels used in Feedstock pre-processing plants). It is still recommended to satisfy the Biomass Requirements in these cases where possible as these positions will be kept under review by DESNZ as biomass sustainability policy develops.

Sustainability Criteria

6.3.   The Sustainability Criteria consist of the Land Criteria, Soil Carbon Criteria, and Forest Criteria, closely following the approach set out in the Renewable Transport Fuel Obligation (RTFO). Which of these criteria apply depend on the classification and source of the biogenic Input – see Table 8 within Annex E for further details:

- Unless indicated in the bullets below, biogenic Inputs shall be required to satisfy the Land Criteria. These prohibit the sourcing of the biogenic Input from land that has or previously had a certain status to preserve biodiversity and carbon stocks.

- Biogenic Inputs that are Residues or Wastes from agriculture shall also meet the Soil Carbon Criteria. These ensure monitoring or management plans are in place to address the impacts on soil quality and soil carbon of harvesting the biogenic Input concerned.

- Biogenic Inputs from forestry (including Wastes and Residues) shall be required to meet the Forest Criteria instead of the Land Criteria. The Forest Criteria ensure monitoring and management plans are in place to address potential negative impacts (related to biodiversity, carbon stocks, soil quality etc.) of harvesting the biogenic Input concerned.

- Biogenic Inputs that are Wastes or Residues that are not from agriculture, aquaculture, fisheries, or forestry do not need to meet any of the Sustainability Criteria.

6.4.   Further details of these Sustainability Criteria and the requirements for demonstrating compliance with them are provided in Paragraphs E. 30 - E. 52.

Minimum Waste and Residue Requirement

6.5.   Any biogenic Inputs used in the Pathway shall satisfy the Standard's Minimum Waste and Residue Requirement as set out in Paragraphs E. 7 - E. 10.

Indirect Land Use Change (ILUC) emissions

6.6.   Emissions associated with direct land-use change (see Paragraphs E. 11 - E. 25) shall be accounted for within the Feedstock Supply Emission Category (see Paragraph 5.21) for biogenic Feedstocks, and within the Energy Supply Emissions Category (see Paragraph 5.26) for biogenic energy Inputs. In contrast, indirect land use change emissions shall be excluded from these calculations but shall be estimated and reported separately. Further guidance on emissions related to indirect land-use change is provided in Paragraphs E. 26 - E. 29.

7. Consignments and monthly averaging

Reporting Units

7.1.   The GHG Emission Intensity of the Hydrogen Product from a Hydrogen Production Facility will in most cases vary over time as accounted for under the GHG Emission Intensity Calculation Methodology in Chapter 5, given changes in the performance of the Facility and its various Inputs and Outputs.

7.2.   The Standard sets a common Reporting Unit of 30 minutes to measure and report the GHG Emission Intensity of the Hydrogen Product when a Hydrogen Production Facility is operational.

Generation of Discrete Consignments

7.3.   The Hydrogen Product made within a Reporting Unit shall be divided into separate amounts (on a MJ_{LHV} energy basis as per Paragraph 5.9) where within each separate amount all the Hydrogen Product shares the same Environmental Characteristics. Each amount of Hydrogen Product shall be defined as a Discrete Consignment. Note that Discrete Consignments are not amounts of Feedstock or energy Inputs. Any Reporting Unit without generation of Hydrogen Product does not form a Discrete Consignment.

7.4.   For Pathways with a Feedstock, a Discrete Consignment shall have the following identical Environmental Characteristics:

- Feedstock.

- Feedstock form (solid, liquid, gas).

- Feedstock country of origin.

- Feedstock classification (Waste, Residue, Co-Product, or Product).

- Feedstock type (biogenic, fossil, nuclear, renewable Fuel of non-biological origin).

- Where relevant, the counterfactual use for any Fossil Waste/Residue Feedstocks.

- Where relevant, compliance of biogenic Feedstocks with the Biomass Requirements (see Annex E).

- Steps within the Hydrogen Production Pathway.

- Final GHG Emission Intensity of the Hydrogen Product.

7.5.   For Pathways without a Feedstock (for example, electrolysis Pathways), a Discrete Consignment shall have the following identical Environmental Characteristics:

- Energy Input form (electricity, heat, steam).

- Type of energy generation technology.

- Energy Input country of origin, and for any initial biogenic sources generating biogenic energy Inputs, their country of origin,

- Where relevant, electricity Input type (specific generator (biogenic, fossil, nuclear, renewable energy of non-biological origin, Electricity Storage System); Private Network not linked to a specific generator; grid import not linked to a specific generator; Electricity Curtailment Avoidance).

- Where relevant, heat or steam Input type (biogenic, fossil, nuclear, renewable energy of non-biological origin).

- Where relevant, the counterfactual use for any Fossil Waste/Residue materials used in energy generation.

- Where relevant for biogenic energy Inputs, compliance of the original biogenic material with the Biomass Requirements (see Annex E).

- Steps within the Hydrogen Production Pathway.

- Final GHG Emission Intensity of the Hydrogen Product.

7.6.   Hydrogen Production Facilities may use multiple Feedstocks or multiple energy Inputs with different associated Environmental Characteristics. Facilities may also use mixed Feedstocks that have component fractions with different associated Environmental Characteristics. Where not all the Hydrogen Product generated during a Reporting Unit shares the same identical set of Environmental Characteristics (due to the presence of multiple Feedstocks, Feedstock component fractions, or mixed energy Inputs), Hydrogen Product shall be split into separate Discrete Consignments. Every Reporting Unit that has Hydrogen Product generated will have at least one Discrete Consignment.

7.7.   All Discrete Consignments shall be reported and assessed separately for compliance or non-compliance with the Standard (before being subject to weighted averaging which is covered later in Paragraphs 7.28 - 7.35).

7.8.   If there is at least one Feedstock for the Pathway, any imported electricity, heat or steam may be treated as single Inputs (each with one GHG Emission Intensity respectively) for a given Reporting Unit, and the imported electricity, heat or steam

does not have to be split into their original sources with different Environmental Characteristics. In other words, where there is at least one Feedstock for the Pathway, the generation of Discrete Consignments shall be driven by the differences in Feedstocks alone.

7.9. Where there is no Feedstock for the Pathway (e.g., electrolysis) and there are multiple sources for the imported electricity, heat, or steam, differences in these energy sources shall result in the generation of separate Discrete Consignments.

An indicative example of how different Discrete Consignments are generated for a two-hour and thirty-minute period of Hydrogen Production is shown below in where each amount on the top row is indicatively 1 MJ_{LHV} of hydrogen:
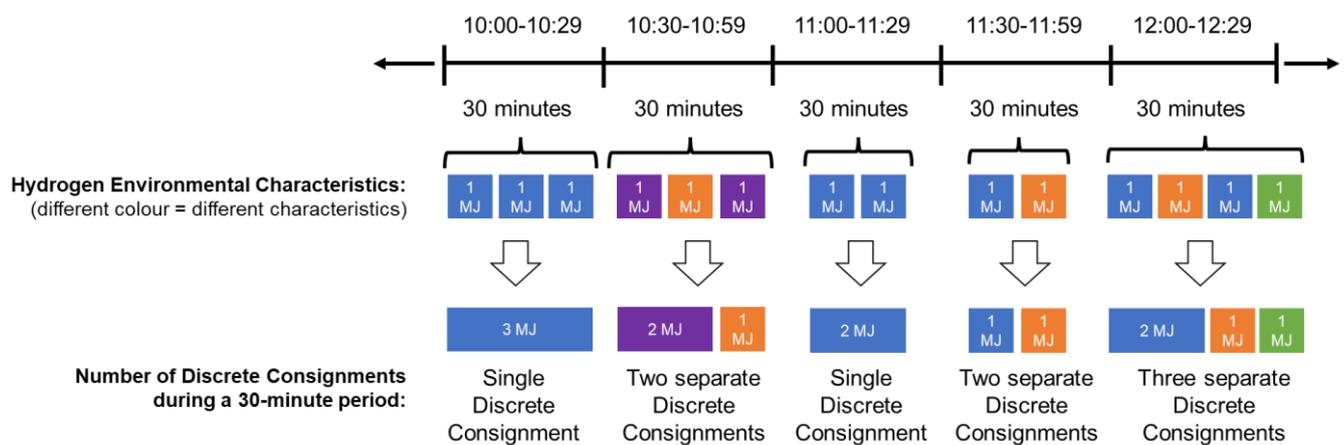
Figure 2: Illustrative diagram for generation of Discrete Consignments

Input-specific requirements for generating Discrete Consignments

Pathways without a Feedstock

7.10. For Pathways without a Feedstock such as electrolysis, the use of electricity during a Reporting Unit that is sourced from the Electricity Grid and not linked to a specific generator shall not be split into its component parts (such as gas, coal, nuclear, wind, solar etc). Similarly, the consumption of electricity discharged from an Electricity Storage System during a Reporting Unit shall not be split into the component parts used to charge the Electricity Storage System.

7.11. For a Pathway without a Feedstock using energy generated from mixed Waste (with fossil and biogenic components), both fossil and biogenic Discrete Consignments shall be generated – the Hydrogen Production Facility cannot choose to generate only one Discrete Consignment. The use of a mixed Waste to generate energy as an Input to a

Pathway with a Feedstock shall require both fossil and biogenic components of the mixed Waste to be accounted for within the GHG Emission Intensity of the Input electricity.

7.12. For Pathways without a Feedstock, electricity consumed from each Electricity Storage System shall form its own Discrete Consignment (with its own GHG Emission Intensity) separate from other electricity source Discrete Consignments. Electricity consumed from multiple generation assets via a single Eligible PPA shall be separated into electricity Input types as per Paragraph 7.5 (each Discrete Consignment sharing the same electricity delivered GHG Emission Intensity).

Example: For a Reporting Unit, 10 MWh$_{LHV}$ of electrolytic hydrogen is produced using 20% UK grid average electricity; 10% electricity from an Electricity Storage System (pumped hydro storage); 30% electricity from an Electricity Storage System (battery); and 40% electricity via an eligible PPA with a wind farm. This example would result in four Discrete Consignments during that Reporting Unit as given the absence of a Feedstock for this Pathway. The Discrete Consignments are determined by the energy Inputs:

2 MWh$_{LHV}$ of Hydrogen Product based on the grid average electricity GHG Emission Intensity.
1 MWh$_{LHV}$ of Hydrogen Product based on the Electricity Storage System (pumped hydro storage) discharged electricity GHG Emission Intensity factoring in T&D losses between the pumped hydro storage and the electrolyser.
3 MWh$_{LHV}$ of Hydrogen Product based on the Electricity Storage System (battery) discharged electricity GHG Emission Intensity factoring in T&D losses between the battery and the electrolyser.
4 MWh$_{LHV}$ of Hydrogen Product based on the wind farm electricity GHG Emission Intensity (nil) with any T&D losses between the wind farm and the electrolyser therefore being irrelevant to the delivered electricity GHG Emission Intensity.

Pathways with a Feedstock

7.13. For Pathways with a Feedstock, electricity from Electricity Storage Systems shall not form their own Discrete Consignments although electricity from Electricity Storage Systems will impact the resulting hydrogen GHG Emission Intensity. In these cases, Discrete Consignments are defined based on the Feedstock.

7.14. The use of fossil natural gas sourced from the UK Gas Network is considered as one Input during a Reporting Unit and shall not be split into its component parts (for example, UK production, piped imports, imported liquified natural gas etc). Biomethane that is transported via the UK Gas Network, mixing with fossil natural gas, may be claimed as Input biomethane during a Reporting Unit, provided all the evidence requirements set out in Annex F are met.

7.15. For fossil gas Inputs where a mix of different sources of the same type of fossil gas (for example, fossil natural gas sourced from the UK Gas Network and via a direct connection to a North Sea field) are used within a Reporting Unit, these shall be separated into individual Discrete Consignments.

Example: For a Reporting Unit, 250 MWh_{LHV} of H_2 is produced in an autothermal reforming with CCS Hydrogen Production Facility in England using 40% gas from the UK Gas Network; 20% Refinery Off Gas; 10% biomethane via direct connection to an anaerobic digester using half sustainable maize and half manure; and 30% directly imported Norwegian natural gas (% shares based on LHV energy contents) whilst also using 20 MWh_e of UK grid average electricity and 5 MWh_e of wind power. This example would produce five Discrete Consignments determined by the Feedstocks and not by the Input electricity.

100 MWh_{LHV} of Hydrogen Product based on the UK Gas Network GHG Emission Intensity.
50 MWh_{LHV} of Hydrogen Product based on Refinery Off Gas calculations.
12.5 MWh_{LHV} of Hydrogen Product based on the maize biomethane calculations.
12.5 MWh_{LHV} of Hydrogen Product based on the manure biomethane calculations.
75 MWh_{LHV} of Hydrogen Product based on the imported Norwegian natural gas calculations.

Note that in all these Discrete Consignments the Input electricity GHG Emission Intensity is calculated using 80% GB Electricity Grid and 20% wind power.

7.16. Where a mixed Waste Feedstock has a biogenic and a fossil component (for example, municipal solid Waste), this shall be considered as two distinct Feedstocks resulting in two Discrete Consignments split in line with the biogenic and fossil fractions on a LHV energy basis (see Paragraphs H. 48 - H. 49).

Example: For a Reporting Unit, 10 MWh_{LHV} of hydrogen is produced by gasification using mixed Waste with a composition of 55% biogenic and 45% Fossil Waste content by LHV energy. This would produce two Discrete Consignments based on the Feedstock components.

5.5 MWh_{LHV} of Hydrogen Product based on biogenic Waste calculations.
4.5 MWh_{LHV} of Hydrogen Product based on Fossil Waste calculations including the Fossil Waste/Residue Counterfactual Emissions Category.

Calculation of Discrete Consignment GHG Emission Intensity

Emissions included in Discrete Consignments

7.17. The emissions attributed to a Discrete Consignment shall follow the emission categories set out in the GHG Emission Intensity Calculation Methodology.

7.18. Emissions for each Discrete Consignment shall be calculated based on the use of Inputs and release/capture of Outputs within each Reporting Unit, irrespective of whether these emissions relate to Hydrogen Production processes during that Reporting Unit, or to the operation of Hydrogen Storage or pre/post-production ancillary processes (e.g., onsite Feedstock pre-processing, Buffer Storage, hydrogen purification).

7.19. For Inputs that arrive onsite via a permanent connection, emissions shall be accounted for based on the amount of Input that flows across the System Boundary within each Reporting Unit.

7.20. For Inputs that arrive onsite as batches (and are likely stored onsite prior to use, e.g., a truck load of a particular chemical or diesel), emissions shall be accounted for based on the consumption of these Inputs within the Hydrogen Production Facility for each Reporting Unit. All the emissions associated with the delivery itself (such as from the delivery vehicle) shall be spread over the consumption of the Input and not accounted for within the Reporting Unit when the delivery arrives onsite. See Paragraphs H. 50 - H. 52 for further information on emissions accounting for batch Inputs.

7.21. Emissions for Outputs (for example, Fugitive non-CO_2 emissions) shall be accounted for within the Reporting Unit in which they occur.

7.22. Similarly, any LHV Energy Allocation of emissions to Co-Products shall be based on the Reporting Unit in which the Hydrogen Product and Co-Products are generated.

7.23. Discrete Consignment emissions shall not be based on tracking individual units of Hydrogen Product between Reporting Units. For example, emissions linked to running on-site Hydrogen Storage are accounted for by any Hydrogen Product generated within that Reporting Unit rather than being assigned to the Discrete Consignments already generated and stored within the Hydrogen Storage.

GHG Emission Intensity calculations for each Discrete Consignment

7.24. The Raw GHG Emission Intensity calculated (using Equation 2) for each Discrete Consignment shall be calculated as gCO_2e/MJ_{LHV} Hydrogen Product based on the GHG emissions generated within the Reporting Unit and the Hydrogen Product (including impurities) produced within the same Reporting Unit. Note that the calculation shall not use gCO_2e/MJ_{LHV} *pure* hydrogen, gCO_2e/MJ_{LHV} hydrogen *sold*, or gCO_2e/MJ_{LHV} hydrogen *stored*.

7.25. If there are any Reporting Unit(s) where no Hydrogen Product is generated but there are still GHG emissions being generated (for example, due to energy consumption during hot standby or maintenance periods), then these Cumulative Non-Production Emissions shall be spread across the first 24 hours of Hydrogen Product once Hydrogen Production restarts using the following method:

- The GHG emissions occurring across a consecutive sequence of Reporting Units without generation of Hydrogen Product shall be added together to form the Cumulative Non-Production Emissions (in gCO_2e). If there is only a single Reporting Unit without generation of Hydrogen Product, the GHG emissions occurring within this Reporting Unit will form the Cumulative Non-Production Emissions.

- As soon as Hydrogen Production restarts (that is, there is a Reporting Unit in which Hydrogen Product is generated), the Cumulative Non-Production Emissions shall be divided by the total Hydrogen Product (in MJ_{LHV}) produced within the 24-hour period from the beginning of the Reporting Unit in which Hydrogen Production restarted.

- The resulting average extra gCO_2e/MJ_{LHV} Hydrogen Product value shall then be added onto the Raw GHG Emission Intensities for every Discrete Consignment within the 24-hour period from the beginning of the Reporting Unit in which Hydrogen Production restarted to achieve the Final GHG Emission Intensity result (gCO_2e/MJ_{LHV} Hydrogen Product) for these Discrete Consignments. This is set out in Equation 29. Note these extra emissions shall be assigned to every Discrete Consignment of Hydrogen Product within the 24-hour period and not necessarily assigned to every Reporting Unit within the 24-hour period.

Equation 29

$$Final\ GHG\ Emission\ Intensity_{DC}\ (gCO_2e/MJ_{LHV})$$

$$= Raw\ GHG\ Emission\ Intensity_{DC}\ (gCO_2e/MJ_{LHV})$$

$$+ \frac{\sum_{RU\ stop\ +1}^{RU\ restart\ -1} GHG\ emissions\ (gCO_2e)}{\sum_{RU\ restart}^{RU\ restart\ +47} Hydrogen\ Product\ (MJ_{LHV})}$$

Where:

- RU = Reporting Unit

- DC = Discrete Consignment

7.26. Passing midnight at the end of a calendar month has no impact on these GHG Emission Intensity calculations. Any Cumulative Non-Production Emissions shall continue to accumulate and be rolled over until the next Reporting Unit with Hydrogen Product generated even if this is several months later.

7.27. It is possible that Hydrogen Production might restart, stop shortly after (with new Cumulative Non-Production Emissions then occurring), then restart again within 24 hours of the first restart. If this situation arises, the above principles for calculating

Final GHG Emission Intensities shall still apply and some of the Raw GHG Emission Intensities will have two sets of Cumulative Non-Production Emissions added to them (a further fraction shall be added to Equation 29 for the relevant Discrete Consignments). If there are even more frequent restarts and Cumulative Non-Production Emissions occurring during these short intermediate non-production periods, the same principles shall still apply (further fractions shall be added to Equation 29 for the relevant Discrete Consignments).

Figure 3: Illustrative GHG emissions and Final GHG Emission Intensities with the reallocation of the Cumulative Non-Production Emissions (red) shows an indicative example adding the Cumulative Non-Production Emissions resulting from a spell of no Hydrogen Production (red boxes) to the Raw GHG Emission Intensities for each Discrete Consignment in the 24-hours following the restart of Hydrogen Production.
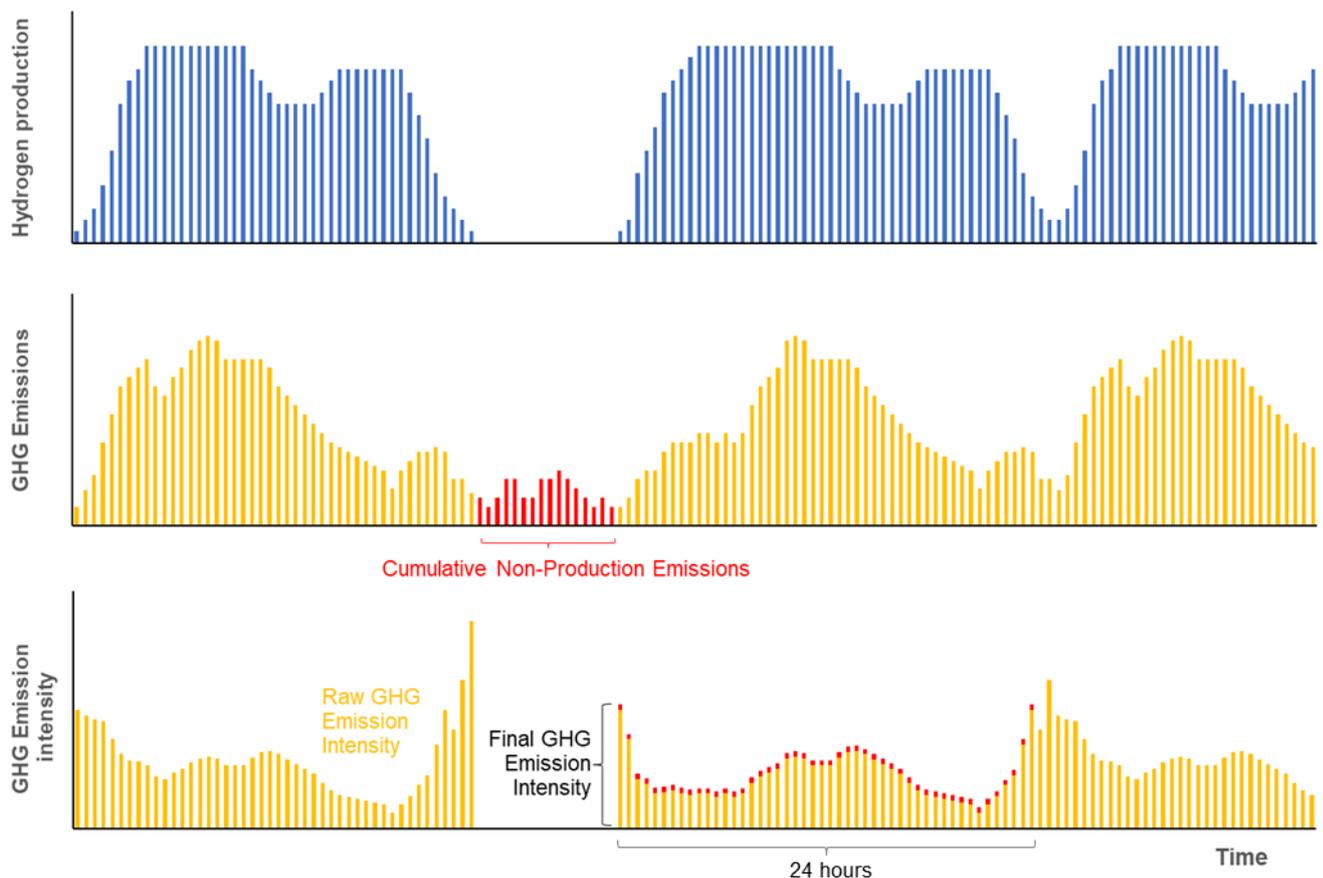

Figure 3: Illustrative GHG emissions and Final GHG Emission Intensities with the reallocation of the Cumulative Non-Production Emissions (red)

Monthly Reporting and Weighted Average Consignments

7.28. Each Discrete Consignment during a calendar month shall be reported separately at the end of the calendar month along with its Raw and Final GHG Emission Intensities and other Environmental Characteristics as set out in Paragraphs 7.4 - 7.5. This reporting includes any Discrete Consignments that fail to meet the GHG Emission Intensity Threshold or are generated when a Hydrogen Production Facility is not meeting the Conditions of Standard Compliance.

7.29. At the end of each calendar month the Hydrogen Production Facility has the option to calculate, and report Weighted Average Consignments based on a selected aggregation of any Discrete Consignments in that calendar month meeting the Conditions of Standard Compliance and having a non-negative Final GHG Emission Intensity. Any Weighted Average Consignment shall report a Final GHG Emission Intensity that is the weighted average of its constituent Discrete Consignments based on the MJ_{LHV} energy contents of the selected Discrete Consignments (note this is not a simple arithmetic average of the Final GHG Emission Intensity values).

Example: A Hydrogen Production Facility produces 57 MJ_{LHV} of Hydrogen Product over month split into the following Discrete Consignments:

6 MJ_{LHV} with a Final GHG Emission Intensity of -15 gCO_2e/MJ_{LHV}
14 MJ_{LHV} with a Final GHG Emission Intensity of 9 gCO_2e/MJ_{LHV}
9 MJ_{LHV} with a Final GHG Emission Intensity of 18 gCO_2e/MJ_{LHV}
11 MJ_{LHV} with a Final GHG Emission Intensity of 35 gCO_2e/MJ_{LHV}
5 MJ_{LHV} with a Final GHG Emission Intensity of 41 gCO_2e/MJ_{LHV}
12 MJ_{LHV} with a Final GHG Emission Intensity of 50 gCO_2e/MJ_{LHV}

The first 6 MJ_{LHV} Discrete Consignment is not included in any Weighted Average Consignment and is reported separately as it has a negative Final GHG Emissions Intensity.

If the next three Discrete Consignments are combined, this will result in a Weighted Average Consignment with a weighted average GHG Emission Intensity of

$$\frac{(14\ MJ_{LHV} \times 9\ gCO_2e/MJ_{LHV}) + (9\ MJ_{LHV} \times 18\ gCO_2e/MJ_{LHV}) + (11\ MJ_{LHV} \times 35\ gCO_2e/MJ_{LHV})}{14\ MJ_{LHV} + 9\ MJ_{LHV} + 11\ MJ_{LHV}} = \frac{673\ gCO_2e}{34\ MJ_{LHV}}$$

= 19.8 gCO_2e/MJ_{LHV}. Hence this Weighted Average Consignment would comply with the Standard's threshold.

The final two Discrete Consignments can either be reported separately or as a single Weighted Average Consignment with a weighted average GHG Emission Intensity of

$$\frac{(5\ MJ_{LHV} \times 41\ gCO_2e/MJ_{LHV}) + (12\ MJ_{LHV} \times 50\ gCO_2e/MJ_{LHV})}{5\ MJ_{LHV} + 12\ MJ_{LHV}} = \frac{805\ gCO_2e}{17\ MJ_{LHV}} = 47.4\ gCO_2e/MJ_{LHV}.$$ Hence this Weighted Average Consignment would not comply with the Standard's threshold.

7.30. Discrete Consignments with negative Final GHG Emission Intensities[7] shall not be included in a Weighted Average Consignment and shall be reported separately.

7.31. There is no requirement for the individual Discrete Consignments included within or excluded from a Weighted Average Consignment to be compliant with the GHG Emission Intensity Threshold. There is also no requirement that any Weighted Average Consignment itself is compliant with the GHG Emission Intensity Threshold[8].

7.32. If the Final GHG Emission Intensity of a Weighted Average Consignment is less than or equal to the GHG Emission Intensity Threshold, then **all** Discrete Consignments included within that Weighted Average Consignment may be claimed as complying with the GHG Emission Intensity Threshold. Alternatively, if the Final GHG Emission Intensity of a Weighted Average Consignment is above the GHG Emission Intensity Threshold, then **none** of the Discrete Consignments included within that Weighted Average shall be claimed as complying with the GHG Emission Intensity Threshold.

7.33. The Discrete Consignments selected for a monthly Weighted Average Consignment do not have to be from the same or consecutive Reporting Units nor do they have to share the same Environmental Characteristics. However, only Discrete Consignments that are generated when the Hydrogen Production Facility meets the Conditions of Standard Compliance may be included within a Weighted Average Consignment.

7.34. The Hydrogen Production Facility may choose to report as many Weighted Average Consignments within each calendar month as they desire. However, each Discrete Consignment can only be included within one Weighted Average Consignment (no double counting of Discrete Consignments). Only Discrete Consignments produced in the calendar month can be included in Weighted Average Consignments for that month.

7.35. Any relevant Weighted Average Consignments shall be reported every calendar month. It shall be indicated which Discrete Consignments have been included within each Weighted Average Consignment.

Example: Figure 4 provides an illustrative example of Discrete Consignments produced over a month ordered by increasing Final GHG Emission Intensity. The width of the column represents the MJ_{LHV} of Hydrogen Product while the height of the columns represents the Final GHG Emission Intensity of each Discrete Consignment.

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[7] A negative GHG Emission Intensity does not imply necessary or sufficient evidence has been provided to meet UK Government requirements for a 'Greenhouse Gas removal', or 'permanence' of storage for biogenic CO_2/Solid Carbon, or monitoring/reporting/verification of the same. Separate UK policies are being developed in these areas.

[8] However, note that Discrete Consignments or a Weighted Average Consignment needs to be compliant with the Standard to qualify for support from the policies which apply the Standard.

Discrete Consignments coloured in green and yellow have a Final GHG Emission Intensity below the GHG Emission Intensity Threshold. Discrete Consignments coloured in orange and red have a Final GHG Emission Intensity above the GHG Emission Intensity Threshold.

If all the orange Discrete Consignments are combined with all the yellow Discrete Consignments, this will result in a Weighted Average Consignment with a weighted average GHG Emission Intensity of 19.6 gCO_2e/MJ_{LHV} (shown as a purple line) that is still below the GHG Emission Intensity Threshold.

As a result of the Weighted Average Consignment, the amount of Hydrogen Product that now meets the GHG Emission Intensity Threshold will increase and include green, yellow and orange Discrete Consignments. The red Discrete Consignments are not included in this Weighted Average Consignment as they would cause the Weighted Average Consignment to exceed the GHG Emission Intensity Threshold.

The red Discrete Consignments could either be reported separately or reported as a second Weighted Average Consignment however the GHG Emission Intensity Threshold will be exceeded in both cases.

The green Discrete Consignments are reported separately and are not included in any Weighted Average Consignment as these Discrete Consignments have negative Final GHG Emission Intensities.
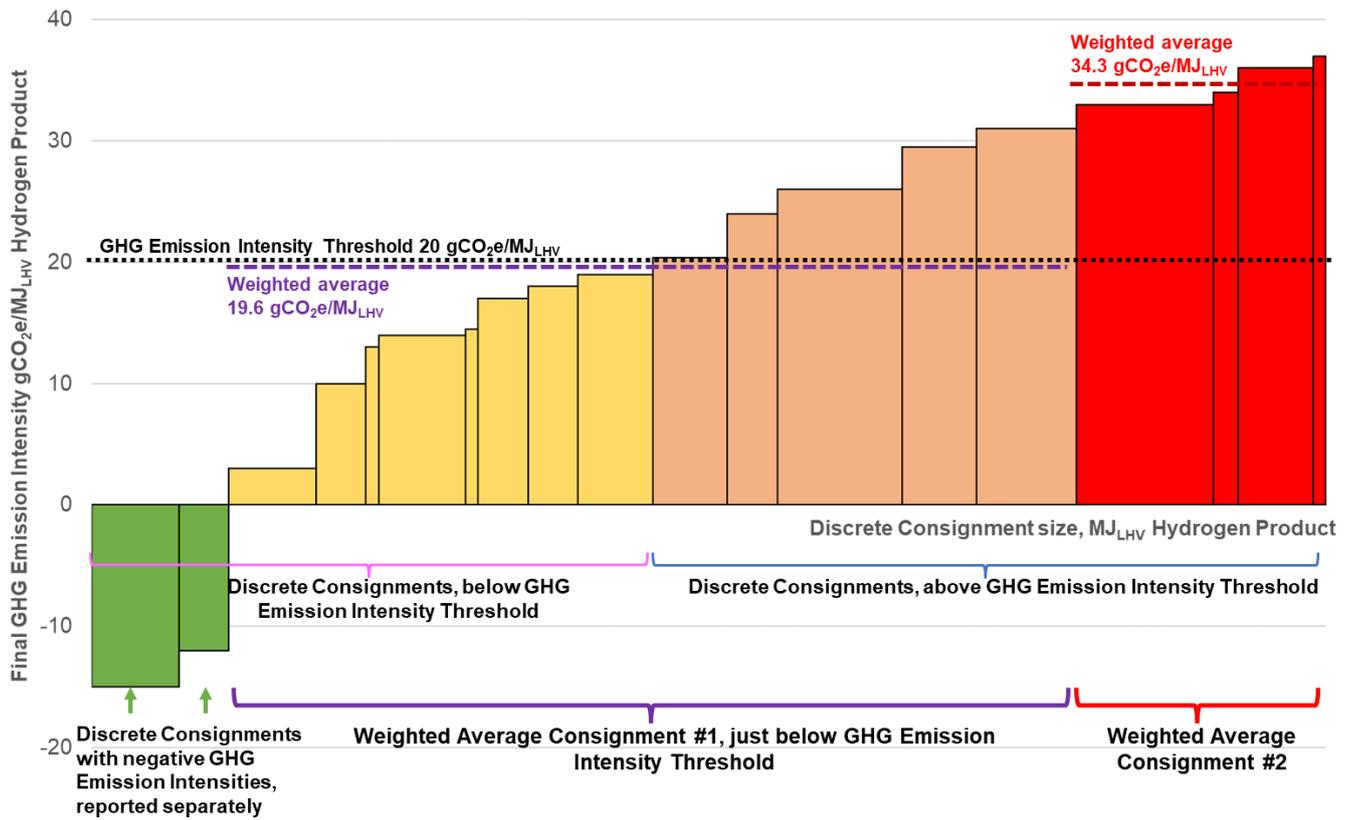
Figure 4: Illustrative example of optional monthly weighted averaging

8. Monitoring, Reporting and Verification (MRV) Framework

8.1.   Data and supporting evidence will need to be provided to substantiate whether Consignments are compliant with the Standard. This chapter provides a monitoring, reporting, and verification (MRV) framework to set minimum requirements for metering, measurement, data provision, reporting, audit, and other verification for the purposes of calculating the GHG Emission Intensity of the Hydrogen Product and determining compliance with the Standard. This Chapter should be read in conjunction with the requirements in Chapter 9 and Annex H including those relating to the Data Collection and Monitoring Procedure (DCMP).

8.2.   Individual schemes applying the Standard may specify additional or more detailed MRV requirements that shall be complied with by the relevant Hydrogen Production Facilities both before and during Facility operation.

8.3.   Schemes which apply the Standard may require different types of information to be submitted at multiple points including at application, during study/construction stages, at build completion, and on an ongoing basis once Hydrogen Production begins. This chapter sets minimum requirements for Facilities providing emissions projections against the Standard before Hydrogen Production has begun and separately for Facilities reporting against the Standard once Hydrogen Production is underway.

Before Facility operation

8.4.   Proof that a prospective Hydrogen Production Facility is capable of meeting the Standard is often required as an eligibility criterion for schemes which apply the Standard, such as the Hydrogen Production Business Model (HPBM).

8.5.   Prospective Hydrogen Production Facilities are likely to be required to demonstrate through calculation and supporting evidence, to the satisfaction of the scheme applying the Standard, that Hydrogen Product generated by their Facility will likely be able to comply with the GHG Emission Intensity Threshold and the Conditions of Standard Compliance.

8.6.   Prospective Hydrogen Production Facilities are likely to be required to use the 'Hydrogen Emissions Calculator' (HEC)[9], a comprehensive tool which implements the Standard GHG Emission Intensity Calculation Methodology. For Eligible Hydrogen

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[9] Available through Hydrogen Emissions Calculator online

Production Pathways, the HEC assesses the likely average Hydrogen Product GHG Emission Intensity over the course of a future year of projected Facility operations.

8.7. If a Hydrogen Production Facility intends to use an Input for which the material classification is unclear, evidence shall be submitted to DESNZ and/or Delivery Partner following the guidance under Paragraph 5.10.

8.8. More detail on the required or optional data choices at this stage is provided in Chapter 9. It is understood that before Facility operation there may be gaps in prospective Facility data. Supporting Typical Data and Default Data is provided in the Data Annex to assist with filling these gaps. Regardless of the data used, pre-operational Hydrogen Production Facilities shall clearly reference the assumptions and supporting evidence behind any data (or other claims) used and should be prepared to provide further evidence if requested.

8.9. Note that a HEC submission demonstrating a compliant GHG emissions result is not proof that a prospective Hydrogen Production Facility is capable of complying with the Standard nor eligible for any schemes which apply the Standard. HEC submissions and supporting evidence will be subject to verification within the schemes applying the Standard. Only once a completed version of the HEC[10] and all accompanying evidence have been subject to detailed review for validity and consistency will the relevant scheme applying the Standard be able to state whether a prospective Facility is likely to be capable of complying with the Standard.

8.10. Before the start of commercial operations, the Hydrogen Production Facility shall formulate and agree a Data Collection and Monitoring Procedure (DCMP) with the Delivery Partner. See Annex H for details.

During Facility operation

8.11. Once a Facility has begun commercial operation, Hydrogen Production Facilities shall calculate the GHG Emission Intensity of their Hydrogen Product on a Discrete Consignment basis as described in Chapter 7. Hydrogen Production Facilities receiving support from or enrolled in schemes applying the Standard shall measure, calculate, report, verify, and be subject to audit on compliance with the Standard on a Discrete Consignment basis following the requirements of their latest DCMP and according to the agreed terms of the relevant scheme applying the Standard.

Monitoring

8.12. For any reporting or auditing activities, Hydrogen Production Facilities shall monitor, record, calculate, and hold available all data and supporting evidence demonstrating

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[10] Note that this may be one or multiple files, as in some cases, multiple HEC files are needed to represent multiple Consignments. More information can be found in the HEC file online.

compliance with the requirements of the Standard including the following data (where applicable):

On a monthly basis:

- Assessment of Emission Sources during the month against the Materiality Threshold and confirmation that all Material Emission Sources in the month have been accounted for in the GHG Emission Intensity calculations or that there is compelling evidence that a given Material Emission Source has been impossible to quantify.

- The Environmental Characteristics of each Discrete Consignment (as per Paragraph 7.4 - 7.5 depending on the Pathway) including Final GHG Emission Intensity.

- For Inputs with a mix of biogenic and fossil contents, the LHV energy share of the biogenic and fossil fractions.

- The references for the Input or Output GHG Emission Intensity values – either identifying the Typical Data used from the Data Annex or evidencing the calculations and sources underpinning any Non-Typical GHG Emission Intensities with justification for their use where Typical Data is not available.

- For Input energy sources, any Fuel used; generation LHV efficiency (where relevant) along with the name, location, and capacity of the installation where the energy was generated; and losses in delivery (e.g., Transmission and Distribution or thermal losses).

- For all electricity Inputs, evidence that such electricity Inputs comply with the requirements of Annex B and Annex C where relevant.

- Evidence of the calculations and sources underpinning any estimated fugitive non-CO_2 emissions from the Hydrogen Production Facility with justification for their use.

- Evidence that CO_2 claimed as a CO_2 Sequestration credit has been captured from the Hydrogen Production Facility and injected into a CO_2 T&S Network as demonstrated by a connection agreement and transfer of responsibility for the CO_2.

- Evidence that any intended Solid Carbon Sequestration credit to be claimed links to a corresponding tonnage of Solid Carbon that will be used in a Solid Carbon Permissible End Use as defined within the Data Annex (under Solid Carbon Sequestration). This shall include evidence of the carbon content and the form of the Solid Carbon produced, i.e. the morphology (including but not limited to carbon black or graphene) and the bulk physical state (such as pellets or powder).

- Evidence of the quantity of Solid Carbon claimed as a Solid Carbon Sequestration credit which includes measurement of the mass of Solid Carbon produced at the

HPF's site; and measurement data at the Solid Carbon End User Point (b) Directors' Certificate assurance that Solid Carbon received will be used in a Solid Carbon Permissible End Use and (c) Evidence relating to Inputs, losses and activities within the Solid Carbon Distribution steps.

- For all biomethane Inputs, evidence that such biomethane Inputs comply with the requirements of Annex E and Annex F.

- Allocation Factors used for each Co-Product within the Pathway and Cumulative Allocation Factors. LHV efficiencies of each Step within the Pathway.

- Metering and measurement data: Activity Flow Data for all relevant Feedstocks, Energy Supply, Input Materials, and for all relevant Outputs. Further requirements for metering and measuring Activity Flows is set out in Annex H. In the case of Measurement and Meter Failure, the Hydrogen Production Facility shall record the time of failure and contact the Delivery Partner to agree on an approach to manage this.

- Invoices recording the quantities of Inputs and Outputs during the month and mass balance evidence where required to derive Estimated Data (see Annex H).

- For all biogenic Feedstocks and biogenic energy Inputs, evidence that the Sustainability Criteria (Land Criteria, Soil Carbon Criteria, and/or Forest Criteria) and the Minimum Waste and Residue Requirement are met (see Annex E).

- The GWP dataset used in the GHG Emission Intensity calculations.

- Raw GHG Emission Intensities for each Discrete Consignment with a breakdown by Emission Category.

- Identification of which Discrete Consignments produced in the month comply or do not comply with the Standard including compliance (or not) with each of the Conditions of Standard Compliance.

- Calculations for the determination of Weighted Average Consignments, clearly identifying which Discrete Consignments are included in each Weighted Average Consignment; the Final GHG Emission Intensity of each Weighted Average Consignment; and which Weighted Average Consignments (and their constituent Discrete Consignments) comply or do not comply with the Standard.

- For all biogenic Feedstocks and biogenic energy Inputs, estimated indirect land-use change (ILUC) GHG emissions (given in gCO2e/MJLHV Hydrogen Product) reported separately to the Final GHG Emission Intensities for all the Discrete Consignments. Evidence shall include the original biomass material used, supply chain efficiency, and ILUC factor applied.

- Any other Data Collection and Monitoring Procedure data as agreed with the Delivery Partner.

On an annual basis:

- The total number of REGO certificates procured, in accordance with Annex B requirements, to cover the relevant volume of REGO registered electricity that has been sourced for Hydrogen Production during each REGO Year.

- An updated Fugitive Hydrogen Emissions Risk Reduction Plan (see Chapter 10).

- The Fugitive Hydrogen Emissions Annual Report (see Chapter 10).

- Where relevant, an annual statement of last year's total electricity consumption across a Private Network if relevant.

- For any Electricity Storage System, the percentage State of Health, Design Capacity, Self Discharge Loss, and Round-Trip Efficiency.

- Any other Data Collection and Monitoring Procedure data as agreed with the Delivery Partner.

- For any Solid Carbon Output, report annually the total volumes (by mass) of Solid Carbon generated by the Hydrogen Production Facility, distinguishing between: Solid Carbon directed to Solid Carbon Permissible End Uses and non-permissible end uses.

On an ongoing basis, to be updated only if changes occur:

- The Eligible Hydrogen Production Pathway and Hydrogen Production technology utilised.

- For Input heat and/or steam from outside the System Boundary, a diagram showing the pipework connecting the energy generation asset and the Hydrogen Production Facility.

- Any other Data Collection and Monitoring Procedure data as agreed with the Delivery Partner.

8.13.   The following list shows example data/documents that may be required as supporting evidence to back up the lists above:

- The main equipment list for Hydrogen Production.

- Process flow diagrams, piping, and instrumentation diagrams.

- Business licenses, permits, or planning permissions.

- Supply agreements for Feedstock, Fuel, energy, and Input Materials.

- Signed statements from third parties evidencing GHG Emission Intensities.

- Mass and energy balances.

- Metering system diagrams, Single Line Diagrams, or equivalent, as deemed satisfactory to the Delivery Partner.

- The list of Steps in the Pathway including locations of Feedstocks, storage, transport, and pre-processing prior to the Facility.

- Operations date, production capacity, and utilisation information.

Reporting

8.14. Schemes applying the Standard may require a range of information to be reported for the purposes of evidencing compliance with the Standard. Relevant periods for reporting may also vary. Hydrogen Production Facilities shall refer to the Delivery Partner regarding the list of monthly, annual, continual, and/or one-off reporting requirements that apply for a particular scheme.

8.15. Hydrogen Production Facilities shall provide data for any Material Emission Sources even if data is uncertain. However, if there is compelling evidence provided that an individual Emission Source is impossible to quantify for a particular Step, despite it being likely to be a Material Emission Source, the Delivery Partner may agree that this Emission Source can be excluded and reported as a data exclusion. Agreed data exclusions shall be reported at a frequency set by the Delivery Partner with evidence for the omission.

Verification

8.16. Hydrogen Production Facilities shall ensure that all relevant data and supporting evidence is recorded and reported fully and accurately to the best of their knowledge and as required by the relevant scheme applying the Standard. Where data is sourced from a third-party, the Hydrogen Production Facilities should ensure that due and careful enquiries are made to verify the data quality and reference the data sources used.

8.17. All data and other information submitted for the purpose of the Standard shall be subject to comprehensive verification processes on a frequency set by the Delivery Partner. These should include verification by an independent third party and more frequent risk-based verification of important data sources. Schemes applying the Standard may choose to implement spot check audits (including site visits) especially if there is a perceived inconsistency with any reporting.

8.18. In cases where data and supporting evidence for a Discrete Consignment is required to be included but is missing or is deemed to be of insufficient quality, the Discrete Consignment shall be considered not compliant with the Standard unless the Delivery Partner agrees alternative data can be provided or an exclusion applied.

9. Data types and quality

9.1. A Hydrogen Production Facility will need to refer to a variety of data sources to support GHG Emission Intensity calculations and to determine Standard Compliance. This chapter introduces the types of data and principles of data use that shall apply to all supporting data. Note that data values provided by DESNZ for use within the Standard are mostly given in the Data Annex and are not provided in this Chapter.

Data types

9.2. Three categories of data underpin the GHG Emission Intensity calculations for each Discrete Consignment following Equation 1 in Chapter 5:

- Activity Flow Data for every relevant Emission Source.

- GHG Emission Intensities (and/or GWPs) for every relevant Emission Source.

- The total quantity of Hydrogen Product, P (see Equation 2, Chapter 5).

9.3. Hydrogen Production Facilities reporting against the Standard shall use accurate and high-quality data. Table 2 sets out the different types of data which shall be sourced either before or during the operation of a Hydrogen Production Facility.

Table 2: Appropriate data sources before and during operations

Stage	Activity Flow Data	GHG Emission Intensity	Hydrogen Product
Before Facility operation	Projected Data shall be used.	Typical Data shall be used for the relevant future year (see Data Annex). Where Typical Data is not available, representative Non-Typical Data shall be sought for the relevant future year.	Projected Data shall be used.
Before Facility operation (where Projected Data and/or both Typical Data and Non-Typical Data are not available within the Feedstock Supply, Energy Supply, and/or Input Materials Emission Categories)	Default Data (see Data Annex under Default Data) for the respective Emission Category.	Default Data (see Data Annex under Default Data) for the respective Emission Category.	Projected Data shall be used.

During Facility operation	Measured Data shall be used in the cases specified in Annex H. In all other cases, reasonable Estimated Data shall be used and supported with evidence.	Typical Data shall be used for the relevant time period (see Data Annex). Where Typical Data is not available, representative Non-Typical Data shall be sought for the relevant time period.	Measured Data shall be used, as detailed in Annex H.

9.4. Typical Data values are provided in the Data Annex and shall be used if these Inputs or Outputs are used within the Hydrogen Production Pathway. Where Typical Data values are not available in the Data Annex for the Pathway in question, representative Non-Typical Data values shall be used and if a methodology for deriving a GHG Emission Intensity for a particular Input or Output is given in the Standard, this methodology shall be used. If such a methodology for Non-Typical Data is not specified in the Standard, the Facility shall reference a reputable source or calculate its own value with a justification and appropriate supporting evidence for its applicability and aiming to be as consistent as possible with the overall GHG Emission Intensity Calculation Methodology in Chapter 5.

9.5. Default Data values are provided in the Data Annex under Default Data on an Emission Category basis in line with Equation 1 (see Chapter 5) and are only available for certain Pathways and certain Emission Categories. They are based on central estimates from Pathway modelling and are generally multiplied by a factor of 1.4 to provide conservative values. A pre-operational Hydrogen Production Facility which does not have Default Data available for their Pathway or Emission Category shall use Projected Data and Typical Data or Non-Typical Data. For a given Emission Category for a pre-operational Hydrogen Production Facility, either only the Default Data value shall be used or Projected Data combined with Typical Data or Non-Typical Data. Default Data shall not be used once a Hydrogen Production Facility is operational.

9.6. Measured Data values shall be determined following the requirements of Annex H and any scheme applying the Standard. In the absence of Measured Data, Estimated Data shall be used as specified in Annex H.

9.7. Where the Standard requires theoretical calculations for hydrogen Compression and Purification, Hydrogen Production Facilities shall consult the Data Annex paragraphs under Compression and Purification of Hydrogen.

Data quality

9.8.   Irrespective of data type, any underlying calculations; evidence and assumptions behind the data value; and the justification for its use shall be held available by the Hydrogen Production Facility for any MRV requirements in Chapter 8 to be met.

9.9.   The Hydrogen Production Facility should record the following quality aspects when providing data:

- Time-related coverage: age of data and the minimum length of time over which data shall be collected.

- Geographical coverage: geographical area from which data for unit processes shall be collected.

- Technology coverage: specific technology or technology mix.

- Precision: measure of the variability of each data value expressed (for example, variance).

- Completeness: percentage of total flow that is measured or estimated.

- Representativeness: qualitative assessment of the degree to which the data set reflects the true activity of interest (that is, geographical coverage, time period, and technology coverage).

- Consistency: qualitative assessment of whether the methodology used is applied uniformly to the various components of the analysis.

- Reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the reported results.

- Sources of the data.

- Uncertainty of the information.

9.10.   Assessments of data quality undertaken by a Hydrogen Production Facility, independent third-party auditor, Delivery Partner, or any other party applying MRV against the Standard shall be informed by the aspects listed above.

10. Fugitive Hydrogen Emissions

10.1.   Hydrogen itself does not trap infrared radiation and so is not a direct GHG. However, if released to atmosphere (for instance, through fugitive emissions) hydrogen would change the chemistry of the atmosphere and could prolong the lifetime of other direct GHGs, particularly methane. This would increase the warming effect of methane in the atmosphere. This and other 'indirect' effects mean emissions of hydrogen have an impact on climate change.

10.2.   DESNZ commissioned work from the University of Cambridge to understand the climate impact of Fugitive Hydrogen Emissions using modern climate models[11]. This has reinforced the finding that hydrogen is an indirect Greenhouse Gas. We also commissioned work to better understand where fugitive emissions stem from in the Hydrogen Production technology[12].

10.3.   Work is still ongoing to narrow uncertainties for both the Global Warming Potential (GWP) impact and leakage rates from Hydrogen Production, but a hydrogen GWP may be included within the GHG Emission Intensity calculation under the Standard in the future. Ahead of this, Hydrogen Production Facilities should apply Best Available Techniques set out by the UK Government and its agencies.

Specific requirements for Hydrogen Production Facilities

Fugitive Hydrogen Emissions Risk Reduction Plan

10.4.   Prior to operations commencing, Hydrogen Production Facilities shall complete a Fugitive Hydrogen Emissions Risk Reduction Plan containing the sections outlined below and meeting the requirements entailed therein. Failure to complete this Fugitive Hydrogen Emissions Risk Reduction Plan will prevent compliance with the Standard.

   Section 1: Demonstrate how Fugitive Hydrogen Emissions at the Hydrogen Production Facility will be minimised:

10.5.   A plan shall be provided demonstrating how the Hydrogen Production Facility will be designed and operated to ensure that expected Fugitive Hydrogen Emissions are kept as low as reasonably practical. As a minimum, the plan shall consider each Fugitive Hydrogen Emissions source detailed in Paragraph 10.13 that is relevant to the Hydrogen Production Facility. All assumptions shall be stated.

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[11] https://www.gov.uk/government/publications/atmospheric-implications-of-increased-hydrogen-use
[12] https://www.gov.uk/government/publications/fugitive-hydrogen-emissions-in-a-future-hydrogen-economy

10.6. Paragraphs 10.14 - 10.15 below outline some possible actions that may be taken to minimise Fugitive Hydrogen Emissions.

Section 2: Provide estimates of expected rates of Fugitive Hydrogen Emissions by the Facility:

10.7. Hydrogen Production Facilities shall provide the expected future Fugitive Hydrogen Emissions in kg pure H_2/year assuming the mitigation plan in Paragraph 10.4 is followed. The estimate shall include a breakdown of different Fugitive Hydrogen Emissions sources considered and as a minimum shall show consideration of each source described in Paragraph 10.13 that is relevant to the Hydrogen Production Facility. All assumptions shall be stated, and justification shall be provided where any Fugitive Hydrogen Emissions sources are considered negligible.

Section 3: Prepare a monitoring methodology for Fugitive Hydrogen Emissions:

10.8. A methodology for measuring and monitoring overall Fugitive Hydrogen Emissions from the Hydrogen Production Facility in operation shall be provided. The methodology shall account for each Fugitive Hydrogen Emission source described in Paragraph 10.13 that is relevant to the Hydrogen Production Facility. Fugitive Hydrogen Emissions sources identified as not measurable do not need to be monitored.

10.9. The Hydrogen Production Facility may use their discretion in determining the monitoring methodology provided they are able to account for all potential measurable Fugitive Hydrogen Emissions streams. Approaches may include direct monitoring of hydrogen streams (for example, in vent ducts) or mass balance approaches to track overall flows of hydrogen.

Fugitive Hydrogen Emissions Annual Report and Annual Review

10.10. Once operational, a Hydrogen Production Facility shall provide a Fugitive Hydrogen Emissions Annual Report each year which sets out an estimate of the Fugitive Hydrogen Emissions that have occurred in the past year in kg pure H_2. The estimate shall include a breakdown of different Fugitive Hydrogen Emissions sources considered and as a minimum shall consider each source described in Paragraph 10.13 that is relevant to the Hydrogen Production Facility. All assumptions shall be stated, and justification shall be provided where any Fugitive Hydrogen Emissions sources are considered negligible. The report shall include any actions taken in the past year to mitigate Fugitive Hydrogen Emissions.

10.11. The Fugitive Hydrogen Emissions Risk Reduction Plan in Paragraphs 10.4 - 10.9 shall be reviewed and updated annually and shall report on any progress made to minimise emissions. The Fugitive Hydrogen Emissions Risk Reduction Plan shall be updated to address:

- Any progress that has been made to minimise Fugitive Hydrogen Emissions set out in Paragraph 10.5 including any updates implemented to reflect evolving best practices.

- An updated estimate of expected future annual Fugitive Hydrogen Emissions as per Paragraph 10.7.

- Any changes made to the monitoring methodology in Paragraphs 10.8 - 10.9.

10.12. Failure to provide a Fugitive Hydrogen Emissions Annual Report or an annual update to the Fugitive Hydrogen Emissions Risk Reduction Plan will result in non-compliance with the Standard for all Discrete Consignments produced after an agreed deadline with the Delivery Partner for the submission of such documents. Non-compliance due to this reporting failure can only be reversed if the required documents are subsequently provided.

Guidance: Fugitive Hydrogen Emissions sources at a Hydrogen Production Facility

10.13. The following processes have been identified as being potentially significant sources of Fugitive Hydrogen Emissions at a Hydrogen Production Facility and shall be considered by a Hydrogen Production Facility when considering how to minimise Fugitive Hydrogen Emissions. This list is not exhaustive, and further significant sources may exist.

Process venting

- Cold vents are likely to be the most significant source of Fugitive Hydrogen Emissions at a Hydrogen Production Facility.

- 'Routine' hydrogen vents may arise because of hydrogen purification or separation Steps where some residual hydrogen remains in a Waste stream. Possible occurrences include:

- Where a purging flow of hydrogen is used to regenerate separation adsorbents.

- Hydrogen cross-over into the oxygen stream (electrolysis only) or pass through into tail gases during purification.

- Hydrogen may also be vented during Hydrogen Production Facility start-up and shutdown when equipment is purged. The significance of this will depend on the frequency of Hydrogen Production Facility start-ups and shutdowns.

Compressors

- Hydrogen compressors are likely to be a source of Fugitive Hydrogen Emissions and shall be considered when they are included on site at the Hydrogen Production Facility. Fugitive emissions may arise due to:

- Permeation through seals.

- Compressor venting for maintenance (likely to be negligible depending on frequency).

On-site Storage

- Above-ground stationary Hydrogen Storage is likely to be a significant source of Fugitive Hydrogen Emissions and shall be considered when this is included on site at the Hydrogen Production Facility.

- Compressed hydrogen cylinders are susceptible to leakage. The significance will depend on the storage pressure, cylinder material, cylinder size, and valve type.

- Liquid Hydrogen Storage may result in fugitive emissions arising from hydrogen boil-off.

Flares (Negligible)

- Incomplete combustion in any flares may result in some residual hydrogen being released to the atmosphere. This is expected to be negligible provided flares are well designed and maintained.

Leakage through pipework and joints (Negligible)

- Hydrogen leakage through joints, valves etc. are expected to be negligible provided that best practice is followed including using welded joints wherever possible and ensuring that equipment is maintained in good condition.

Guidance: Minimising Fugitive Hydrogen Emissions

10.14. As a priority, Hydrogen Production Facilities should minimise all cold venting of hydrogen. This may be achieved by:

- Ensuring that hydrogen is fully separated from any vented streams (for example, water vapour or oxygen).

- Finding alternative uses for the hydrogen within the Hydrogen Production Facility and recirculating it.

- Directing Waste streams to flare rather than cold vent.

- It is especially important that "routine" vents are minimised. Occasional vents may be permissible (for example, if they are deemed to be necessary for safety).

10.15. Hydrogen leakage throughout the Hydrogen Production Facility should be minimised by ensuring best practice is followed, including:

- Using welded joints wherever possible.

- Ensuring use of suitable materials and valves, in particular for high pressure equipment.

- Fully leak-testing the Hydrogen Production Facility during commissioning.

Annex A: Eligible Hydrogen Production Pathways

Overview

A. 1.   Paragraph 4.2 sets out the Eligible Hydrogen Production Pathways under the Standard. This Annex provides more detail on these Pathways, which informs how specific Hydrogen Production Facilities are categorised under the Standard.

Electrolysis

A. 2.   A typical water electrolysis cell consists of an anode and a cathode separated by a membrane immersed in an electrolyte (a conductive solution). When the electrodes are connected to a direct current power supply, electricity causes the water to split into oxygen at the anode, with ions flowing through the electrolyte, and hydrogen forming at the cathode. Each electrolyser system consists of a stack of electrolysis units, a gas purifier and dryer, compression, and an apparatus for heat removal.

A. 3.   There are currently three main electrolyser technologies, distinguished by the electrolyte (and associated operating temperatures): alkaline (ALK) electrolysers, polymer electrolyte membrane (PEM) electrolysers and solid oxide (SOEC) electrolysers.

A. 4.   Hydrogen and oxygen gas products are purified, dried, and cooled prior to storage and/or delivery to market, subject to required Product specifications. The oxygen gas should be safely vented to the atmosphere or recovered and utilised.

A. 5.   For illustrative purposes, simplified flow diagrams are shown in Figure 5 and Figure 6 for low temperature electrolysis and for high-temperature electrolysis using nuclear generated electricity and heat. These provide information on the primary Inputs used and the resulting primary Outputs. Note that Inputs and Outputs may vary (for example, oxygen may be utilised, electricity used for deionisation may vary, water Input sources may vary, and not all electrolysers may require chemical Inputs for water deionisation).
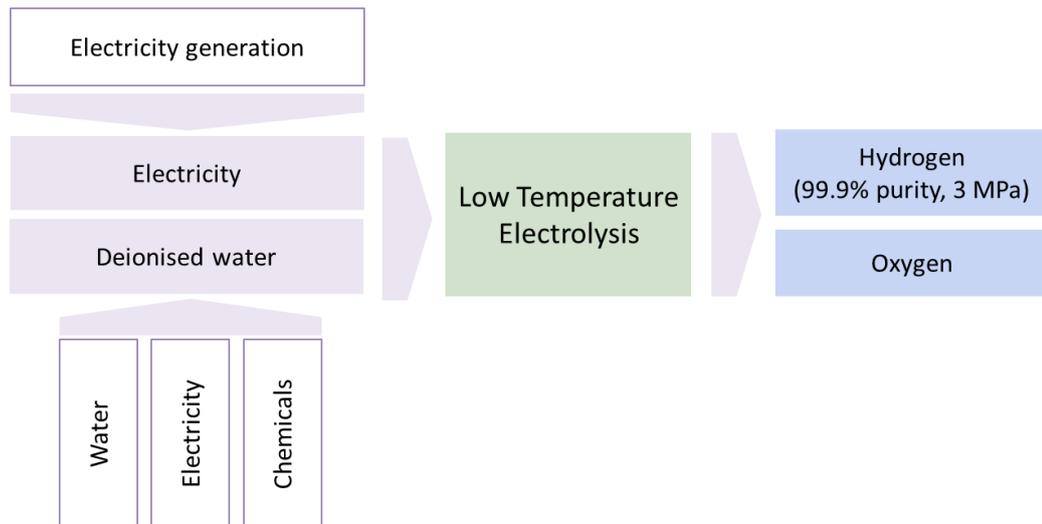
Figure 5: Illustrative process flow diagram for low temperature electrolysis
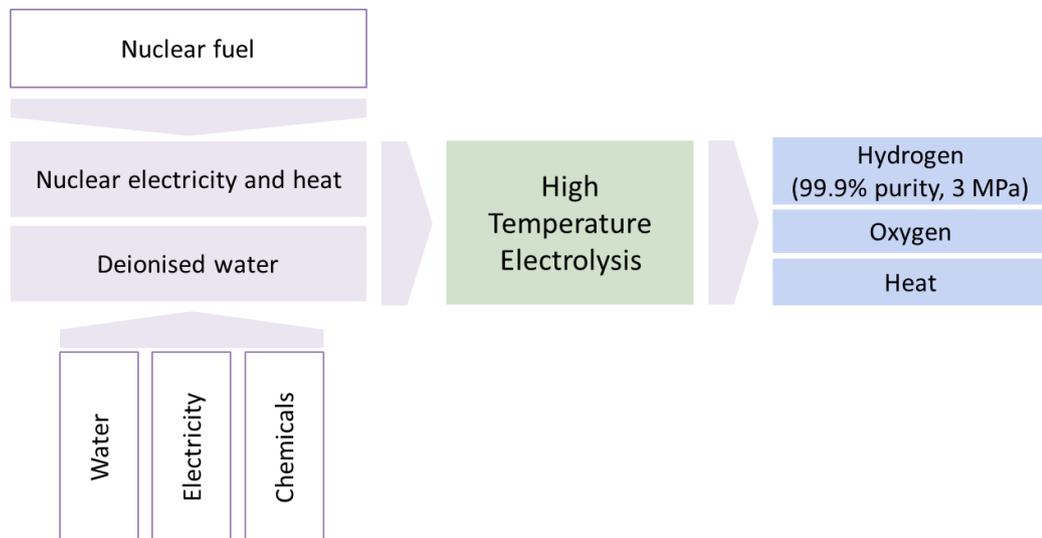
Figure 6: Illustrative process flow diagram for high-temperature electrolysis with nuclear electricity and heat

Fossil gas reforming with CCS

A. 6.   There are currently three main technologies considered within this Pathway – steam methane reformation (SMR), auto thermal reformation (ATR) and partial oxidation (POX), that use fossil gases such as natural gas as their Feedstock. A simplified main block flow diagram for these three illustrative technologies is shown in Figure 7. Note that Inputs and Outputs may vary – for example, different electricity sources. The Steps associated with the original Input Feedstock have been simplified and will depend on the Feedstock and its material classification.
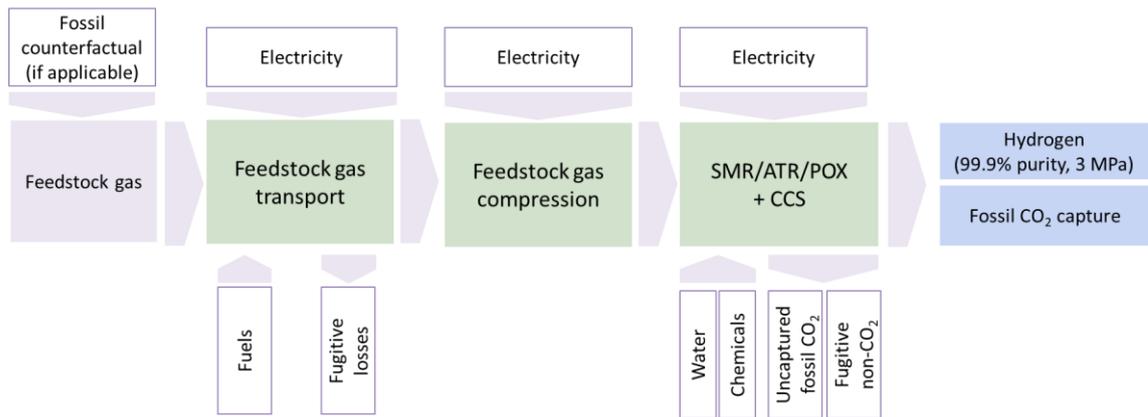
Figure 7: Illustrative process flow diagram for fossil gas reforming with CCS

SMR with CCS process description

A. 7. A steam methane reformer (SMR) is a commercially mature production process in which a heat source provides high-temperature heat and steam for the endothermic reforming reaction to take place. This process produces hydrogen and CO_2 from the Input fossil Feedstock Gas using a catalyst. External heat sources may be required, but oxygen is not an Input. CO_2 will be generated from different parts of the process at varying concentrations, and will require capture, drying and compression.

ATR with CCS process description

A. 8. In autothermal reforming (ATR), some of the Input fossil Feedstock Gas is first partially combusted by oxygen to produce heat to drive the reforming process. Contrary to SMR, the autothermal reactor does not require any heat from an external furnace (although other minor external heating operations may still be required, such as pre-heaters). The only major CO_2 source is within the hydrogen stream, and this CO_2 can be separated out at high capture rates, dried and compressed. Oxygen is separated in an air separation unit (ASU), typically using cryogenic methods.

POX with CCS process description

A. 9. In partial oxidation (POX), all the Input fossil Feedstock Gas is first partially oxidised by oxygen to produce hydrogen and carbon monoxide, prior to a water gas shift reaction to generate hydrogen and CO_2, with CO_2 capture, drying and compression then occurring. As with ATR, POX typically requires oxygen for the partial oxidation Step, generated in an ASU.

Biogenic gas reforming

A. 10.   These Pathways uses the same technologies as the fossil gas reforming with CCS Pathway, but the Feedstock Gas is biogenic instead. The use of CCS may or may not be necessary to meet the GHG Emission Intensity Threshold.

A. 11.   Biomethane is the main Input biogenic gas considered here. The production of biomethane, or another Input biogenic gas, occurs prior to reforming and forms part of the Pathway. This may involve biogenic Feedstock cultivation, harvesting/collection, pre-treatment, transport, bio-digestion (such as anaerobic digestion) and biogenic gas pre-treatment (such as upgrading to biomethane).

A. 12.   A simplified flow diagram is shown in Figure 8 below for an illustrative biogenic gas reforming Pathway. This provides information on the primary Inputs used and the resulting primary Outputs. Note that Inputs and Outputs may vary – for example, different Feedstocks and/or a different biogenic gas may be used, and CCS may not be used.
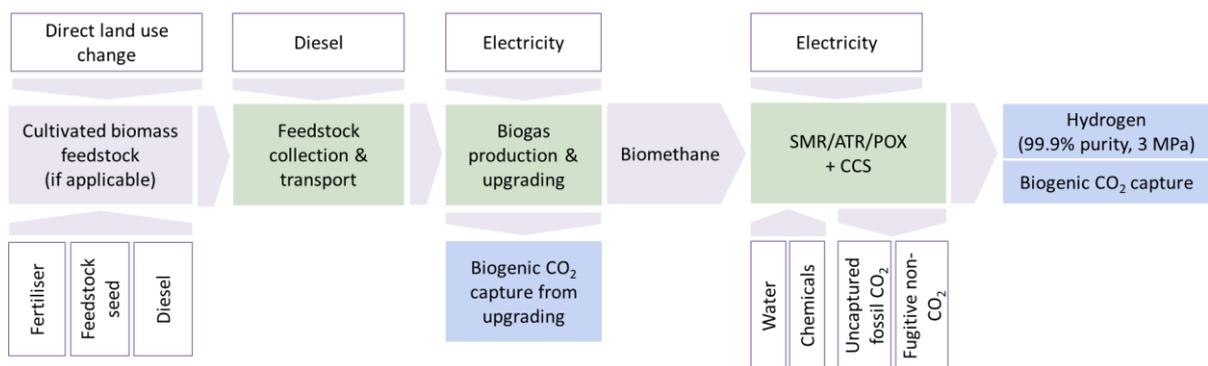
Figure 8: Illustrative process flow diagram for biomethane reforming with CCS

Biomass gasification

A. 13.   Biomass gasification broadly refers to technologies which use heat and the presence of limited or no oxygen to break down biomass Feedstocks into syngas (a mixture of hydrogen, carbon monoxide and other hydrocarbons). It may involve Feedstock pre-treatment, gasification, some combustion of Feedstocks or side streams for process heating or reforming of side streams, followed by a high-temperature water gas shift reaction to convert syngas into hydrogen and CO_2.

A. 14.   CCS may or may not be integrated into this Pathway. Similar CCS technologies to the CCS technologies used in fossil gas reforming Pathways are likely to be used for this Pathway. Depending on the Facility scale and gasification process, CO_2 may be captured by different methods such as chemical solvents, physical solvents and pressure swing adsorption.

A. 15.   A simplified flow diagram is shown in Figure 9 below for an illustrative biomass gasification Pathway. Note that Inputs and Outputs may vary – for example, there may be variation in Feedstocks and the exact gasification technology used, and CCS may not be used.
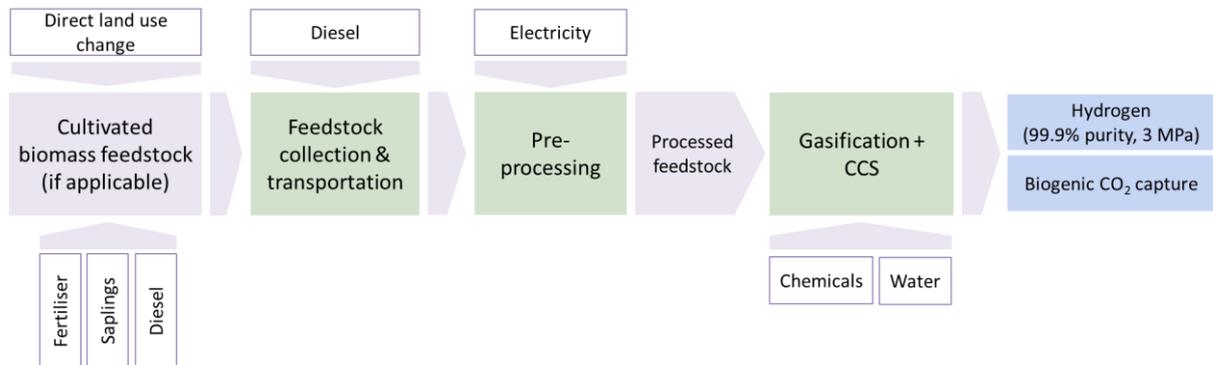
Figure 9: Illustrative process flow diagram for biomass gasification with CCS

Waste gasification

A. 16.   This Pathway broadly uses the same technologies as the biomass gasification Pathway. However, the Input Feedstock is classified as a Waste, and may be biogenic, fossil or mixed.

A. 17.   A simplified flow diagram is shown in Figure 10 below for an illustrative mixed Waste gasification Pathway. Note that Inputs and Outputs may vary – for example, there may be variation in Feedstocks and/or exact gasification technology used, and CCS may not be used.
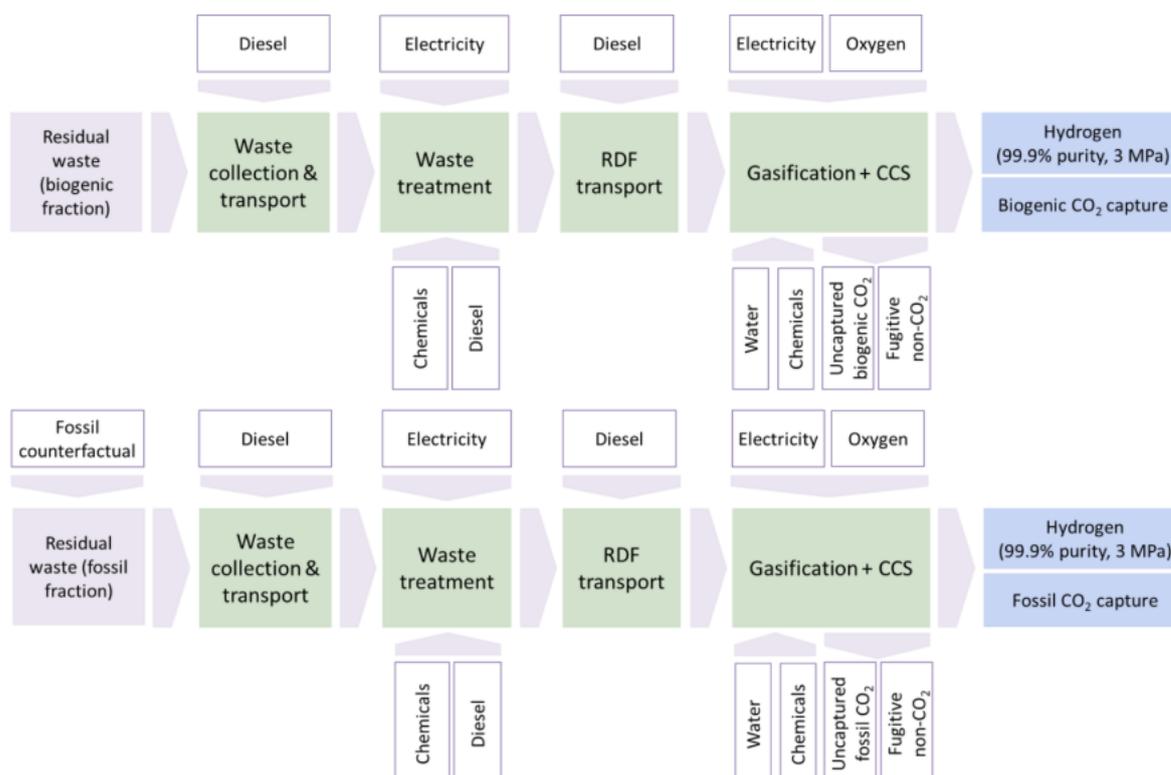
Figure 10: Illustrative process flow diagrams for mixed Waste gasification with CCS (top row biogenic fraction, bottom row fossil fraction)

Gas splitting producing Solid Carbon

A. 18. These Pathways include novel technologies, such as thermal pyrolysis, catalytic pyrolysis, plasma pyrolysis or plasma splitting, to split Feedstock Gases into primarily hydrogen and Solid Carbon.

A. 19. The main Feedstocks currently proposed are fossil natural gas, biomethane, and various other gaseous industrial Wastes or Residues. Liquid Feedstocks are also permitted if they are converted to a gas or plasma during the process.

A. 20. Depending on the technology and process conditions, the Solid Carbon produced from gas splitting can potentially take several forms, including powdered carbon black, graphite or graphene. Eligible uses of Solid Carbon are given in the Data Annex section on Solid Carbon Sequestration.

A. 21. If fossil Fuels are combusted to provide onsite heating (as can occur for thermal pyrolysis and catalytic pyrolysis), there may be a CO_2 Sequestration credit if CO_2 capture is used (in addition to any Solid Carbon Sequestration credit).

A. 22. A simplified flow diagram for an illustrative gas splitting Pathway is shown in Figure 11. Note that Inputs and Outputs may vary – for example, gas transport and compression may not be required, depending on relative locations and technology requirements.

The Steps associated with the original Input Feedstock have been simplified and will depend on the Feedstock and its material classification.
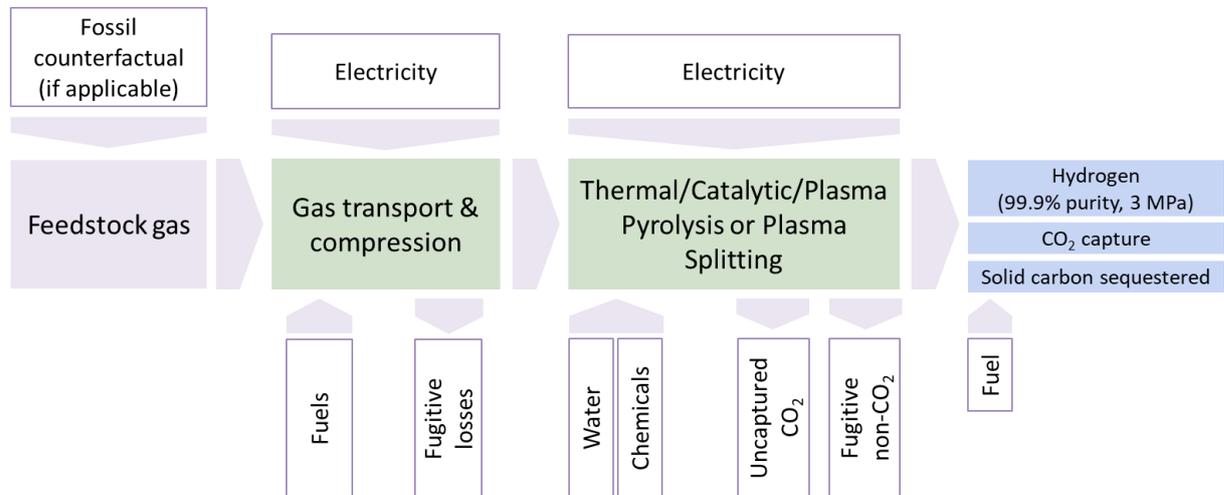
Figure 11: Illustrative process flow diagram for gas splitting with Solid Carbon

Thermal pyrolysis process description

A. 23.   Thermal pyrolysis uses an external heat source (either electrical resistive heating or combustion of a significant side stream of the Input Feedstock) to provide very high temperatures inside, typically, a moving bed or molten metal reactor in the absence of any air. The temperature is sufficient to split the methane and other gaseous hydrocarbons into their component atoms of hydrogen and carbon. The Solid Carbon either precipitates out or floats on the liquid metal and is collected, and the gaseous hydrogen stream is purified.

Catalytic pyrolysis process description

A. 24.   Catalytic pyrolysis uses an external heat source (either electrical resistive heating or combustion of a significant side stream of the Input Feedstock) to provide high temperatures inside the reactor in the absence of any air. A metal-based catalyst is typically used to assist in splitting the methane and other gaseous hydrocarbons into their component atoms of hydrogen and carbon. The carbon precipitates out and is collected, and the gaseous hydrogen stream is purified.

Plasma pyrolysis process description

A. 25.   Plasma pyrolysis uses an Input electricity source to drive plasma torches that operate at localised high to very high temperatures, in the absence of any air. The plasma generated is responsible for transferring heat into the Feedstock, splitting the methane and other gaseous hydrocarbons into their component atoms of hydrogen and carbon. Catalysts may also be used to lower reaction temperatures. The Solid Carbon precipitates out and is collected, and the gaseous hydrogen stream is purified.

Plasma splitting process description

A. 26. Plasma splitting uses an Input electricity source to drive plasma torches or generate microwaves to create localised extremely high temperatures, in the absence of any air. A strong electrical current or microwaves act directly on the Feedstock to generate a plasma, splitting the methane and other gaseous hydrocarbons into their component ions of hydrogen and carbon. Upon cooling of the plasma, the carbon precipitates out and is collected, and the gaseous hydrogen stream is purified. Typically, no catalyst is used, and residual heat is generated as a result of the process rather than being required as an Input (as in the pyrolysis options above).

Annex B: Electricity Supply

Overview

B. 1.   Electricity consumption by Hydrogen Production Facilities is likely to be a significant contributor to the GHG emissions of the hydrogen produced. Hydrogen Production Facilities shall evidence the GHG emissions associated with all electricity Inputs used in Hydrogen Production. Hydrogen Production Facilities shall comply with the evidence requirements set out in this Annex, and where relevant, the evidence requirements for electricity transited via an Electricity Storage System, as set out in Annex C.

B. 2.   This Annex defines the permissible Electricity Supply configurations, associated criteria and evidence required to meet the Standard; the GHG Emission Intensities associated with Input electricity for each Reporting Unit; how to account for any Transmission and Distribution Losses in the volume and GHG Emission Intensity of the electricity sourced; requirements for Renewable Energy Guarantees of Origin (where relevant); and the supporting information for wider reporting requirements.

Electricity Supply configurations: Evidence requirements for calculating the GHG Emission Intensity of electricity Inputs

B. 3.   Electricity Supply configurations shall be assessed in accordance with the four configurations listed below, as set out in Paragraph 5.30. Hydrogen Production Facilities may source electricity from any combination of these four Electricity Supply configurations in a Reporting Unit.

- Electricity sourced from a specific generator or generators in GB or NI via Eligible PPAs (or equivalent where the generators and Hydrogen Production Facility are owned by the same legal entity).

- Electricity sourced from a Private Network in GB or NI and not linked to a specific generator, excluding grid import to the Private Network.

- Electricity sourced from the GB or NI Electricity Grid and not linked to a specific generator.

- Electricity Curtailment Avoidance.

B. 4.   The Hydrogen Production Facility's metered electricity consumption shall be broken down into the percentage volumes of electricity that are stated to come from each of these configurations in each Reporting Unit (an example is given in Paragraph 7.12).

B. 5.   The evidence requirements for each of these Electricity Supply configurations are set out below in Table 3 to Table 6. Further details on each supply configuration, including which GHG emissions intensities are to be applied in each configuration, is set out in Paragraphs B. 7 to B. 19.

Table 3: Evidence requirements for electricity sourced from specific generator(s)

Criteria	Evidence Required
Eligible PPA for electricity supplied to the Hydrogen Production Facility from specific generator(s)	A contract entered into with the Hydrogen Production Facility for the supply, physical delivery and Transfer of Title in electricity to the Hydrogen Production Facility from specific generators, signed ahead of Gate Closure. This contract shall either be with: • Generators of electricity (including any Electricity Storage System). • An Electricity Supply Party (See Chapter 2). The Eligible PPA shall contain terms that: • Provide for the physical supply of electricity to the Hydrogen Production Facility (and where relevant Electricity Storage System) either directly, via a Private Network, or via the Electricity Distribution Network or Electricity Transmission Network, including Transmission and Distribution Losses, as per Paragraphs B. 26 - B. 36. • Enable the Hydrogen Production Facility to evidence the required electricity supplies pursuant to generator metered data, invoices or statements, the GHG Emission Intensity of the electricity volumes supplied and (where relevant) compliance with Biomass Requirements, for the relevant electricity supplies. • Enable the Hydrogen Production Facility to evidence the existence of the above terms in any associated arrangements with generators, notwithstanding that the Hydrogen Production Facility may not have a direct contractual relationship with the generator(s). An Eligible PPA shall not be an Excluded PPA (see Chapter 2). A Hydrogen Production Facility located in GB shall only enter into an Eligible PPA with a generator located in GB, or with an Electricity Supply Party that has associated arrangements with generators located in GB. Similarly, a Hydrogen Production Facility located in NI shall only enter into an Eligible PPA with a generator located in NI, or with an Electricity Supply Party that has associated arrangements with generators in NI. This position on the treatment of PPAs outside of GB or NI may be reviewed in the future, and we welcome engagement from industry (via uklchs@energysecurity.gov.uk), on alternative forms of evidence that could be used to demonstrate compliance with the LCHS, for electricity sourced outside of GB and NI for Hydrogen Production Facilities in those respective locations.

Transaction evidence	The Hydrogen Production Facility shall provide Electricity Supply and/or settlement invoices or statements broken down per Reporting Unit, showing: a match between metered generation data and invoiced supply volumes per Reporting Unit. at least a match to the Hydrogen Production Facility electricity consumption, including Transmission and Distribution Losses (as described in Paragraphs B. 26 - B. 36, using Equation 30: **Equation 30** $$\sum_{Specific\ generator\ i} \left\{ \begin{array}{c} Supply\ invoices_i\ (MWh) \\ \times\ (1 - T\&D\ loss_i\ (\%)) \end{array} \right\} \geq$$ $$\sum_{RU\ j} \left\{ \begin{array}{c} Facility\ metered\ consumption_j\ (MWh) \\ \times\ electricity\ consumed\ from\ specific\ generators_j\ (\%) \end{array} \right\}$$
Temporal Correlation between generation and consumption	**Single generator** (where a Hydrogen Production Facility is supplied by a single generator or Electricity Storage System, either by direct contract or via an Electricity Supply Party): 30-minute metering data is required to show that the contracted and delivered volumes of metered electricity generated exceeds or matches the Hydrogen Production Facility's metered electricity consumption, per Reporting Unit. **Multiple generators** (where a Hydrogen Production Facility is supplied by multiple generators and/or Electricity Storage Systems, either by multiple direct contracts, or via Electricity Supply Parties): 30 minute metering data is required from each generator or Electricity Storage System, to show that the sum of the contracted and delivered volumes of metered electricity generation exceeds or matches the Hydrogen Production Facility's metered electricity consumption, per Reporting Unit. In each case above, any Transmission and Distribution Losses (as described in Paragraphs B. 26 - B. 36) shall be included in the Temporal Correlation calculations, using Equation 31: **Equation 31** $$\sum_{Specific\ generator\ i} \left\{ \begin{array}{c} Metered\ generation_i\ (MWh) \\ \times\ (1 - T\&D\ loss_i\ (\%)) \end{array} \right\}$$ $$\geq Facility\ metered\ consumption\ (MWh)$$ $$\times\ Electricity\ consumed\ from\ specific\ generators\ (\%)$$
Exemption from Eligible PPA where specific generator(s) and Hydrogen	For a generation asset that is owned by the same legal entity as the Hydrogen Production Facility (including in the event where the generation asset is located on-site), an Eligible PPA is not required but equivalent evidence shall be provided.

Production Facility are owned by the same legal entity	In this case, the following evidence shall be provided by the same legal entity (not a parent or subsidiary company) that owns both the Hydrogen Production Facility and the specific generator(s): • Metered data to prove physical delivery and Temporal Correlation of electricity from the specific generators, accounting for Transmission and Distribution Losses (as per the requirements in the above row). • Transaction evidence such as invoices, statements, or internal transaction logs for the electricity volumes supplied. • The claimed GHG Emission Intensity of the electricity volumes supplied. • Where relevant, evidence of compliance with the Biomass Requirements. Note that whilst a contractual arrangement may be exempt from the Eligible PPA requirements, such arrangements shall still not comprise an Excluded PPA.
Other	Provision of the name, type, location and installed capacity of each generator that supplies electricity in connection with Eligible PPAs or equivalent (including for supply from Electricity Supply Parties). Where the identity of generators cannot be disclosed due to confidentiality provisions, the Delivery Partner may request alternative evidence to verify compliance. If requested, provision of a Single Line Diagram, or equivalent (which is in the form and content satisfactory to the Delivery Partner), for any Hydrogen Production Facility and its generators, evidencing sufficient line capacity for the volumes of Eligible PPA electricity that are sourced.

Table 4: Evidence requirements for electricity sourced from a Private Network and not linked to specific generator(s)

Criteria	Evidence Required
Electricity Supply contractual arrangements	A contract entered into between the Hydrogen Production Facility and a Private Network operator to evidence the physical delivery and Transfer of Title of electricity to the Hydrogen Production Facility from the Private Network to which the Hydrogen Production Facility is connected. The contract shall contain terms that provide for the physical supply of electricity, along with provision of metering data and transaction evidence such as invoices and statements broken down per Reporting Unit.
Transaction evidence	For all volumes of electricity consumed by the Hydrogen Production Facility from a Private Network, there shall be Electricity Supply transaction evidence provided such as invoices or statements that match or exceed the volumes of electricity

	consumed by the Hydrogen Production Facility per Reporting Unit, including any Transmission and Distribution Losses (as described in Paragraphs B. 33 - B. 36). This is summarised using Equation 32: **Equation 32** $$\sum Private\ Network\ supply\ invoices\ (MWh)$$ $$\times\ (1 - Private\ Network\ T\&D\ losses\ (\%))$$ $$\geq\ Facility\ metered\ consumption\ (MWh)$$ $$\times\ Electricity\ consumed\ from\ Private\ Network\ (\%)$$
Temporal Correlation between generation and consumption	Metering data is required from each generator on the Private Network, to show the sum of the metered data of the electricity generators on the Private Network matches or exceeds the Hydrogen Production Facility's metered data for electricity consumed from the Private Network, per Reporting Unit including any Transmission and Distribution Losses (as described in Paragraphs B. 33 - B. 36), calculated using Equation 33. Electricity that is subject to an Eligible PPA or equivalent, is imported from the wider grid, or is from Electricity Curtailment Avoidance shall be metered separately and considered as separate Electricity Supply configurations, as per Table 3, Table 5 and Table 6. **Equation 33** $$\sum Private\ Network\ metered\ generation\ (MWh)$$ $$\times\ (1 - Private\ Network\ T\&D\ losses\ (\%))$$ $$\geq\ Facility\ metered\ consumption\ (MWh)$$ $$\times\ Electricity\ consumed\ from\ Private\ Network\ (\%)$$
Other	Provision of the name, type, location and installed capacity of each generator that supplies electricity in connection within the Private Network. Where the identity of generators cannot be disclosed due to confidentiality provisions, the Delivery Partner may request alternative evidence to verify compliance. If requested, provision of a Single Line Diagram, or equivalent (which is in the form and content satisfactory to the Delivery Partner), for the Private Network, that shows the connections to the Hydrogen Production Facility and evidences sufficient line capacity for the volumes of Private Network generated electricity claimed.

Table 5: Evidence requirements for electricity sourced from grid import and not linked to a specific generator

Criteria	Evidence Needed
Electricity Supply contractual arrangements	Contract entered into between an Electricity Supply Party and the Hydrogen Production Facility. The contract shall contain terms that provide for transaction evidence such as invoices and statements.
Transaction evidence	For all volumes consumed by the Hydrogen Production Facility from grid import and not linked to a specific generator, the Hydrogen Production Facility shall provide Electricity Supply transaction evidence such as invoices or statements that match the consumption meter data each Reporting Unit as per Equation 34: **Equation 34** $$\sum Grid\ import\ supply\ invoices\ (MWh)$$ $$\geq Facility\ metered\ consumption\ (MWh)$$ $$\times Electricity\ consumed\ from\ Grid\ import\ (\%)$$
Metering	The Hydrogen Production Facility shall provide their metered electricity consumption data per Reporting Unit, and the % that is stated to be sourced from grid import.
Other	If requested, provision of a Single Line Diagram, or equivalent (which is in the form and content satisfactory to the Delivery Partner), for the Hydrogen Production Facility's grid connection, evidencing sufficient line capacity for the volumes of grid import electricity claimed. Where this grid connection is part of or via a Private Network, details of any generators (generator asset names, generation types, locations, installed capacities) on the Private Network shall be provided.

Table 6: Requirements to evidence Electricity Curtailment Avoidance

Criteria	Evidence Needed
Proof of electricity consumed via a Bid Offer Acceptance	Hydrogen Production Facility registered in a Primary Balancing Mechanism Unit (BMU) in GB: • Metered electricity consumption data for the corresponding period of the Bid Offer Acceptance recorded by the Hydrogen Production Facility's electricity meter. • Bid Offer Acceptances issued by the GB System Operator.

	Hydrogen Production Facility registered in a Secondary Balancing Mechanism Unit (i.e. by a Virtual Lead Party) in GB:
	• Metered electricity consumption data for the corresponding period of the Bid Offer Acceptance recorded by Settlement Meter registered by the Virtual Lead Party in its Secondary BMU.
	• Bid Offer Acceptances issued by the GB System Operator in respect of the Secondary BMU that the Facility is registered in.
	• Hydrogen Production Facility registered in a Balancing Market Unit (BMU) in NI:
	• Metered electricity consumption data for the corresponding period of the Bid Offer Acceptance recorded by the Hydrogen Production Facility's electricity meter.
	• Bid Offer Acceptances issued by the Irish System Operator.
	For each case above, the following transaction evidence shall be provided in each Reporting Unit as per Equation 35:
	Equation 35
	$$\sum Bid\ Offer\ Acceptances\ (MWh)$$ $$\geq Facility\ metered\ consumption\ (MWh)$$ $$\times Electricity\ consumed\ from\ Curtailment\ Avoidance\ (\%)$$
Other	Evidence of the location of the BMU in which the Hydrogen Production Facility is located, and therefore which Distribution Network Operator licenced area applies.
	If requested, provision of a Single Line Diagram, or equivalent (which is in the form and content satisfactory to the Delivery Partner), for the Hydrogen Production Facility's grid connection, evidencing sufficient line capacity for the volumes of Electricity Curtailment Avoidance claimed.

B. 6. Paragraphs B. 7 to B. 19 set out which GHG Emission Intensity values should be used for each of the different Electricity Supply configurations.

Electricity sourced from a specific generator via an Eligible PPA (or equivalent)

B. 7. Electricity sourced from a specific generator can be claimed at the GHG Emission Intensity of that specific generation asset per Reporting Unit, if the evidence requirements in Table 3 are satisfied. In this case, the Generated electricity GHG Emission Intensity of that generation asset shall use the relevant values from the Electricity generation GHG Emission Intensities Table of the Data Annex, or, if the generator used is not listed, the methodology in Annex G shall be applied. The minimum Generated electricity GHG Emission Intensity of any generator shall be zero.

B. 8. The Delivered Electricity GHG Emission Intensity from Equation 36, shall be used for calculating Electricity Supply emissions in Equation 15, that includes any Transmission

and Distribution Losses (as described in Paragraphs B. 26 - B. 36) between the specific generation asset and the Hydrogen Production Facility.

Equation 36

$$Delivered\ Electricity\ GHG\ Emission\ Intensity\ (gCO_2e/MJ_e) =$$

$$\frac{Generated\ electricity\ GHG\ Emission\ Intensity\ (gCO_2e/MJ_e)}{1 - T\&D\ Losses\ (\%)}$$

B. 9.   Electricity sourced from multiple specific generators shall apply B. 7, B. 8 and Equation 36 for each specific generation asset per Reporting Unit. Paragraph 7.5 sets out the requirements for any grouping of electricity sources by type for the formation of Discrete Consignments.

B. 10.   See Annex E for the Biomass Requirements that apply to specific generators that consume biogenic Input. If the requirements of Table 3 are not met and the requirements of Annex E are also not met for a particular Consignment of hydrogen, the consequences set out in Annex E are applied, and not those set out in Paragraph B. 20.

Electricity sourced from a Private Network and not linked to a specific generator, excluding grid import to the Private Network

B. 11.   Electricity sourced from several generation assets on a Private Network can be claimed at the weighted average GHG Emission Intensity of the Private Network generators per Reporting Unit, if the evidence requirements set out in Table 4 are satisfied. If so, the Generated GHG Emission Intensity of each electricity generation source on the Private Network shall use the relevant values from the Electricity generation GHG Emission Intensities Table of the Data Annex, or, if the generator used is not listed, the methodology in Annex G shall be applied. The minimum GHG Emission Intensity of any generator shall be zero. For certain electricity generators on a Private Network, there are some specific requirements that shall be followed when applying the Annex G methodology:

- For a generator on a Private Network that uses hydrogen as a Fuel source to generate electricity, then unabated fossil natural gas (combined upstream and combustion values from the Data Annex's Fuel GHG Emission Intensity and Fuel combustion CO2 Emission Intensity Tables) shall be used as the GHG Emission Intensity for the hydrogen consumed by the generation asset, before the rest of the methodology in Annex G is applied.

- For a generator on a Private Network that uses fossil natural gas with CCS to generate electricity, then the GHG Emission Intensity of this generation shall be calculated as per the methodology in Annex G, but any credit for captured CO2 is ignored, i.e. the eccs term is set to 0.

B. 12.   Any arrangement seeking to claim the GHG Emission Intensity of a specific generator on a Private Network shall meet the requirements of Paragraphs B. 7 to B. 10. If electricity from a specific generator is claimed by a Hydrogen Production Facility, this volume of electricity shall be excluded from the Private Network weighted average GHG Emission Intensity for that Reporting Unit.

B. 13.   Any import of electricity into the Private Network from the wider grid shall be considered separately to the Private Network generation sources (and not part of the Private Network weighted average GHG Emission Intensity calculation), and shall follow the evidence requirements given in Table 5 and Paragraph B. 16.

B. 14.   The Delivered Electricity GHG Emission Intensity from Equation 37 should be used for calculating Electricity Supply emissions in Equation 15, that includes any Transmission and Distribution Losses (as described in Paragraphs B. 26 - B. 36) between the Private Network generators and the Hydrogen Production Facility.

Equation 37

$$Delivered\ Electricity\ GHG\ Emission\ Intensity =$$

$$\frac{Weighted\ average\ GHG\ Emission\ Intensity\ of\ Private\ Network\ generation}{(1 - \%\ Private\ Network\ T\&D\ Losses)}$$

B. 15.   See Annex E for the Biomass Requirements that apply to specific generators on a Private Network that consume biogenic Input. If the requirements of Table 4 are not met and the requirements of Annex E are also not met for a particular Consignment of hydrogen, the consequences set out in Annex E are applied, and not those set out in Paragraph B. 20.

Electricity sourced from the Electricity Grid and not linked to a specific generator

B. 16.   Electricity sourced from grid import not linked to any specific generator may be claimed at the GHG Emission Intensity of the applicable GB or NI Electricity Grid average per Reporting Unit depending on the location of the Hydrogen Production Facility, if the evidence requirements set out in are satisfied. See the Data Annex Paragraphs on Electricity sourced from the Electricity Grid and not linked to a specific generator for the GHG Emission Intensity values to use under this scenario.

Electricity Curtailment Avoidance

B. 17.   Electricity may be determined as Electricity Curtailment Avoidance for the Reporting Unit and claimed at the Regional GHG Emission Intensity value (if such data is available) corresponding to the Hydrogen Production Facility's location if the evidence requirements set out in Table 6 are satisfied.

B. 18.	See the paragraphs in the Data Annex on Electricity Curtailment Avoidance for the relevant Regional GHG Emission Intensity values to be used under this supply configuration.

B. 19.	The claimed use of any "credited" electricity, where there is no physical delivery of these electricity volumes, are excluded from the Standard's eligible Electricity Supply configurations and the consequences in B. 20 would apply for this consumption.

Failure to Meet the Relevant Evidence Requirements

B. 20.	If the evidence requirements are not met for a particular Electricity Supply configuration, a Facility may choose to claim the GHG Emission Intensity of another supply configuration, provided the relevant evidence requirements (Table 3, Table 4, Table 5 and Table 6) of that supply configuration are met. Otherwise, if these evidence requirements are not complied with:

- For those Pathways without a Feedstock, where the Input electricity generates a Discrete Consignment, failure to meet the evidence requirements of the chosen supply configuration for which the GHG Emission Intensity is being claimed shall result in that Discrete Consignment being non-compliant with the Standard.

- For those Pathways with a Feedstock, where the Input electricity does not generate a Discrete Consignment, failure to meet the evidence requirements of the chosen supply configuration for which the GHG Emission Intensity is being claimed shall result in that volume of electricity being assigned a GHG Emission Intensity of unabated oil-fired generation from the Electricity generation GHG Emission Intensities Table of the Data Annex, factoring in 10% T&D losses.

Renewable Energy Guarantees of Origin (REGOs)

General REGO Requirements

B. 21.	Hydrogen Production Facilities shall ensure that claims of Renewable Electricity consumption are supported by enough REGOs, in line with the requirements set out in B. 22. REGOs shall account for any applicable Transmission and Distribution Losses, in accordance with B. 26- B. 36, and be rounded up to the nearest whole number. REGOs do not need to be bundled[13] with electricity purchases. It is important that

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[13] REGO 'bundling' refers to an optional contractual arrangement whereby alongside the sale of electricity volumes from a specific generator, the corresponding REGOs for this volume of electricity are issued and transferred to the purchaser of this electricity (i.e. both REGOs and electricity are purchased from the same generation asset).

REGOs are appropriately accounted for to verify Renewable Electricity use and avoid double counting by licensed suppliers under the Fuel Mix Disclosure[14].

B. 22.   Each year, by a deadline set by the Delivery Partner, the Hydrogen Production Facility shall provide evidence, as agreed via the Data Collection and Monitoring Procedure, evidencing that the correct number of REGOs were procured to cover the Renewable Electricity that was consumed by the Hydrogen Production Facility that year. The evidence shall be demonstrated by one of the two methods presented below:

- **In the first instance:** the Hydrogen Production Facility shall evidence, such as through contracts or declarations, that it has contracted with an Electricity Supply Party for the provision of REGO backed Renewable Electricity. The Electricity Supply Party will submit sufficient REGOs to Ofgem to cover this proportion of Renewable Electricity Supply as part of their Fuel Mix Disclosure obligation for GB or NI. The evidence needed to meet this REGO requirement shall be agreed with the Delivery Partner as part of the Data Collection and Monitoring Procedure.

- **Only where it can be demonstrated that electricity from Electricity Supply Parties are not subject to the relevant GB or NI Fuel Mix Disclosure obligations:** a Hydrogen Production Facility shall evidence commitments, such as through contracts or declarations, for themselves or their Electricity Supply Parties to procure and hold a sufficient number of REGOs equivalent to the REGO backed electricity volume supplied to the Hydrogen Production Facility for the relevant year, and commit to not transfer these REGOs to another party. Evidence shall also be made available, where requested by the Delivery Partner, to verify that these commitments have been upheld. The evidence needed to meet this REGO requirement shall be agreed with the Delivery Partner as part of the Data Collection and Monitoring Procedure and could include extracts from any Renewable Electricity Registers relevant to this Renewable Electricity Supply.

B. 23.   The timelines for acquiring the necessary evidence for meeting the REGO requirements stipulated by B. 22 may not align with the annual reporting schedule for the Standard. As a result, REGO evidence may need to be submitted after the reporting deadline, and the Delivery Partner may determine that hydrogen Consignments previously considered compliant are no longer compliant based on the REGO evidence received after the reporting deadline. Any REGO evidence submitted by the Hydrogen Production Facility shall clearly state the reporting periods it relates to.

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[14] The Fuel Mix Disclosure period currently runs 1st April to 31st March, with a requirement for REGOs to be registered, traded and/or cancelled by noon 1st July following the generation disclosure period, at which point all REGOs on the register are redeemed by Ofgem.

B. 24. If a Hydrogen Production Facility fails to comply with the relevant evidence requirements in B. 22, or if insufficient REGOs have been procured in line with the methodologies outlined below in Paragraph B. 25, then:

- For those Pathways without a Feedstock, where the Input electricity generates a Discrete Consignment, the volumes of REGO registered electricity for which REGOs have failed to have been correctly evidenced, will result in the corresponding number of Discrete Consignments being non-compliant with the Standard (using the Hydrogen Production Facility efficiency from electricity to Hydrogen Product). The Facility may choose which Discrete Consignments from the year are deemed to have correctly evidenced REGOs and which have not, provided the annual total shortfall in REGOs is correct.

- For those Pathways with a Feedstock, where the Input electricity does not generate a Discrete Consignment, the volumes of REGO registered electricity for which REGOs have failed to have been correctly evidenced will result in recalculation of the GHG Emission Intensity of all Discrete Consignments that used this electricity. This recalculation shall use unabated oil-fired generation using values from the Data Annex Table on Electricity generation GHG Emission Intensities, factoring in 10% T&D losses. This may result in multiple Discrete Consignments and/or Weighted Average Consignments across the year exceeding the GHG Emission Intensity Threshold.

B. 25. The calculation for the number of REGOs required to be evidenced by the Hydrogen Production Facility in accordance with B. 22 will depend on the electricity Input source used:

- Where the Hydrogen Production Facility wishes to claim their electricity is supplied from a specific generator via an Eligible PPA (or equivalent), but the generation asset is not eligible to be registered within the REGO scheme (e.g., a nuclear power plant), then these REGO requirements do not apply for the volumes of electricity supplied from these generators.

- For any electricity Input being claimed at the GHG Emission Intensity of a specific generation asset registered within the REGO scheme, the number of REGOs needing to be evidence for the Hydrogen Production Facility is calculated using the generator REGO Percentage from the Data Annex Paragraphs on Energy Supply and Equation 38 for each Reporting Unit, before summing over all the Reporting Units within the REGO Year.

Equation 38

$$
\begin{aligned}
REGOs\ Required\ & (Per\ Reporting\ Unit) \\
& \geq Facility\ metered\ consumption\ (MWh) \\
& \times Share\ of\ electricity\ consumption\ from\ the\ specific\ generator \\
& \times Specific\ generator\ \%\ share\ of\ REGO\ registered\ generation \div (1 \\
& - \%\ T\&D\ losses)
\end{aligned}
$$

- For electricity consumed by the Hydrogen Production Facility from a Private Network and not linked to a specific generator, the number of REGOs needing to be evidenced for the Hydrogen Production Facility is calculated using the generator REGO Percentage from the Data Annex Paragraphs on Energy Supply and Equation 39 for each Reporting Unit, before summing over all the Reporting Units within the REGO year. Any Electricity Grid or Otherwise Curtailed Electricity imported via the Private Network or electricity volumes from a generator subject to an Eligible PPA (or equivalent) are to be treated separately.

Equation 39

$$
\begin{aligned}
REGOs\ Required\ & (Per\ Reporting\ Unit) \\
& \geq Facility\ metered\ consumption\ (MWh) \\
& \times Share\ of\ electricity\ consumption\ from\ the\ Private\ Network\ generators \\
& \times Private\ Network\ generator\ \%\ share\ of\ REGO\ registered\ generation \div (1 \\
& - \%\ T\&D\ losses)
\end{aligned}
$$

- For grid import electricity consumed by the Hydrogen Production Facility from the Electricity Grid and not linked to a specific generator, the number of REGOs needing to be evidenced for the Hydrogen Production Facility is calculated by the volume of grid import electricity consumed multiplied by the REGO Percentage given in the Data Annex Paragraphs on Electricity sourced from the Electricity Grid and not linked to a specific generator.

- Where the Hydrogen Production Facility wishes to claim their electricity is supplied from an Electricity Storage System via an Eligible PPA (or equivalent), the REGO requirements in C. 27 - C. 31 shall be followed.

- For Electricity Curtailment Avoidance, the number of REGOs needing to be evidence for the Hydrogen Production Facility is calculated by the volumes of Electricity Curtailment Avoidance electricity consumed multiplied by the REGO Percentage given in the Data Annex Paragraphs on Electricity Curtailment Avoidance.

Transmission and Distribution Losses

B. 26.   This section sets out how Transmission and Distribution (T&D) Losses are to be calculated. T&D Losses impact the volume of generation to be evidenced by a specific generator or by a Private Network not linked to a specific generator, the GHG Emission Intensity of delivered electricity from these sources, and number of REGOs to be cancelled.

B. 27.   Electricity sourced from GB or NI Electricity Grid or Electricity Curtailment Avoidance, in both cases not linked to a specific generator, already have T&D losses included in their GHG Emission Intensity values, so no further instructions are required.

B. 28.   The T&D Losses on a Private Network shall be calculated as a weighted average of specific generators on the Private Network.

B. 29.   Where evidence and a calculation of T&D Losses is not provided, Hydrogen Production Facilities shall use a value of 10%.

> **Example**: A Hydrogen Production Facility in GB sourcing electricity from a nuclear electricity generator fails to provide Transmission and Distribution Losses for a Reporting Unit.
>
> o   The GHG Emission Intensity of nuclear electricity generation = 3.9 gCO$_2$e/MJ$_e$
>
> The correct delivered GHG Emission Intensity to apply in case of failure to report T&D losses is then $\frac{3.9 \text{ gCO}_2\text{e/MJ}_e}{1-10\%} = 4.3 \text{ gCO}_2\text{e/MJ}_e$.

Electricity sourced from specific generators that are connected to the GB / NI Electricity Grid via an Eligible PPA (or Equivalent)

B. 30.   T&D losses are to be calculated in accordance with an appropriate industry standard (e.g., the Balancing and Settlement Code), that is based on the Network(s) between the specific generation asset and the Hydrogen Production Facility (e.g., from generator to Transmission Network, to Distribution Network, to the Hydrogen Production Facility).

B. 31.   The methodology for calculating T&D losses for the Hydrogen Production Facility's specific Electricity Supply scenarios are to be agreed with the Delivery Partner as part of the Data Collection and Monitoring Procedure. The calculation of percentage T&D losses will need to apply the relevant combinations of Transmission Loss Multipliers and Line Loss Factors (for GB) or Transmission Loss Adjustment Factors and Distribution Loss Factors (for NI), for the specified Electricity Supply scenario.

B. 32.   See the Data Annex Paragraphs on Transmission and Distribution Losses projected/Typical Data for further details on the data required to calculate T&D Losses.

> **Example:** An Electrolytic Hydrogen Production Facility in Northern Ireland consumed 18,000 MWh of electricity in a Reporting Unit where the Distribution Loss Adjustment Factor and the Transmission Loss Adjustment Factor between the generator and Hydrogen Production Facility is 0.975 and 0.981 respectively.
>
> o   Transmission and Distribution Losses (%) = $1 - (0.975 \times 0.981) = 4.35\%$
> o   The minimum volume of generated electricity required (e.g., to support Temporal Correlation, transaction evidence and REGO accounts) = $\frac{18,000\ MWh}{1-0.0435} = 18,819\ MWh$

Electricity sourced from a specific generator via a Private Network

B. 33.   For a Hydrogen Production Facility that sources electricity from a specific generator via a Private Network, the Hydrogen Production Facility shall calculate and report T&D losses for that specific generator and support these calculations with evidence, for example, network wire resistivity, network wire length and any equipment losses.

Electricity sourced from a Private Network and not linked to a specific generator

B. 34.   Where a Hydrogen Production Facility uses electricity sourced from a Private Network and not linked to a specific generator, where the Private Network only supplies the Hydrogen Production Facility and does not supply other users, the T&D Losses shall be determined using Equation 40. T&D Losses shall be determined by adding metered volumes of electricity generated for all generators on a Private Network and subtracting the volume of electricity consumed by the Hydrogen Production Facility.

Equation 40

$$T\&D\ Losses\ (\%) =$$

$$\frac{\sum Generation\ Meters\ - Hydrogen\ Production\ Facility\ Meter}{\sum Generation\ Meters} \times 100\%$$
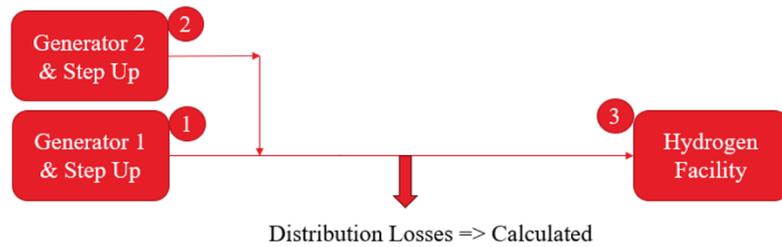
Figure 12: Meters for a specific generator or from several generators on a Private Network connecting only to the Hydrogen Production Facility

B. 35.   For electricity sourced from Private Network and not linked to a specific generator if this Private Network supplies several users including the Hydrogen Production Facility, then the sum of last year's metered generation across the Private Network and an annual statement evidencing last year's total electricity consumption across the Private Network shall be provided. The T&D Losses are then determined using Equation 41.

Equation 41

$$T\&D\ Losses\ (\%) =$$

$$\frac{\sum Generation\ Meters\ - Total\ Private\ Network\ Electricity\ Consumption}{\sum Generation\ Meters} \times 100\%$$

B. 36.   Hydrogen Production Facilities may consume electricity that has been stored within an Electricity Storage System located in the UK. For Pathways without a Feedstock, this transited electricity via an Electricity Storage System will form its own Discrete Consignment when generating hydrogen (see Chapter 7).

Annex C: Stored Inputs

Overview

C. 1.   This Annex sets out the methodology for both the storage of electricity in an Electricity Storage System and the storage of Feedstocks, Precursor Feedstocks and Fuels in an Input Storage System prior to consumption at a Hydrogen Production Facility (or preprocessing facility in the case of Precursor Feedstocks).

Stored electricity supply

C. 2.   Hydrogen Production Facilities may consume electricity that has been stored within an Electricity Storage System located in the UK. For Pathways without a Feedstock, this transited electricity via an Electricity Storage System will form its own Discrete Consignment when generating hydrogen (see Chapter 7).

C. 3.   An Electricity Storage System is a rechargeable technology, and any non-rechargeable technologies are not within scope of the Standard. Electricity Storage Systems may store the electricity in different energy forms between charging and discharging. Other systems that do not input/output electricity, for example, thermal energy stores that input/output heat, are out of scope. The requirements set out in this Annex shall not apply to backup power systems including Uninterruptable Power Supply and capacitors within the Hydrogen Production Facility, as any electricity used for these units fall under the Energy Supply Emission Category (Paragraphs 5.26 - 5.28).

C. 4.   An Electricity Storage System being charged shall follow the same Annex B rules as a Hydrogen Production Facility. When charging, Electricity Storage Systems may consume electricity from any combination of the four permitted Electricity Supply configurations in Annex B. 3.

C. 5.   A Hydrogen Production Facility sourcing electricity from an Electricity Storage System shall follow the same rules as for a specific generator of electricity via an Eligible PPA, as per Table 3 in Annex B. A Hydrogen Production Facility may consume electricity from multiple Electricity Storage Systems.

C. 6.   This Annex details the methodology to calculate the Stored Electricity GHG Emission Intensity and Stored REGO Percentage for the electricity that is stored within and discharged by the Electricity Storage System every Reporting Unit including evidence requirements. Electricity Storage Systems shall be permitted to charge and/or discharge as frequently as desired within each Reporting Unit without any restrictions. The 'charge first' assumption set out in Paragraphs C. 21 - C. 22 below is used for

accounting purposes only and is not a restriction on real-world Electricity Storage System operations.

Evidence required from each Electricity Storage System

C. 7. In addition to the Electricity Storage System fulfilling the evidence requirements given in Annex B Table 3, for the relevant permitted Electricity Supply configuration, a Hydrogen Production Facility consuming discharged electricity from an Electricity Storage System shall also record the following evidence each month:

- The Stored Electricity GHG Emission Intensity (see Annex C. 16 - C. 22) and Stored REGO Percentage (see Annex C. 23 - C. 26), for each Reporting Unit.

- The percentage SoC (State of Charge, given as kWh_e stored/kWh_e stored at full charge) of the Electricity Storage System at the end of each Reporting Unit.

- The percentage mix of electricity sources used to charge the Electricity Storage System for each Reporting Unit.

- The GHG Emission Intensity and REGO Percentage (see the Data Annex Paragraphs on Energy Supply) for the electricity sources used to charge the Electricity Storage System, per Reporting Unit, accounting for any Upstream T&D Losses between the electricity sources and the Electricity Storage System (see Annex B Paragraphs B. 26 - B. 36 but with the role of the Hydrogen Production Facility replaced by the Electricity Storage System).

- The Electricity Storage System itself meets the full requirements of Annex B for the respective Electricity Supply configuration used to charge the Electricity Storage System in each Reporting Unit, whereby the references to 'Hydrogen Production Facility' (or equivalent) shall instead apply to 'Electricity Storage System'. This includes accounting for any Transmission and Distribution Losses between the electricity generators and the Electricity Storage System in any contracted volumes, invoices and metering data for Temporal Correlation.

C. 8. The following Electricity Storage System specifications and data shall be recorded annually:

- The type of Electricity Storage System, including the battery chemistry if the Electricity Storage System is an electrochemical battery;

- The percentage State of Health (SoH) or equivalent;

- The Design Capacity;

- The Self Discharge Loss (see Paragraphs C. 11 - C. 12 for more details);

- The Round Trip Efficiency (see Paragraphs C. 14 - C. 15 for more details).

C. 9. If the mix of electricity sources used to charge an Electricity Storage System cannot be evidenced for a Reporting Unit, the highest GHG Emission Intensity value among the relevant electricity sources used for charging shall be used for the entire amount of electricity used to charge in that Reporting Unit.

C. 10. If the mix of Input electricity sources used to charge an Electricity Storage System cannot be evidenced for a Reporting Unit, the highest of the REGO Percentages of the relevant electricity sources (given in the Data Annex Paragraphs on Typical Data for Energy Supply) shall be used for the entire amount of electricity used to charge in that Reporting Unit.

Self-Discharge Loss evidence

C. 11. Self-Discharge Losses can occur due to various mechanisms, for example, internal chemical reactions, heat dissipation and storage material leakage. The rate of Self Discharge Loss varies significantly between storage technologies but is also influenced by the SoC and environmental conditions.

C. 12. The Self Discharge Loss value (% loss per 30 minutes) for a particular Electricity Storage System shall be evidenced by the provision of either:

- The contractual performance guarantees from the Electricity Storage System equipment manufacturer or technology provider, provided these guarantees state the maximum permissible Self Discharge Loss value over a given time period, and the guarantees cover all applicable components and loads within the Electricity Storage System; or

- System monitoring data over a period of at least one year of Electricity Storage System operations, showing the long-term background average rate of loss of SoC once charging, discharging and RTE losses are backed out of these SoC calculations, or alternatively, the weighted average rate of loss of SoC calculated from all periods in which no charging or discharging occurs.

C. 13. If this Self Discharge Loss evidence is not provided, then for those Electricity Storage System technologies listed in the Conservative 30-minute Self Discharge Loss values for Electricity Storage Systems Table of the Data Annex shall be used instead. If the Self Discharge Loss evidence is not provided and the Electricity Storage System technology is not listed in this table of the Data Annex, a 10% Self Discharge Loss per 30 minutes shall be assumed.

Round Trip Efficiency evidence

C. 14. The Round Trip Efficiency (RTE) value (%) for a particular Electricity Storage System shall be evidenced by the provision of one of:

- The contractual performance guarantees from the Electricity Storage System equipment manufacturer or technology provider, provided these guarantees state (or chart) the minimum permissible Round Trip Efficiency value for the given year of operations, and the guarantees cover all applicable components and loads within the Electricity Storage System; or

- Verified RTE data from the GB/NI Electricity Grid System Operator during any initial grid connection or annual capacity market mandatory testing procedures. If the Electricity Storage System is located in GB and participates in the Balancing Mechanism, the most recent verified RTE test value shall be provided if choosing to rely on Electricity Grid System Operator verified data; or

- Electricity Storage System import and export electricity meter data over a period of at least one month of Electricity Storage System operations, along with the SoC, Design Capacity and SoH data from this period. The RTE is then calculated using Equation 42, Equation 43 and Equation 44.

Equation 42

$$Change\ in\ storage\ =\ Ideal\ Capacity\ \times\ SoH\ \times\ \left(SoC_{final}\ -\ SoC_{initial}\right)$$

Equation 43

$$Losses\ =\ Gross\ Import\ -\ Gross\ Export\ -\ Change\ in\ storage$$

Equation 44

$$Round\ Trip\ Efficiency\ =\ 1 - \frac{Losses}{Gross\ Import}$$

Where:

- Gross Import (kWhe) = total gross charging of the Electricity Storage System occurring during the Reporting Unit.

- Gross Export (kWhe) = total gross discharging of the Electricity Storage System occurring during the Reporting Unit.

- Other terms are as defined in Chapter 2 and elsewhere in this Annex C.

C. 15. If an Electricity Storage System does not evidence their own RTE value, then for those Electricity Storage System technologies listed in the Conservative Round Trip

Efficiencies for Electricity Storage Systems table of the Data Annex, RTE values from the table shall be used instead. If RTE evidence is not provided and the Electricity Storage System technology is an electrochemical battery not listed in this table of the Data Annex, the lead-acid battery value in the Data Annex may be used. If RTE evidence is not provided and the Electricity Storage System technology is not an electrochemical battery and is not listed in this table of the Data Annex, any hydrogen produced from electricity discharged by this Electricity Storage System shall not be compliant with the Standard.

Example: An onsite battery with a Design Capacity of 100 kWh (being able to discharge 100 kWh without charging) starts with a SoH of 95% and $SoC_{initial}$ of 90% (100 kWh×95%×90% = 85.5 kWh starting position). As evidenced by Electricity Storage System import and export electricity meters, a gross total of 6,000 kWh of electricity is imported and 5,000 kWh of electricity is exported over a month. The SOC_{final} at the end of testing period is 60%.

o SOC_{final} = 60%, so new stored electricity = 100 kWh * 95% * 60% = 57.0 kWh.

o Change in storage = 57.0 kWh – 85.5 kWh = -28.5 kWh.

o Losses = Gross units imported – Gross units exported – Change in storage = 6,000 kWh – 5,000 kWh – (-28.5 kWh) = 1,028.5 kWh.

RTE = $1 - \dfrac{\text{Losses}}{\text{Gross import}} = 1 - \dfrac{1,028.5 \text{ kWh}}{6,000 \text{ kWh}} = 1 - 17.1\% = 82.9\%$.

Stored Electricity GHG Emission Intensity and Stored REGO Percentage tracking

Stored Electricity GHG Emission Intensity tracking

C. 16. The required methodology to track the Stored Electricity GHG Emission Intensity of the electricity stored within an Electricity Storage System is a 'charge first' accounting methodology. Within a Reporting Unit, regardless of the sequencing of charging/discharging events, their frequency or duration, it is assumed for accounting purposes that all the charging events occur at the start of the Reporting Unit, and all the discharge events occur at the end of the Reporting Unit.

C. 17. Embodied emissions from the manufacture, construction and decommissioning of Electricity Storage Systems are not included within the scope of the Standard.

C. 18. Equation 45 shall be used for updating the Stored Electricity GHG Emission Intensity (EI) over a Reporting Unit.

Equation 45

$$Final\ Stored\ EI =$$

$$\frac{(Initial\ Stored\ \times Initial\ Stored\ EI) + (Import\ Flow \times Import\ EI) + (Other\ Flow\ \times Other\ EI)}{(Initial\ Stored + Import\ Flow \times RTE) \times (1 - Self\ Discharge\ Loss)}$$

Equation 46 shall be used to derive the discharged electricity GHG Emission Intensity during the same Reporting Unit.

Equation 46

$$Discharged\ EI = \ Final\ Stored\ EI$$

C. 19.   The required information for Equation 45 and Equation 46 is set out below:

- Initial Stored (kWh$_e$) = Electricity available within the Electricity Storage System at the start of a Reporting Unit, which is equal to the electricity available at the end of the previous Reporting Unit. This is calculated as a Product of the SoC, SoH and Design Capacity.

- Initial Stored EI (gCO$_2$e/kWh$_e$) = GHG Emission Intensity of the electricity available within the Electricity Storage System at the start of a Reporting Unit, which is equal to the GHG Emission Intensity of the electricity available at the end of the previous Reporting Unit.

- Import Flow (kWh$_e$) = total gross charging of the Electricity Storage System occurring during the Reporting Unit.

- Import EI (gCO$_2$e/kWh$_e$) = GHG Emission Intensity of the electricity used to charge the Electricity Storage System during the Reporting Unit, including the impact of any Upstream T&D Losses using Equation 47. See Paragraphs G. 6 - G. 12 for the electricity generation GHG Emission Intensity ($EI_{elec\ generation}$) to be applied or calculated.

Equation 47

$$Import\ EI = \frac{EI_{elec\ generation}}{1 - \%\ Upstream\ T\&D\ Losses}$$

- Other Flow (MJ_{LHV} or kg) = non-electricity Inputs/Outputs required for or resulting from operating the Electricity Storage System during the Reporting Unit, such as Fuels, chemicals, or CO_2 and other GHGs emitted.

- Other EI (g CO_2e/MJ_{LHV} or g CO_2e/kg, to match the units of the Other Flow) = GHG Emission Intensity of the Other Flow used to operate the Electricity Storage System during the Reporting Unit. See Tables Fuel GHG Emission Intensity, Input Materials GHG Emission Intensities and Fuel combustion CO_2 Emission Intensity of the Data Annex for GHG Emission Intensities to be applied, including any combustion factors, or Annex G. 6 for the GHG methodology to calculate a delivered heat/steam GHG Emission Intensity).

- RTE (%) = Round Trip Efficiency of the Electricity Storage System, from Electricity Storage System import electricity meter to Electricity Storage System export electricity meter. These include (but are not limited to) step-up and step-down transformers, rectifiers, inverters, DCDC conversion, charging and discharging energy losses (factoring in Coulombic losses and voltage losses) and any heating or cooling duty requirements. See Paragraph C. 14-C. 15 for more details.

- Self-Discharge Loss (%) = expressed as the average percentage of available stored electricity lost by self-discharging over a Reporting Unit. See Paragraph C. 11 - C. 12 for more details.

- Discharged EI (gCO_2e/kWh$_e$) = GHG Emission Intensity of electricity discharged from the Electricity Storage System during the Reporting Unit.

- Final EI (gCO_2e/kWh$_e$) = GHG Emission Intensity of the electricity available within the Electricity Storage System at the end of the Reporting Unit, which is equal to the GHG Emission Intensity of the electricity available within the Electricity Storage System at the immediate start of the subsequent Reporting Unit.

C. 20. The Discharged EI is before accounting for any Downstream T&D Losses that may apply between the Electricity Storge System and the Hydrogen Production Facility, in order to derived a Delivered GHG Emission Intensity at the Facility, as per Equation 48.

Equation 48

$$Delivered\ EI = \frac{Discharged\ EI}{1 - \%\ Downstream\ T\&D\ Losses}$$

C. 21. An illustration of the 'charge first' accounting approach is given below in Figure 13. This shows how charging (with an Import EI in red) leads to recalculation of the Final EI (in orange) as a weighted average of the red charged electricity and yellow stored electricity, prior to discharge being assumed.

C. 22.   In the 'charge first' accounting approach, all charging Inputs in a Reporting Unit shall be combined into a single Input with a single weighted average GHG Emission Intensity (Import EI). All discharges in a Reporting Unit shall be Output with the Discharge EI.
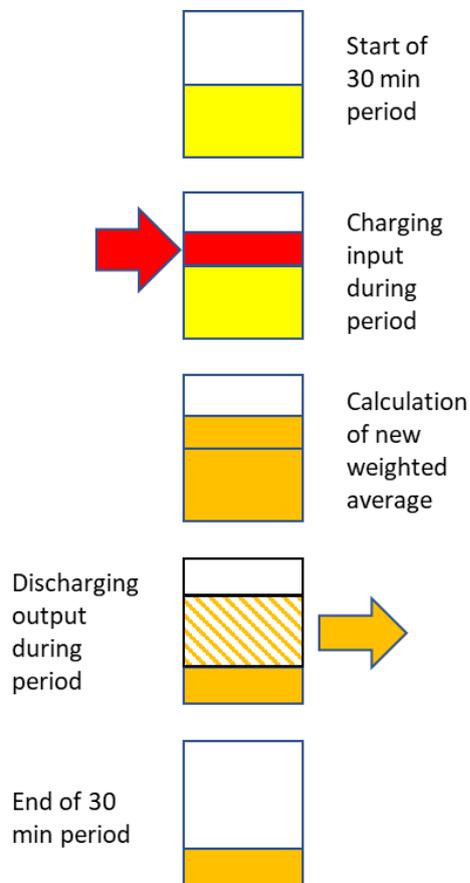
Figure 13: "Charge first" accounting for Stored Electricity GHG Emission Intensity tracking

Stored REGO Percentage tracking

C. 23.   The weighted average Stored REGO Percentage of the electricity stored within the Electricity Storage System shall be the volume of REGO registered electricity stored divided by the total electricity stored. This will change whenever there is electricity Input to charge the Electricity Storage System. The same 'charge first' accounting methodology is used as above for the Stored Electricity GHG Emission Intensity Tracker.

C. 24.   Any electricity discharged from the Electricity Storage System shall be assumed to have the same REGO Percentage as the weighted average Stored REGO Percentage of the electricity within the Electricity Storage System at the end of the Reporting Unit. The discharge of electricity does not change the weighted average Stored REGO Percentage of the electricity that remains stored. Equation 49 shall be used for

updating the Stored REGO Percentage (RP) over a Reporting Unit and Equation 50 shall be used to derive the discharged electricity RP during that Reporting Unit:

Equation 49

$$Final\ RP = \frac{(Initial\ Stored \times Initial\ RP) + (Imported\ Flow \times RTE \times Imported\ RP)}{(Initial\ Stored + Import\ Flow \times RTE)}$$

Equation 50

$$Discharged\ RP = Final\ RP$$

C. 25.   The required information for Equation 49 and Equation 50 is set out below:

- Initial Stored (kWh$_e$) = Electricity available within the Electricity Storage System at the start of the Reporting Unit, which is equal to the electricity available at the end of the previous Reporting Unit.

- Initial RP (%) = REGO Percentage of the electricity available within the Electricity Storage System at the start of the Reporting Unit, which is equal to the REGO Percentage of the electricity available at the end of the previous Reporting Unit.

- Import Flow (kWh$_e$) = total gross charging of the Electricity Storage System occurring during the Reporting Unit.

- Imported RP (%) = REGO Percentage of the electricity used to charge the Electricity Storage System during the Reporting Unit. See the Data Annex Paragraphs on Energy Supply for values to be applied, according to the Input electricity source.

- RTE (%) = Round Trip Efficiency of the Electricity Storage System, from Electricity Storage System import electricity meter to Electricity Storage System export electricity meter. See Paragraphs C. 14 - C. 15 for more details.

- Final RP (%) = REGO Percentage of the electricity available within the Electricity Storage System at the end of the Reporting Unit, which is equal to the REGO Percentage of the electricity available within the Electricity Storage System at the immediate start of the subsequent Reporting Unit.

- Discharged RP (%) = REGO Percentage of the electricity discharged from the Electricity Storage System during the Reporting Unit.

C. 26.   Note the Stored REGO Percentage Tracker is constrained to a value between 0% and 100% (inclusive) and does not directly impact the Stored Electricity GHG Emission Intensity Tracker.

Evidencing of Stored REGOs

C. 27.   As set out in Paragraphs B. 21- B. 25, a Hydrogen Production Facility shall ensure that claims of Renewable Electricity consumption are supported by evidence of sufficient number of REGOs being procured and held by the Hydrogen Production Facility and/or its Electricity Supply Parties, so will need to calculate how much REGO registered electricity it has consumed, in line with the relevant reporting year (1 REGO certificate for 1 MWh of REGO derived electricity).

C. 28.   The calculation for the number of REGOs required to be evidenced in the relevant reporting year for the Hydrogen Production Facility will be calculated in accordance with Equation 51. This uses the discharged REGO Percentage and the volume of electricity discharged from the Electricity Storage System that is consumed by the Hydrogen Production Facility, factoring in losses within the Electricity Storage System (refer to RTE in Paragraph C. 14 - C. 15) and any Upstream T&D Losses and Downstream T&D Losses (refer to Annex B Paragraphs B. 26 - B. 33). Where electricity generation to charge the Electricity Storage System has been sourced from multiple generators, a weighted average for the upstream T&D loss factor shall be used in Equation 51.

Equation 51

$$Number\ of\ REGOs\ required \geq$$

$$\frac{Discharged\ RP \times Stored\ Electricity\ consumed\ (MWh)}{RTE \times (1 - Upstream\ T\&D\ Losses) \times (1 - Downstream\ T\&D\ Losses)}$$

C. 29.   This calculation is carried out for each Reporting Unit and summed across all the Reporting Units within the relevant period for the annual reporting requirement to derive the total number of REGOs required to be evidenced for Electricity Storage System electricity consumed by the Hydrogen Production Facility. The total number of REGOs required to be evidenced shall be rounded up at the end of the relevant period for the annual reporting requirement, to a whole integer number.

C. 30.   Self-Discharge Losses are assumed not to change the REGO Percentage of the electricity within the Electricity Storage System, so are not accounted for in the calculation of the REGO requirement.

C. 31.   Note that there is no generation of REGOs by the Electricity Storage System when discharging. Also note that not all REGO registered electricity generation has a GHG Emission Intensity of 0gCO$_2$e/kWh$_e$.

Example: For one Reporting Unit, 10 MWh of electrolytic hydrogen is produced using 30% electricity from a directly connected Electricity Storage System via a Private Network in Wales, 60% via direct connection to a REGO registered wind farm, and 10% grid imported electricity. The Electricity Storage System in this example has just been charged up from empty using 70% REGO registered solar PV from Scotland (with 10% Upstream T&D losses) and 30% GB grid average electricity in the previous 30 minutes and is assumed to have a RTE of 80% with no Downstream T&D Losses. Self-Discharge Losses are ignored in this example. GB grid average electricity during the current and previous Reporting Unit is assumed to be 160gCO$_2$e/kWh$_e$. The electrolyser has an LHV efficiency of 55.56%. This set-up would result in three Discrete Consignments during the Reporting Unit, as electrolytic Consignments are determined by the energy Inputs:

o   1 MWh of hydrogen based on the GB grid average electricity GHG Emission Intensity (160 gCO$_2$e/kWh$_e$), and the grid average REGO Percentage (0%).

o   3 MWh of hydrogen based on the Stored Electricity GHG Emission Intensity ($\frac{\left(70\%\times\frac{0\ \text{gCO}_2\text{e/kWh}}{1-10\%}\right)+(30\%\times160\ \text{gCO}_2\text{e/kWh})}{80\%} = 60\ \text{gCO}_2\text{e/kWh delivered}$) and Stored REGO Percentage (70%)

o   6 MWh of hydrogen based on a wind electricity GHG Emission Intensity (0 gCO$_2$e/kWh$_e$) and 100% REGO Percentage.

Using the electrolyser LHV efficiency, converting kWh to MJ, and ignoring immaterial emissions in this example, this electrolyser would generate the following Discrete Consignment GHG Emission Intensities and REGO requirements:

o   1 MWh of hydrogen at a GHG Emission Intensity of $\frac{160\ \text{gCO}_2\text{e/kW}h_e\div3.6\ \text{MJ/kWh}}{55.56\%} = 80$ gCO$_2$e/MJ$_{LHV}$ Hydrogen Product, plus a requirement for evidencing $\frac{1\ \text{MWh}}{55.56\%}\times0\%= 0$ REGOs.

o   3 MWh of hydrogen at a GHG Emission Intensity of $\frac{60\text{gCO}_2\text{e/kW}h_e\div3.6\text{MJ/kWh}}{55.56\%}= 0$ gCO$_2$e/MJ$_{LHV}$ Hydrogen Product, plus a requirement for evidencing $\frac{3\ \text{MWh}}{55.56\%}\times\frac{70\%}{80\%\times(1-10\%)\times(1-0\%)}= 5.25$ REGOs.

o   6 MWh of hydrogen at a GHG Emission Intensity of $\frac{0\ \text{gCO}_2\text{e/kW}h_e\div3.6\ \text{MJ/kWh}}{55.56\%}= 0$ gCO$_2$e/MJ$_{LHV}$ Hydrogen Product, plus a requirement for evidencing $\frac{6\ \text{MWh}}{55.56\%}\times100\%= 10.8$ REGOs.

If taking a weighted average of Discrete Consignments from only this Reporting Unit at the end of the month, the Hydrogen Production Facility would report a weighted average GHG Emission Intensity of $\frac{(1\ \text{MWh}\times80\ \text{gCO}_2\text{e/MJ}_{LHV})+(3\ \text{MWh}\times30\ \text{gCO}_2\text{e/MJ}_{LHV})+(6\ \text{MWh}\times0\ \text{gCO}_2\text{e/MJ}_{LHV})}{10\ \text{MWh}} =$

$17.0 \text{ gCO}_2\text{e/MJ}_{\text{LHV}} \text{ H}_2$, = 17.0 0 gCO₂e/MJ_LHV Hydrogen Product, which is below the GHG Emission Intensity Threshold.

For this Reporting Unit, the Hydrogen Production Facility and/or their Electricity Supply Parties shall evidence of a total of 16.05 REGOs (rounding up only occurs at the end of the relevant reporting year after summing all REGO certificates needed across all Reporting Units within that year). If the Facility were to fail to provide evidence of those REGOs for the annual reporting requirement, then 70% of the 3 MWh Electricity Storage System derived Discrete Consignment + 100% of the 6 MWh wind derived Discrete Consignment = 8.1 MWh in total of the hydrogen from this Reporting Unit would be deemed non-compliant with the Standard.

Tracker (re)starting positions

C. 32.   Newly installed Electricity Storage Systems that start discharging electricity to a Hydrogen Production Facility are assumed to begin their Stored Electricity GHG Emission Intensity Tracker: at 0gCO₂e/kWhₑ and begin their Stored REGO Percentage Tracker at 0% for the stored electricity.

C. 33.   If a Hydrogen Production Facility starts consuming discharged electricity from an existing Electricity Storage System, and this Electricity Storage System has not discharged to any Hydrogen Production Facility previously, then this Electricity Storage System is also allowed to begin their Stored Electricity GHG Emission Intensity Tracker: at 0gCO₂e/kWhₑ and Stored REGO Percentage Tracker at 0%. However, once these trackers are established for an Electricity Storage System, they shall continue to be updated every Reporting Unit, so that if a Hydrogen Production Facility stops then later restarts consuming from the Electricity Storage System, the trackers are still accurate.

C. 34.   Similarly, if a Hydrogen Production Facility starts consuming electricity from an Electricity Storage System, and the trackers for that Electricity Storage System are already live, then these live tracker values shall be used by the Hydrogen Production Facility and are not assumed to start at zero. Electricity Storage Systems that discharge to multiple Hydrogen Production Facilities shall therefore provide the same Stored Electricity GHG Emission Intensity and Stored REGO Percentage values for any Reporting Unit to each of these Hydrogen Production Facilities.

C. 35.   An Electricity Storage System shall only stop tracking its Stored Electricity GHG Emission Intensity and Stored REGO Percentage when the Electricity Storage System is decommissioned. An Electricity Storage System undergoing maintenance or refurbishment shall continue to update its trackers during these periods.

C. 36.   Failure to continue to update the trackers during periods with no discharge to any Hydrogen Production Facility shall result in the Electricity Storage System restarting its trackers using a Stored Electricity GHG Emission Intensity of unabated oil-fired

generation from the Electricity generation GHG Emission Intensities Table of the Data Annex (factoring in 10% T&D losses) and a Stored REGO Percentage of 100% upon discharge to a Hydrogen Production Facility resuming.

C. 37.   Failure to continue to update the trackers during Reporting Units with discharge to a Hydrogen Production Facility shall result in the Paragraph C. 7 requirements not being met, and therefore the consequences set out in Annex B. 20 shall apply to the electricity delivered from the Electricity Storage System during these Reporting Units.

Stored Feedstocks and Fuels

C. 38.   Feedstocks or Fuels may be stored in Input Storage Systems prior to their use at a Hydrogen Production Facility. In some instances, Inputs will have different Environmental Characteristics but are mixed in a single Input Storage System. For example, crude oil from different countries may be mixed in tanks prior to use in a Refinery.

C. 39.   In the following requirements, all references to Hydrogen Production Facilities may also include upstream processing facilities as appropriate and any reference to Feedstocks may also include Precursor Feedstocks. Similarly, any reference to the Reporting Unit may also be substituted for an alternative reporting period as agreed with the Delivery Partner as part of the Data Collection and Monitoring Procedure.

C. 40.   Input Storage Systems are often integrated with supply chain processing steps or the Hydrogen Production Facility. If an Input Storage System is integrated and the processing Step already fully accounts for the storage operational emissions and losses, there is no need to apply these requirements. However, if the Input Storage System is a standalone facility, or is separately owned, or the storage losses and operational emissions are not accounted for within the supply chain processing step or Hydrogen Production Facility calculations, then these requirements apply.

C. 41.   Input Storage Systems shall be permitted to fill and/or dispense as frequently as desired within each Reporting Unit without any restrictions, regardless of the storage accounting approach chosen.

Chain of Custody Accounting Approaches

C. 42.   There are four permissible chain of custody accounting approaches to calculate the GHG Emission Intensity for materials that are extracted from Input Storage Systems:

- Identity Preservation: All material stored concurrently within an Input Storage System shall come from a single source and have the same Environmental Characteristics, including GHG Emission Intensity. This accounting approach may only be applied for an empty Input Storage System that inputs identical material all within a single Reporting Unit. Only if the Input Storage System is emptied can it

then be refilled with Inputs having a new identical set of Environmental Characteristics.

- Sequential Mass Balance: Assumes either that material entering an Input Storage System last is then the first to be removed ('last in first out') or material entering an Input Storage System first is then the first to be removed ('first in first out'). The use of either 'last in first out' or 'first in first out' approach for an Input Storage System shall be agreed with the Delivery Partner as appropriate for the type of material being stored.

- Ledger-Based Mass Balance: Inputs, stored materials and Outputs are recorded in a ledger, with the Input Storage System Operator choosing which Inputs (or parts of Inputs) are recorded as exiting the system and therefore which remain.

- Weighted Average Segregation: Assumes that when material is added to an Input Storage System, the contents of the Input Storage System are homogeneously mixed and therefore any Output takes on the weighted average characteristics of the Input Storage System's current contents. This accounting approach shall only be applied for the storage of non-biogenic Inputs. Inputs using this approach shall also be the same (e.g., same Feedstock, same Precursor Feedstock or same Fuel) and of the same type (e.g., fossil, nuclear, renewable Fuel of non-biological origin), same classification (e.g., Waste, Residue, Product) and same form (solid, liquid, gas), but other Environmental Characteristics, such as GHG Emission Intensities may differ. For example, the storage of crude oil Precursor Feedstocks with different countries of origin may use this approach.

C. 43.   The accounting approach for calculating the GHG Emission Intensity for each Input Storage System shall be agreed in advance with the Delivery Partner as part of the Data Collection and Monitoring Procedure. This accounting approach cannot be varied during the lifetime of the Input Storage System unless explicitly agreed with the Delivery Partner.

C. 44.   Regardless of the storage type, all materials that are stored shall follow the requirements set out for that specific Feedstock, Precursor Feedstock, Fuel, or other Input in the relevant chapters or Annexes of the LCHS.

Evidence requirements from Input Storage Systems

C. 45.   Input Storage System Operators shall maintain a Stored Input GHG Emission Intensity Tracker to record the Stored Input GHG Emission Intensity of stored material. Operators shall also record additions to, and removals from, the system as well as compliance with the Biomass Requirements and other relevant criteria.

C. 46.   In addition to evidence requirements for Inputs set out in the relevant chapters or Annexes of the LCHS, a Hydrogen Production Facility consuming an Input which has

been stored in an Input Storage System shall also provide the following evidence to the Delivery Partner each month:

- The quantity of materials input into the Input Storage System during each Reporting Unit, along with their Environmental Characteristics (such as GHG Emissions Intensities and compliance with the Biomass Requirements).

- The quantity of materials output from the Input Storage System during each Reporting Unit, along with their Environmental Characteristics (such as GHG Emissions Intensities and compliance with the Biomass Requirements).

- The quantity of materials remaining within the Input Storage System at the end of each Reporting Unit, along with their Environmental Characteristics (such as GHG Emissions Intensities and compliance with the Biomass Requirements).

Losses from Input Storage Systems

C. 47.   Any losses of materials within an Input Storage System and as a result of storage operations will increase the GHG Emission Intensity of stored material as time progresses. To calculate the impact of any losses and other emissions sources at a standalone or separately measured Input Storage System, it is assumed that all the input, emission and loss events occur at the start of the relevant Reporting Unit, and all the export events occur at the end of the relevant Reporting Unit, regardless of their actual sequencing or timing within the Reporting Unit.

C. 48.   Any losses and other sources of emissions from the Input Storage System or from its operation shall be distributed proportionally across all stored material within a Reporting Unit.

C. 49.   Where there is loss of a gaseous stored material, the relevant GWPs for the gas components should be used, as per the Global Warming Potentials (GWP) table in the Data Annex.

C. 50.   Where there is loss of a solid or liquid stored material, site measurements or literature should be used to estimate the mix of Greenhouse Gases ultimately released to atmosphere, applying the relevant GWPs. For example, wood chip piles can release significant amounts of methane and N_2O.

C. 51.   Where the fate of the lost material cannot be estimated, full oxidisation before loss to atmosphere should be assumed, applying the relevant biogenic or fossil CO_2 GWPs.

Methodology for Identity Preservation, Sequential Mass Balance and Ledger-Based Mass Balance approaches

C. 52.   For Identity Preservation, Sequential Mass Balance and Ledger-Based Mass Balance approaches, the GHG Emission Intensity of each Input stored within the Input Storage

System is calculated separately (and separately from other parts of the same Input that have different Environmental Characteristics).

C. 53.   It is assumed that all the input events occur at the start of the relevant Reporting Unit, and all the Output events occur at the end of the relevant Reporting Unit, regardless of their actual sequencing and timing within the Reporting Unit. So, if a material is Input then extracted again within a single Reporting Unit, the Output EI will be higher than the Input EI.

C. 54.   These accounting approaches therefore effectively only apply between Reporting Units, not within Reporting Units (for example, agreeing a Sequential Mass Balance approach does not avoid the impact of losses and storage operations, regardless of how short the storage duration of that particular Input).

C. 55.   The GHG Emission Intensity of specific Inputs (or parts of Inputs which share the same Environmental Characteristics) shall be determined using Equation 52 for any material already stored within the Input Storage System at the start of the Reporting Unit or using Equation 53 for each Input into the Input Storage System during the Reporting Unit. This calculation may be performed using one of either energy, mass or volume units, however it shall be correctly converted such that the Final GHG Emission Intensity is expressed in energy units (gCO_2e/MJ_{LHV}).

Equation 52

$$Final\ EI_i = \frac{Initial\ EI_i + \sum_j\left(Other\ Sources_j \times Other\ EI_j\right) \times \dfrac{Initial\ Quantity_i}{Initial\ Quantity_{sys} + Total\ Input\ Quantity}}{\left(1 - \dfrac{Loss}{Initial\ Quantity_{sys}}\right)}$$

Equation 53

$$Final\ EI_i = \frac{Input\ EI_i + \sum_j\left(Other\ Sources_j \times Other\ EI_j\right) \times \dfrac{Input\ Quantity_i}{Initial\ Quantity_{sys} + Total\ Input\ Quantity}}{\left(1 - \dfrac{Loss}{Initial\ Quantity_{sys}}\right)}$$

Where:

- Final EI$_i$ is the GHG Emission Intensity of the specific Input, i, (or the part of Input i that shares all the same Environmental Characteristics) within the Input Storage System at the end of the Reporting Unit, which is equal to the GHG Emission Intensity of the specific Input, i, (or the part of Input i that shares all the same Environmental Characteristics) available within the Input Storage System at the start of the subsequent Reporting Unit.

- Initial EI$_i$ is the GHG Emission Intensity of specific Input, i, (or the part of Input i that shares all the same Environmental Characteristics) available within the Input Storage System at the start of the Reporting Unit. This is equal to the GHG Emission Intensity of Input i (or the part of Input i that shares all the same Environmental Characteristics) available at the end of the previous Reporting Unit.

- Other Sources$_i$ refers to other sources of GHG emissions, j, resulting from operating the Input Storage System during the Reporting Unit, such as electricity, Fuels, chemicals, CO2 and other GHGs emitted (including fugitive losses).

- Other EI$_j$ is the GHG Emission Intensity of the Other Sources, j. Reference should be made to the Fuel GHG Emission Intensity, Input Materials GHG Emission Intensities and Fuel Combustion CO2 Emission Intensity tables of the Data Annex for GHG Emission Intensities to be applied, including any combustion factors, and Annex G. 7 for the methodology to calculate the GHG Emission Intensity of delivered electricity, heat or steam.

- Initial Quantity$_i$ is the initial amount of specific Input, i, (or the part of Input i that shares all the same Environmental Characteristics) within the Input Storage System at the start of the Reporting Unit.

- Initial Quantity$_{sys}$ is the total quantity of initial material within the Input Storage System at the start of the Reporting Unit which is equal to the material available at the end of the previous Reporting Unit.

- Total Input Quantity is the sum of the Input Quantities during the Reporting Unit.

- Input EI$_i$ is the GHG Emission Intensity of a specific Input, i, imported during the Reporting Unit.

- Input Quantity$_i$ is the total gross import of a specific Input, i, to the Input Storage System during the Reporting Unit.

- Loss is the quantity of material lost from the system (other than material deliberately extracted) during the Reporting Unit, given by Equation 54.

Equation 54

$$Loss = \left(Initial\ Quantity_{sys} + Total\ Input\ Quantity\right) - \left(Final\ Quantity_{sys} + Total\ Export\ Quantity\right)$$

Where:

- Final Quantity$_{sys}$ is the Final material within the Input Storage System at the end of a Reporting Unit.

- Total Export Quantity is the sum of the quantities extracted from the Input Storage System during the Reporting Unit.

Methodology for Weighted Average Segregation approach

C. 56. If using the Weighted Average Segregation accounting approach, it is assumed that all the input events occur at the start of the relevant Reporting Unit, and all the Output events occur at the end of the relevant Reporting Unit, regardless of their actual sequencing and timing within the Reporting Unit.

C. 57. The GHG Emission Intensity of materials within an Input Storage System shall be determined using Equation 55. This calculation may be performed using one of either energy, mass or volume units, however it shall be correctly converted such that the Final GHG Emission Intensity is expressed in energy units (gCO_2e/MJ_{LHV}).

Equation 55

$$Final\ EI = \frac{\left(Initial\ Quantity_{sys} \times Initial\ EI_{sys}\right) + \sum_i(Input\ Quantity_i \times Input\ EI_i) + \sum_j\left(Other\ Sources_j \times Other\ EI_j\right)}{\left(Initial\ Quantity_{sys} + Total\ Input\ Quantity\right) \times \left(1 - \frac{Loss}{Initial\ Quantity_{sys}}\right)}$$

C. 58. Where these terms have the same meanings as above for the other chain of custody approaches, and:

- Final EI is the GHG Emission Intensity of all material within the Input Storage System at the end of the Reporting Unit, which is equal to the GHG Emission Intensity of the material available within the Input Storage System at the start of the subsequent Reporting Unit.

- Initial EI$_{sys}$ is the GHG Emission Intensity of all material available within the Input Storage System at the start of the Reporting Unit, which is equal to the GHG Emission Intensity of the material available at the end of the previous Reporting Unit.

C. 59. Equation 56 shall be used to derive the GHG Emission Intensity of any exported material during the same Reporting Unit (Output EI). This exported material shall have the same weighted average GHG Emission Intensity as the stored material, and other Environmental Characteristics (for example country of origin) defined at the Output point from the Input Storage System.

C. 60. Hydrogen generated from the Outputs of an Input Storage System using the Weighted Average Segregation approach shall form its own Discrete Consignment.

Equation 56

$$Output\ EI = Final\ EI$$

Stored Input GHG Emission Intensity Tracking

C. 61.   The Stored Input GHG Emission Intensity Tracker (re)starting position requirements set out in this sub-chapter apply regardless of the accounting approach taken.

C. 62.   Newly installed Input Storage Systems that have not previously provided any materials to a Hydrogen Production Facility are assumed to begin operations empty, so the Stored Input GHG Emission Intensity Tracker is assumed to initially begin at zero.

C. 63.   If a Hydrogen Production Facility starts consuming an Input from an existing Input Storage System which has not previously provided Inputs to any Hydrogen Production Facility, then the Stored Input GHG Emission Intensity shall be calculated as a weighted average of the Inputs into the Input Storage System since it was last empty, up to a maximum of the previous 12 months (or other time period as agreed with the Delivery Partner) ignoring any exports or losses.

C. 64.   Once a Stored Input GHG Emission Intensity Tracker is established for an Input Storage System, it shall continue to be updated every Reporting Unit, so that if a Hydrogen Production Facility stops then later restarts consuming from the Input Storage System, the tracker is still accurate.

C. 65.   Similarly, if a Hydrogen Production Facility starts consuming Inputs from an Input Storage System, and the Stored Input GHG Emission Intensity Tracker for that Input Storage System is already live, then the Stored Input GHG Emission Intensity values of that tracker may be used. Input Storage Systems that export to multiple Hydrogen Production Facilities shall therefore provide the same Stored Input GHG Emission Intensity for any Reporting Unit to each of these Hydrogen Production Facilities.

C. 66.   An Input Storage System shall only stop updating the Stored Input GHG Emission Intensity Tracker when decommissioned. An Input Storage System undergoing maintenance refurbishment shall continue to update its tracking mechanism during these periods.

C. 67.   Failure to continue to update the Stored Input GHG Emission Intensity Tracker during Reporting Units where material from an Input Storage System is consumed by a Hydrogen Production Facility shall result in any hydrogen generated to be considered non-compliant with the Standard during that timeframe.

C. 68.   Failure to continue to update the Stored Input GHG Emission Intensity Tracker during periods with no output to any Hydrogen Production Facility shall result in the Input Storage System restarting its tracker using the following assumption upon export to a Hydrogen Production Facility or upstream processing facility resuming:

   • All stored material now has the Stored Input GHG Emission Intensity of that of fossil heavy Fuel oil, combining the upstream and combustion values from the Fuel GHG

Emission Intensity and Fuel Combustion CO$_2$ Emission Intensity tables of the Data Annex.

Annex D: Fossil Gas Supply

Overview

D. 1.   Fossil gas – as a Feedstock or Fuel – is a likely Input to several Hydrogen Production Pathways. Any Hydrogen Production Facility using Input fossil gas shall follow the requirements set out in this Annex, as relevant to the Input fossil gas in question, in helping to determine the appropriate GHG Emission Intensity associated with the Input fossil gas for the Hydrogen Production Facility. Similarly, energy generation assets that consume fossil gas and supply energy to the Hydrogen Production Facility shall follow the requirements set out in this Annex.

Natural gas supply

D. 2.   Natural gas supply configurations shall be assessed in accordance with the three configurations listed below. Hydrogen Production Facilities may source natural gas from any combination of these three natural gas supply configurations in a Reporting Unit:

- Natural gas sourced from the UK Gas Network (either Transmission or Distribution Network) and not linked to a specific source.

- Natural gas sourced from the UK Gas Network (either Transmission or Distribution Network) and linked to a specific source.

- Natural gas not sourced from the UK Gas Network.

Natural gas from the UK Gas Network not linked to a specific source

D. 3.   Hydrogen Production Facilities receiving natural gas that has only transited via the UK gas Transmission Network (and not the UK gas Distribution Network) shall use the UK Gas Transmission Network value provided in the Fuel GHG Emission Intensity Table of the Data Annex to account for emissions associated with this natural gas supply. A contract with a licenced supplier for physical delivery of natural gas shall be evidenced, with invoices or statements to match the Facility's gas consumption meter data each month.

D. 4.   Hydrogen Production Facilities receiving natural gas that has transited via the UK Gas Distribution Network shall use the UK Gas Distribution Network value provided in the Fuel GHG Emission Intensity table of the Data Annex that is the most appropriate to the pressure at which the Hydrogen Production Facility withdraws gas from the Distribution Network. A contract with a licenced supplier for physical delivery of natural gas shall be evidenced, with invoices or statements to match the Hydrogen Production

Facility's gas consumption meter data each month.

Natural gas from the UK Gas Network linked to a specific source

D. 5.   Natural gas sourced from a specific gas field, where this gas has transited via the UK Gas Network, cannot currently be claimed at the delivered GHG Emission Intensity per Reporting Unit specific to this upstream source. This is due to a lack of an established GHG Emission Intensity accounting methodology and evidence framework within the fossil gas supply industry.

D. 6.   DESNZ will investigate the potential for an evidence framework to allow linkage to specific gas sources in a future version of the Standard. This may include contractual evidence detailing the specific sources and the delivered GHG Emission Intensity.

Natural gas not from the UK Gas Network

D. 7.   Where Hydrogen Production Facilities are receiving natural gas that has not transited via the UK Gas Network (for example through direct pipeline connection with a UK gas field, or direct use of imported liquified natural gas via ship), they may claim the delivered GHG Emission Intensity for the production and supply of natural gas from this specific source, if the following evidence is provided:

- A supply contract signed with the Hydrogen Production Facility ahead of the physical delivery of natural gas;

- Invoicing evidence to match the Facility's gas consumption meter data each month;

- The location of the natural gas production;

- The planned route and modes of delivery and storage between the point of natural gas production and the Hydrogen Production Facility;

- The Projected, Estimated or Measured Data specific to the supply chain, along with any Typical or Non-Typical Data used.

D. 8.   Hydrogen Production Facilities providing their own data shall account for all GHG emissions associated with natural gas exploration, drilling, extraction, flaring, venting, processing, compression, any liquefaction and regasification, and transport from the extraction point to the Hydrogen Production Facility. These emissions can be incurred anywhere globally and are not restricted to only the UK. This includes the use of electricity, heat/steam, Fuels, chemicals, and other Input Materials to the natural gas supply chain, along with losses and fugitive CO_2, methane and other GHG emissions.

D. 9.   Further details for undertaking the extraction and processing emission calculations can be found in Section 9 and Appendix F of the Atmospheric Emissions Calculations

document[15].

D. 10.   Where facilities within the supply chain produce multiple Products and/or Co-Products, for example, crude oil and natural gas, an LHV Energy Allocation Method (as described in Chapter 5, Paragraphs 5.12–5.20) shall be used to allocate GHG emissions between the Products and Co-Products.

Refinery Off Gas supply

D. 11.   Some Hydrogen Production Facilities may choose to use Refinery Off Gases (ROG) as Feedstock and/or Fuel to generate Input energy. In UK Refineries, ROG is typically combusted on-site to provide heat (and in some cases power) for the Refinery. Globally, ROG is also commonly known as 'Refinery fuel gas' or 'Refinery still gas'.

D. 12.   Any ROG Stream sourced shall be supplied to the Hydrogen Production Facility by dedicated transport mode and shall not be mixed with fossil natural gas or other Feedstocks before reaching the Hydrogen Production Facility.

D. 13.   The material classification of ROG will follow the approach given in Paragraphs 5.10 - 5.11.

- If ROG is classified as a Co-Product, the System Boundary extends back to the extraction of the original Feedstock at the start of the supply chain. The LHV Energy Allocation Method given in Chapter 5 shall be used to apportion both the original Precursor Feedstock Supply GHG emissions and Refinery processing GHG emissions between the ROG and other Refinery Co-Products. The GHG Emission Intensity of the original Precursor Feedstock shall be either based on field-level data (which shall be evidenced by contracted supplies and supply chain calculations) or based on GHG Emission Intensity of crude oil imports table of the Data Annex for the country of production if crude oil is the original Precursor Feedstock. Where the Refinery uses multiple Precursor Feedstocks, a weighted average mix of these based on their LHV energy content shall be used to calculate the overall Feedstock Supply emissions.

- If ROG is classified as a Residue, the System Boundary starts at the point of collection of the ROG at the Refinery, and any GHG emissions upstream of this point shall be excluded. ROG classified as a Residue shall instead be assigned Fossil Waste/Residue Counterfactual emissions at the point of collection, as specified in the Fossil Waste/Residue counterfactual section of the Data Annex, unless the provisions set out in D. 14 are applicable.

D. 14.   For any ROG Stream that is classified as a Residue, if Hydrogen Product from the Hydrogen Production Facility returned to the ROG Refinery and is consumed on site

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[15] https://www.gov.uk/guidance/oil-and-gas-eems-database

for the purpose of Refinery operations, the Fossil Waste/Residue Counterfactual may be disapplied for an equivalent amount of the ROG Stream subject to the following:

- The monthly total MJ_{LHV} of Hydrogen Product (generated by the Hydrogen Production Facility) consumed for the purpose of Refinery operations at the ROG Refinery sets an upper bound for the total MJ_{LHV} of ROG classified as a Residue that may disapply the Fossil Waste/Residue Counterfactual in that month.

- Any shortfall in the MJ_{LHV} of Hydrogen Product being consumed for the purpose of Refinery operations at the ROG Refinery, compared to the total MJ_{LHV} of ROG classified as a Residue, shall lead to the same shortfall amount of MJ_{LHV} of ROG remaining classified as a Residue and applying the counterfactual set out in the Data Annex section on Fossil Waste/Residue Counterfactual.

- For example, if 90 MJ_{LHV} of ROG classified as a Residue is delivered to the Hydrogen Production Facility by the Refinery and 70 MJ_{LHV} of the Hydrogen Production Facility's Hydrogen Product is returned and consumed at the ROG Refinery, and 10 MJ_{LHV} of hydrogen from a separate source is also consumed at the ROG Refinery. In this case, 70 MJ_{LHV} of ROG may have the Fossil Waste/Residue Counterfactual emissions disapplied, and 20 MJ_{LHV} of ROG shall still include these counterfactual emissions. This will result in two different ROG-derived Discrete Consignments with different GHG Emission Intensity.

- For the avoidance of doubt, this returned Hydrogen Product may be derived from the ROG Stream or from other Feedstocks, but the returned Hydrogen Product must be produced by the Hydrogen Production Facility that consumes the ROG Stream for the counterfactual to be disapplied. If the ROG Refinery consumes hydrogen from a different source, this cannot be included in the calculation as to how much ROG classified as Residue may disapply the counterfactual.

D. 15.   The Hydrogen Production Facility shall record the following data on a daily and monthly basis. On a monthly basis, the following data in Table 7 shall be reported, where applicable, as agreed within the DCMP:

Table 7: Data required for ROG Feedstocks

Data	Frequency
ROG mass flow at the Hydrogen Production Facility	Daily & Monthly Totals
ROG energy content (Lower Heating Value) at the Hydrogen Production Facility	Daily & Monthly Totals
ROG % mol compositional analysis at the Hydrogen Production Facility	Daily & Monthly Averages
Natural gas mass flow at the Hydrogen Production Facility	Daily & Monthly Totals

Data	Frequency
Natural gas energy content (Lower Heating Value) at the Hydrogen Production Facility	Daily & Monthly Totals
Natural gas % mol compositional analysis at the Hydrogen Production Facility	Daily & Monthly Averages
Hydrogen mass flow returned to the ROG Refinery from Hydrogen Production Facility	Daily and Monthly Totals
Hydrogen Product energy content (Lower Heating Value) returned to the ROG Refinery from Hydrogen Production Facility	Daily & Monthly Totals
Hydrogen Product % mol compositional analysis Output from Hydrogen Production Facility	Daily & Monthly averages
Crude oil mass flow to the Refinery Unit	Daily & Monthly Totals
Other Precursor Feedstock mass flows into the ROG Refinery	Daily & Monthly Totals

D. 16.   It is also expected that the following upfront information shall be provided to the Delivery Partner ahead of Hydrogen Production Facility operations:

- High-level pipework arrangements for ROG Streams at the ROG Refinery and to the Hydrogen Production Facility (giving one/two-way valves, flow direction, and expected average flow rates & pressures).

- High-level pipework arrangements for Hydrogen Product return points within the ROG Refinery (giving one/two-way valves, flow direction, and expected flow rates & pressures), and a statement of where the Hydrogen Product is used in the Refinery.

- A contract between the Hydrogen Production Facility and ROG Refinery for the Hydrogen Product return, including any provisions for installation of meter measurement systems at the ROG Refinery deemed necessary by the Delivery Partner.

Other fossil gas supply

D. 17.   Hydrogen Production Facilities may choose to use other fossil gas Feedstocks from other fossil Fuel production processes. The same principles as for ROG will apply, with the material classification to be determined on a Facility-by-Facility basis by DESNZ and/or Delivery Partner. Any Waste/Residue classification shall result in the fossil material being assigned Fossil Waste/Residue Counterfactual emissions, or alternatively, a Co-Product classification which will require use of LHV Energy Allocation Method to partition the Upstream and Step Emissions. A contract with a

supplier for physical delivery of the gas shall be evidenced, with invoices or statements to match the Facility's gas consumption meter data each month.

Annex E: Biogenic Inputs

E. 1.   Biogenic Inputs (including biogenic Products, Co-Products, Wastes and Residues) are derived from biomass. Biomass is defined as any material of biological origin that has been recently (in geological terms) produced by living organisms consuming atmospheric carbon sources, naturally occurring carbon sources or other biogenic material.

E. 2.   Biogenic Inputs may include conventional food and feed crops (e.g., cereals, sugars, vegetable oils), food and agricultural Waste, perennial energy crops (e.g., miscanthus grass) and short rotation coppice (e.g., willow, poplar), short rotation forestry (e.g., birch), agricultural Residues (e.g., straw), forest Residues and Residues from processing, and marine-based and novel Feedstocks (e.g., microalgae). Note that this list is not exhaustive – for any biogenic Inputs which are not listed above, the definition of biomass (provided in Paragraph E. 1) shall be taken as a guide to whether the Input in question, or a component of it, is biogenic.

Overview

E. 3.   The Biomass Requirements given for biogenic Inputs in this Annex are applicable to all biogenic Feedstocks and biogenic Fuel Inputs used within a Hydrogen Production Facility, as well as to all biogenic Inputs used to generate energy that is consumed by a Hydrogen Production Facility (e.g., sourcing of biomass-derived electricity from specific generators, either via Eligible PPAs [or equivalent] or from Private Networks).

E. 4.   Biogenic Inputs shall meet certain Sustainability Criteria, the Minimum Waste and Residue Requirement, and report on indirect land-use change (ILUC) emissions, the details of which are outlined later in this Annex. The Sustainability Criteria closely follow those set out in the Renewable Transport Fuel Obligation (RTFO).

E. 5.   Where the biogenic Input concerned is converted to biomethane and then stored or transported prior to being used in Hydrogen Production, the biomethane requirements set out in Annex F shall be followed.

E. 6.   Hydrogen Production Facilities using biogenic Feedstocks shall account for emissions related to direct land-use change within the Feedstock Supply Emission Category and/or within the Energy Supply Emissions Category, as set out in Chapter 5. These direct land-use change emissions shall follow the methodology and approach set out in this Annex.

Minimum Waste and Residue Requirement

E. 7.   For a Hydrogen Production Facility using biogenic Feedstock, at least 50% of the biogenic hydrogen produced (by LHV energy content) shall be derived from biogenic Waste or Residue Feedstocks (as defined in Chapter 2). For a Hydrogen Production Facility using biogenic Fuel (where this biogenic Fuel use does not generate a separate Discrete Consignment), at least 50% of the biogenic Fuel (by LHV energy content) consumed by a Hydrogen Production Facility shall be derived from biogenic Wastes or Residues. For a Hydrogen Production Facility that sources Input energy (e.g., electricity, heat, steam) from specific bioenergy generation plants, at least 50% of the bioenergy consumed by a Hydrogen Production Facility shall be derived from biogenic Wastes or Residues.

E. 8.   For a Hydrogen Production Facility using biogenic Feedstock, or Pathways without a Feedstock that source Input energy from a specific bioenergy generator, the Hydrogen Production Facility shall meet the Minimum Waste and Residue Requirement on the basis of a weighted average across all Discrete Consignments of biogenic hydrogen produced in a calendar month (independent of which Discrete Consignments are chosen to be included in a Weighted Average Consignment for that month). If the Hydrogen Production Facility cannot comply with the Minimum Waste and Residue Requirement, those Discrete Consignments produced that fall short of the Minimum Waste and Residue Requirement shall not be compliant with the Standard.

E. 9.   Where the use of biogenic Fuels or bioenergy sourced from a specific generators do not generate Discrete Consignments (e.g., the Pathway's Discrete Consignments are determined by the Feedstocks), the Hydrogen Production Facility shall meet the Minimum Waste and Residue Requirement on the basis of a weighted average across all biogenic Fuel or bioenergy Inputs consumed by the Hydrogen Production Facility in a calendar month. If the Hydrogen Production Facility cannot comply with the Minimum Waste and Residue Requirement, the GHG Emission Intensity of the proportion of the biogenic Inputs that fall short of the Minimum Waste and Residue Requirement shall be calculated on the basis that the biomass material that generated this proportion of the Input is fossil heavy Fuel oil (see the Fuel GHG Emission Intensity and Fuel combustion CO_2 Emission Intensity tables of the Data Annex, and applying any electricity, heat or steam efficiencies as per Annex G). Any biogenic CO_2 generated at the Facility from this proportion of the Input shall also be considered as fossil CO_2.

E. 10.   Hydrogen Production Facilities shall provide evidence of commercial arrangements for each Input (e.g., invoices with suppliers of Wastes and/or Residues), and sampling data according to the agreed DCMP (refer to Annex H).

Land-use change

Direct land-use change

E. 11.   Land-use change can occur due to the cultivation of biogenic Input for Hydrogen Production. Direct land-use change describes the land-use change which occurs within the land used to create the biogenic Input. An example would be previously uncultivated land (for example, forest, peatland, grassland) being converted for agricultural use.

E. 12.   Annualised emissions from carbon stock changes caused by direct land-use change shall be calculated by dividing total emissions equally over 20 years. These emissions shall be calculated with Equation 57[16]:

Equation 57

$$e_I = (CS_R - CS_A) \times 3.664 \times \left(\frac{1}{20}\right) \times \left(\frac{1}{P}\right)$$

Where:

- e_I = the annualised GHG emissions from carbon stock change due to land-use change (in gCO_2e/MJ_{LHV} crop). 'Cropland'[17] and 'perennial cropland'[18] shall be regarded as one land use.

- CS_R = the carbon stock associated with the reference land use in hectares (that is, the land use in January 2008 or 20 years before the Input was obtained, whichever was later) (in gC/ha).

- CS_A = the carbon stock associated with the actual land use in hectares (in gC/ha). In cases where the carbon stock accumulates over more than one year, the value attributed to CSA shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever was earlier.

- P = the productivity of the crop (in MJ_{LHV} crop/ha/year).

Calculation of carbon stock for land-use change emissions (CS_R and CS_A)

E. 13.   Equation 57 shall be used for reporting emissions relating to direct land-use change. The key part of the land-use change calculation is an estimation of the change in carbon stocks. This is based on the difference between the carbon stock from the latest available data (which should be, at most, within three years of the reporting

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[16] The quotient obtained by dividing the molecular weight of CO_2 (44.010 g/mol) by the molecular weight of carbon (12.011 g/mol) is equal to 3.664.
[17] Cropland as defined by IPCC.
[18] Perennial crops are defined as multi-annual crops, the stem of which is usually not annually harvested such as short rotation coppice and oil palm.

month) and the carbon stock in January 2008 (or 20 years before the Input was obtained, whichever is the later date).

E. 14.   Carbon stock shall be calculated using Equation 58.

Equation 58

$$CS_i = SOC + C_{VEG}$$

Where:

- CS_i is the carbon stock of the land.
- SOC is the soil organic carbon (in gC/ha).
- C_{VEG} is the above and below-ground vegetation carbon stock (in gC/ha).
- Carbon stock estimates are based on a number of key parameters which shall be determined by the Hydrogen Production Facility:
  - ○ previous land use.
  - ○ climate and in some cases ecological zone.
  - ○ soil type.
  - ○ soil management (for both previous and new land use).
  - ○ soil Input (for both previous and new land use).

E. 15.   Definitions of the different land use categories for determining previous land use (and their associated carbon stock values) are provided below:

- Cropland – non-protected: this category includes cropped land (including rice fields and set-aside), and agroforestry systems where the vegetation structure falls below the thresholds used for the forest categories[19]. The cropland is not in a nature-protected area.

- Cropland – protected – no interference with nature protection purpose: same as above, but the cropland is in a nature protection area, and the production of the raw material did not interfere with the nature protection purpose.

- Cropland - protected/protection status unknown: this category of cropland shall be used where:
  - ○ the cropland had protected status, but evidence could not be provided that there was no interference with the nature protection purpose; or

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[19] Note that perennial crop plantations are classed as cropland under this Standard.

- o the protection status could not be determined.

- Grassland (and other wooded land not classified as forest): this category includes rangelands and pastureland that are not considered cropland, but which have an agricultural use. It also includes grasslands without an agricultural use but excludes highly biodiverse grassland and cropland lying temporarily fallow for less than 5 years. It additionally includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the forest land categories including both those with and without an agricultural use. It includes extensively managed rangelands as well as intensively managed (for example, with fertilisation, irrigation, species changes) continuous pasture and hay land.

- Highly biodiverse grassland: this is defined as any grassland spanning more than one hectare which is included as a 'priority grass and habitat'[20] under the UK Biodiversity Action Plan[21]. For grasslands located outside of the UK, definitions of highly biodiverse grassland according to the relevant competent authority in that country may be used. This category cannot be reported for natural grassland that is highly biodiverse. It shall only be reported for non-natural highly biodiverse grasslands that would cease to be grassland in the absence of human intervention, where evidence is provided that harvesting of the raw material is necessary to preserve its grassland status.

- Highly biodiverse forest: highly biodiverse forest and other wooded land which is species-rich and not degraded[22].

- Forest greater than 30% canopy cover: continuously forested areas, namely land spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30%, or trees able to reach those thresholds in situ.

- Forest 10 to 30% canopy cover: land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10% and 30%, or trees able to reach those thresholds in situ.

- Wetland: land that is covered with or saturated by water permanently or for a significant part of the year.

- Undrained peatland: this is peatland that was not completely drained in January 2008 (or 20 years before the Input was obtained, whichever is the later date). This

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[20] https://jncc.gov.uk/our-work/uk-bap-priority-habitats/#list-of-uk-bap-priority-habitats

[21] Further guidance on what constitutes a priority grassland habitat is also available in Annex 2 of the JNCC Guidelines for the Selection of Biological Sites of Special Scientific Interest (SSSIs) https://hub.jncc.gov.uk/assets/cf50f420-1b38-4253-89f8-1cb7ba010f27

[22] More specific guidance on how to determine if land is highly biodiverse forest will be provided as soon as it is available.

includes peatland that was not drained at all and peatland that was partially drained.

- Settlement: includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. Examples of settlements include land along streets, in residential (rural and urban) and commercial lawns, in public and private gardens, in golf courses and athletic fields, and in parks, provided such land is functionally or administratively associated with particular cities, villages or other settlement types and is not accounted for in another land use category[23].

E. 16.   Hydrogen Production Facilities shall determine the exact location of the land-use change. Soil management (whether full-till, reduced-till or no-till) and soil Inputs (low, medium, high-with manure, and high-without manure) are factors that also need to be determined and included in the calculations.

E. 17.   In most cases, it is possible to use the information above to find values within the references given in the Data Annex Paragraphs on Direct land use change (DLUC). However, under certain conditions, actual carbon stock measurements or other calculation methodologies will need to be undertaken, for example, if the soil is a histosol or if no value exists in the reference given in the Data Annex. In the absence of specified carbon stock, the carbon stock shall be measured for any settlement or degraded land converted for Hydrogen Production.

Soil organic carbon - mineral soils

E. 18.   Hydrogen Production Facilities may use several methods to determine soil organic carbon (SOC), including measurements[24]. When measurements are not used, the method used shall take into account climate, soil type, land cover, land management and Inputs.

E. 19.   As a default method, Equation 59 shall be used:

Equation 59

$$SOC = SOC_{ST} \times F_{LU} \times F_{MG} \times F_I$$

Where:

- SOC_{ST} is the standard soil organic carbon in the 0 - 30 cm topsoil layer (in gC/ha).

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[23] This definition is taken from the 2006 IPCC Guidelines for National GHG inventories (Vol 4).
[24] Soil organic carbon levels can traditionally be measured using mass loss on ignition or wet oxidation. However, newer techniques are being developed, which can either be carried out in the field or remotely (near-infrared reflectance spectrometry, remote hyperspectral sensing).

- F_{LU} is the land use factor reflecting the difference in soil organic carbon associated with the type of land use compared to the standard soil organic carbon (no unit).

- F_{MG} is the land use factor reflecting the difference in soil organic carbon associated with the principle management practice compared to the standard soil organic carbon (no unit).

- F_I is the land use factor reflecting the difference in soil organic carbon associated with different levels of carbon Input to soil compared to the standard soil organic carbon (no unit).

- SOC_{ST} can be looked up in the reference given in the Data Annex Paragraphs on direct land use change (DLUC), depending on climate region and soil type. The climate region can be determined from the climate region data layers within the reference given in this section. The soil type can be determined by following the flow diagram in Figure 14 or following the soil type data layers within in the reference given in the Data Annex Paragraphs on DLUC.

- F_{LU}, F_{MG} and F_I can be looked up within the reference given in the Data Annex Paragraphs on DLUC, depending on climate region, land use, land management and Input.
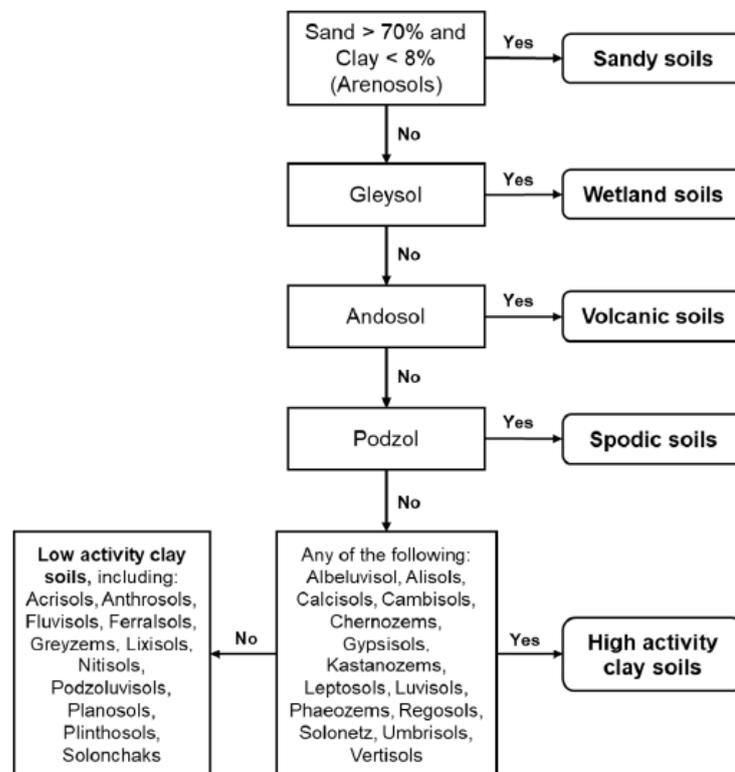

Figure 14: Flow diagram for classifying soil type

Soil organic carbon - organic soils (histosols)

E. 20.   No default method is available for determining the SOC value of organic soils. However, the method used by the Hydrogen Production Facility shall take into account the entire depth of the organic soil layer as well as climate, land cover, land management and Input. Such methods may include measurements.

E. 21.   Where carbon stock is affected by soil drainage, losses of carbon following drainage shall be taken into account by appropriate methods, potentially based on annual losses of carbon following drainage.

Above and below-ground vegetation carbon stock (C_{VEG})

E. 22.   For some vegetation types, C_{VEG} can be directly read from the reference given in Data Annex Paragraphs on direct land use change (DLUC). Relevant ecological zones can be determined from maps produced within the reference given in the same section of the Data Annex.

E. 23.   If a value is not available in the references provided, vegetation carbon stock shall be calculated according to Equation 60, taking into account both above and below-ground carbon stock in living stock (C_{BM} in gC/ha) and above and below-ground carbon stock in dead organic matter (C_{DOM} in gC/ha), noting the Data Annex Paragraphs on DLUC.

Equation 60

$$C_{VEG} = C_{BM} + C_{DOM}$$

E. 24.   Above and below-ground carbon stock in living stock shall be calculated using Equation 61 or Equation 62:

Equation 61

$$C_{BM} = (B_{AGB} \times CF_B) + (B_{BGB} \times CF_B)$$

Equation 62

$$C_{BM} = (B_{AGB} \times CF_B) \times (1 + R)$$

Where:

- B_{AGB} is the weight of above-ground living biomass (in kg dry matter/ha) which shall be taken to be the average weight of the above-ground living biomass during the production cycle for cropland, perennial crops and forest plantations.

- B_{BGB} is the weight of below-ground living biomass (in kg dry matter/ha) which shall be taken to be the average weight of the below-ground living biomass during the production cycle for cropland, perennial crops and forest plantations.

- CF$_B$ is the carbon fraction of dry matter in living biomass (in kgC/kg dry matter), refer to the Data Annex Paragraphs on DLUC.

- R is the ratio of below-ground carbon stock in living biomass to above-ground carbon stock in living biomass which can be read in the reference given in the Data Annex Paragraphs on DLUC.

E. 25. Above and below-ground carbon stock in dead organic matter shall be calculated with Equation 63.

Equation 63

$$C_{DOM} = (DOM_{DW} \times CF_{DW}) + (DOM_{LI} \times CF_{LI})$$

Where:

- DOM$_{DW}$ is the weight of the deadwood pool (in kg dry matter/ha).

- CF$_{DW}$ is the carbon fraction of dry matter in the deadwood pool (in kgC/kg dry matter), refer to the Data Annex Paragraphs on Direct land use change (DLUC).

- DOM$_{LI}$ is the weight of litter (in kg dry matter/ha).

- CF$_{LI}$ is the carbon fraction of dry matter in the litter (in kgC/kg dry matter), refer to the Data Annex Paragraphs on DLUC.

Indirect land-use change

E. 26. Indirect land-use change (ILUC) is the global knock-on effect of the expansion of agricultural land use resulting from the cultivation of biogenic Inputs for Hydrogen Production, due to Input market pricing impacts. GHG emissions associated with ILUC vary depending on the situation but can be significant to a point which greatly reduces (or even nullifies) the GHG emission benefits generally associated with low carbon Hydrogen Production and use. There is ongoing work to improve our understanding of ILUC emissions, the outcomes of which will inform any future changes to the Standard.

E. 27. The requirements outlined in this Annex help to mitigate the risk of high emissions associated with ILUC. In particular, the Land Criteria (see below for more detail) and Minimum Waste and Residue Requirement help to limit the role that high-risk ILUC Inputs can play in Hydrogen Production.

E. 28. Estimated ILUC emissions in gCO$_2$e/MJ$_{LHV}$ Hydrogen Product shall be reported for all biogenic Feedstocks and for all biogenic energy Inputs (electricity, heat, steam, Fuels) to a Hydrogen Production Facility. This reporting shall be accompanied by the ILUC factors applied (from the ILUC values of biomass groups table in the Data Annex) and the conversion factors from MJ$_{LHV}$ of cultivated biomass to MJ$_{LHV}$ of Hydrogen Product that apply to the Pathway (there may be multiple conversion factors if there is ILUC

associated with the biomass Feedstock and ILUC also associated with e.g., biofuel heating Inputs). These calculations are entirely separate to the GHG Emission Intensity Calculation Methodology and do not form part of the Final GHG Emission Intensities. A report of nil ILUC emissions shall be submitted if there are no ILUC emissions associated with the biogenic Feedstocks or biogenic energy Inputs to a Hydrogen Production Facility.

E. 29.   The consequences of failing to report on estimated ILUC emissions are set out below:

- Where a biogenic Feedstock generates a Discrete Consignment of Hydrogen Product (refer to Paragraph 7.4): Should the Facility not report on estimated ILUC emissions for the biogenic Feedstock, the resulting Discrete Consignment shall not be compliant with the Standard.

- For a Pathway without a Feedstock, where a biogenic energy Input to a Facility generates a Discrete Consignment of Hydrogen Product (refer to Paragraph 7.5): Should the Facility not report on estimated ILUC emissions for the biomass material that generated this biogenic energy Input, the resulting Discrete Consignment shall not be compliant with the Standard.

- For a Pathway with a Feedstock, where a non-Feedstock biogenic energy Input (electricity, heat, steam) to a Facility does not generate a separate Discrete Consignment of Hydrogen Product: Should the Facility not report on estimated ILUC emissions for the biomass material that generated this biogenic energy Input, the GHG Emission Intensity of the Input shall be calculated on the basis that the biomass material is fossil heavy Fuel oil (combining the upstream and combustion data from the Fuel GHG Emission Intensity and Fuel combustion CO_2 Emission Intensity tables of the Data Annex, and applying the electricity, heat or steam efficiencies as per Annex G).

- For a Pathway with a Feedstock, where a non-Feedstock biogenic Fuel Input to a Facility does not generate a separate Discrete Consignment of Hydrogen Product: Should the Facility not report on estimated ILUC emissions for the biomass material that generated this biogenic Fuel Input, the GHG Emission Intensity of the Input shall use the production and supply GHG Emission Intensity of fossil heavy Fuel oil (refer to the Fuel GHG Emission Intensity table of the Data Annex), and any biogenic CO_2 generated at the Facility from the use of the Input shall also be considered as fossil CO_2 in calculating the Process CO_2 emissions (refer to the Global Warming Potential (GWP) of GHGs without climate feedback table of the Data Annex).

Sustainability Criteria

E. 30.   Certain biogenic Inputs shall comply with relevant Sustainability Criteria to be compliant with the Standard, to mitigate against other negative environmental and

social outcomes. Table 8 below lists the relevant Sustainability Criteria (Land Criteria, Forest Criteria and/or Solid Carbon Criteria) that different types of biogenic Inputs shall meet, following the precedent set out in the RTFO.

Table 8: Relevant Sustainability Criteria that types of biogenic Input shall meet

Inputs	Land Criteria	Forest Criteria	Soil Carbon Criteria
Forest biomass, including Residues from Forestry or Wastes from forestry		✓	
Residues or Wastes from Agriculture	✓		✓
Residues, including processing Residues, which are not Residues from Agriculture, Aquaculture, Fisheries or Forestry			
Wastes, which are not Wastes from Agriculture, Aquaculture, Fisheries or Forestry			
Any biogenic Input not falling within entries listed above	✓		

E. 31.   It is strongly recommended that Hydrogen Production Facilities using biogenic Inputs[25] meet the Land, Forest and Soil Carbon Criteria by reporting through a voluntary scheme that has been recognised as demonstrating compliance with the relevant criteria, as this means that no further evidence is required. Demonstrating compliance is covered in more detail in the sections below.

E. 32.   The consequences of failing to evidence compliance with these Sustainability Criteria are set out below:

- Where a biogenic Feedstock generates a Discrete Consignment of Hydrogen Product (refer to Paragraph 7.4). Should this biogenic Feedstock not satisfy all the relevant Sustainability Criteria, the resulting Discrete Consignment shall not be compliant with the Standard.

- For a Pathway without a Feedstock, where a biogenic energy Input to a Facility generates a Discrete Consignment of Hydrogen Product (refer to Paragraph 7.5): Should the biomass material that generated this biogenic energy Input not satisfy all the relevant Sustainability Criteria, the resulting Discrete Consignment shall not be compliant with the Standard.

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[25] A Hydrogen Production Facility may handle the original biogenic Input, or a Product derived from it (e.g., biogas, biomethane, electricity from biogenic sources). Either way, it is the original biogenic material, prior to any engineered conversion, that is subject to the Sustainability Criteria laid out in the Standard.

- For a Pathway with a Feedstock, where a non-Feedstock biogenic energy Input (electricity, heat, steam) to a Facility does not generate a separate Discrete Consignment of Hydrogen Product: Should the biomass material that generated this biogenic energy Input not satisfy all the relevant Sustainability Criteria, the GHG Emission Intensity of the Input shall be calculated on the basis that the biomass material is fossil heavy Fuel oil (combining the upstream and combustion data from the Fuel GHG Emission Intensity and Fuel combustion CO_2 Emission Intensity tables of the Data Annex, and applying the electricity, heat or steam efficiencies as per Annex G).

- For a Pathway with a Feedstock, where a non-Feedstock biogenic Fuel Input to a Facility does not generate a separate Discrete Consignment of Hydrogen Product: Should the biomass material that generated this biogenic Fuel Input not satisfy all the relevant Sustainability Criteria, the GHG Emission Intensity of the Input shall use the production and supply GHG Emission Intensity of fossil heavy Fuel oil (refer to the Fuel GHG Emission Intensity table of the Data Annex), and any biogenic CO_2 generated at the Facility from the use of the Input shall also be considered as fossil CO_2 in calculating the Process CO_2 emissions (see the Global Warming Potential (GWP) of GHGs without climate feedback table of the Data Annex).

Land Criteria

E. 33. The Land Criteria ensure that relevant biogenic Inputs are sourced in a way that preserves biodiversity and carbon stocks. To achieve this, biogenic Inputs for Hydrogen Production shall not be sourced from land that has or previously had a certain status (high biodiversity or carbon stock). In some cases, it is permitted to source material from land of a certain status if specific criteria are met.

E. 34. The Land Criteria are made up of two sub-criteria, one which covers biodiversity and the other carbon stocks and peatlands.

Biodiversity criteria

E. 35. To satisfy the biodiversity criteria, hydrogen shall not be produced using raw material obtained from land with high biodiversity value in or after January 2008. The prohibited land categories are:

- Primary forest or other wooded land of native species where there is no clearly visible indication of human activity and ecological processes are not significantly disturbed.

- Highly biodiverse forest or other wooded land which is species-rich and not degraded except in cases where the land is designated for nature protection purposes and the production of relevant Input is a necessary management action

that did not interfere with the purposes for which the land concerned was designated for nature protection purposes.

- Land designated for nature protection purposes, including those designated for the protection of rare, threatened, or endangered ecosystems or species, unless production of the relevant Input can be shown not to have interfered with those nature protection purposes.

- Natural highly biodiverse grassland[26] spanning more than one hectare.

- Non-natural highly biodiverse grassland spanning more than one hectare, unless harvesting of the raw material is necessary to preserve its status as highly biodiverse grassland.

E. 36.   For the exemptions permitted in the land categories above, evidence shall be provided that the exemption is valid.

Carbon stocks and peatlands criteria

E. 37.   Hydrogen shall not be made using raw material if the sourcing of such biomass would cause adverse effects on land carbon stocks or to peatlands. To satisfy the carbon stocks and peatlands criteria, the following need to be satisfied:

- Hydrogen shall not be made from raw material obtained from land which had the following land status at any time in January 2008 and no longer has that status:

  - Wetlands, defined as land that is covered with or saturated by water permanently or for a significant part of the year.

  - Continuously forested areas spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30%, or trees able to reach those thresholds in situ.

- Where raw material is sourced from land which at any time in January 2008 was a forested area spanning more than one hectare with trees higher than five metres and a canopy cover of between 10% and 30%, or trees able to reach those thresholds in situ, and the land no longer has that status, Hydrogen Production Facilities shall take into account emissions due to direct land-use change.

E. 38.   Hydrogen shall not be made from raw material obtained from land, which was peatland at any time in January 2008, unless it can be demonstrated that the cultivation and harvesting of that raw material did not involve drainage of previously undrained soil.

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[26] Natural grassland is grassland that would remain as grassland and that maintains its natural species composition, ecological characteristics and processes in the absence of human intervention.

Soil Carbon Criteria

E. 39.   The Soil Carbon Criteria apply specifically to hydrogen made from Wastes and Residues derived from agriculture and is in addition to the Land Criteria.

E. 40.   To meet the Soil Carbon Criteria, Hydrogen Production Facilities shall demonstrate that monitoring or management plans are in place to address the impacts on soil quality and soil carbon of the harvesting of the biogenic Input concerned.

E. 41.   To comply with the Soil Carbon Criteria, Hydrogen Production Facilities shall demonstrate that appropriate monitoring or management practices are either:

- Required by law in the country of origin of the Input, and that their implementation is monitored and enforced;

- In place at the farms from which the material was sourced.

Forest Criteria

E. 42.   The Forest Criteria apply to hydrogen made from forest biomass, including Wastes and Residues from forestry. Such biogenic Inputs do not have to meet the Land Criteria.

E. 43.   Where hydrogen is derived from forest biomass Inputs, it shall be demonstrated that the Inputs meet the following criteria:

- The material has not been harvested from wetlands, peatlands or protected land areas unless the land is designated for nature protection purposes and the production of the relevant Input did not interfere with the purposes for which the land concerned was designated for nature protection purposes;

- The material has been legally harvested;

- The material has been harvested in such a way that negative impacts on soil quality and forest biodiversity are minimised, and which maintains or improves the long-term production capacity of the forest from which it was harvested;

- Areas that have been harvested are subject to forest regeneration[27];

- Changes in carbon stock associated with forest biomass harvest are accounted for in submissions related to the country's commitment to reduce or limit Greenhouse Gas emissions through the Paris Agreement, or the material has been harvested in such a way that carbon stock and sink levels in the forest are maintained or increased over the long term.

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[27] "Forest regeneration" means the re-establishment of a forest stand by natural or artificial means following the removal of the previous stand by felling or as a result of natural causes, including fire or storm.

E. 44.   To comply with the Forest Criteria, it shall be demonstrated that appropriate monitoring or management practices, which ensure the criteria described in Paragraph E. 43 are satisfied, are either:

- Required by law in the country of origin of the Input, and that their implementation is monitored and enforced;

- In place at the forest sourcing area[28] from which the material is sourced.

Demonstrating compliance with the Sustainability Criteria

E. 45.   Hydrogen Production Facilities shall provide evidence of compliance with the relevant Sustainability Criteria by using one (or more) existing voluntary schemes. Voluntary schemes that may be used to provide evidence of compliance with the Sustainability Criteria are listed in the Data Annex Paragraphs on Sustainability Criteria.

E. 46.   Voluntary schemes are recognised for a specific scope. For example, they might be recognised as providing evidence for one or more of the Land Criteria, Forest Criteria, or Soil Carbon Criteria. Where a voluntary scheme does not provide evidence for all of the Land, Forest and/or Soil Carbon Criteria, then Facilities shall demonstrate compliance with those criteria through another voluntary scheme or by following the compliance routes outlined below.

E. 47.   The chain of custody rules of a voluntary scheme shall be complied with for a Hydrogen Production Facility to claim that the biogenic Input in question complies. A Hydrogen Production Facility shall either be certified under the voluntary scheme or, where it is not certified, check with the voluntary scheme before a claim is made.

E. 48.   Hydrogen Production Facilities utilising voluntary schemes shall have evidence that the biogenic Input in question complies with such a voluntary scheme. It is not sufficient to purchase from an economic operator that has been certified against a voluntary scheme unless the biogenic Input supplied by that entity is accompanied by evidence of meeting the scheme, for example, a proof of sustainability. This is because being certified under a voluntary scheme does not require that entity to only supply sustainable biogenic Inputs.

E. 49.   A certificate issued under the listed voluntary schemes is the only acceptable form of evidence. Additional evidence is not generally required to substantiate the sustainability information included on the certificate. However, the claim of compliance with the scheme and the certificate must be legitimate, the recognised version of the scheme must be used, and the quantity of Input shall be recorded accurately.

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[28] "Sourcing area" means the geographically defined area from which the forest biomass is sourced, from which reliable and independent information is available and where conditions are sufficiently homogeneous to evaluate the risk of the sustainability and legality characteristics of the forest biomass.

E. 50.   The Delivery Partner shall have the right to request more information where necessary, to ensure that the specific requirements of the Standard have been met.

Alternative options for demonstrating compliance with the Sustainability Criteria

E. 51.   If a voluntary scheme is not available (for example, for a particular biogenic Input or region), then Hydrogen Production Facilities shall conduct independent third-party audits to evidence compliance with the Sustainability Criteria.

E. 52.   To evidence compliance, a third-party audit shall capture the same evidence as a listed voluntary scheme. A list of potential evidence sources that may be used as part of a third-party audit report (for example, on historic land use) can be found in the guidance for the RTFO[29], which shares the same Land, Forest, and Soil Carbon Criteria.

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[29] https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-compliance-reporting-and-verification

Annex F: Biomethane Input Supply

Overview

F. 1.   Any Hydrogen Production Facility using biomethane shall follow the requirements set out in this Annex.

F. 2.   Any biomethane supplied to a Hydrogen Production Facility shall be assessed in accordance with the three configurations, or any combination thereof, listed below.

- Biomethane delivered directly to the Hydrogen Production Facility via dedicated pipeline infrastructure or dedicated non-pipeline transport. Dedicated pipeline infrastructure may comprise either a direct supply between a single Biomethane Production Facility and the Hydrogen Production Facility, or a private biomethane network with multiple users including the Biomethane Production Facility and Hydrogen Production Facility.

- Biomethane which has been mixed with fossil natural gas at a point prior to consumption at the Hydrogen Production Facility (e.g., mixed within the UK Gas Network).

- Biomethane produced on-site within the Hydrogen Production Facility.

Biomethane Mass Balance

F. 3.   Biomethane shall only be claimed as an Input to a Hydrogen Production Facility where there is demonstrable, physical delivery via an interconnected supply route, whether by pipeline or alternative transport mode. The infrastructure associated with this interconnected supply route is defined as the Biomethane Mass Balance System.

F. 4.   Where biomethane is transported via shared pipeline infrastructure, e.g., the via the Gas Grid, we recognise that molecules of biomethane may not be physically delivered to the Hydrogen Production Facility. Biomethane can still be claimed as an Input where it can be demonstrated that there is an interconnected pipeline route from the point of injection to the point of withdrawal such that the supply of biomethane going into the pipeline infrastructure could have been in contact with the gas being extracted.

F. 5.   The Biomethane Mass Balance System may include multiple Biomethane Production Facilities supplying multiple end users, provided that traceability and reconciliation of energy content are maintained. Shared infrastructure such as Private Networks or pipelines is permitted, as long as physical delivery and ownership transfer are demonstrable.

F. 6.   Where evidence of physical biomethane supply is demonstrated between a Biomethane Production Facility and Hydrogen Production Facility through a Mass Balance System, as set out in Table 9, this shall be matched to quantities of biomethane claimed as an Input to the Hydrogen Production Facility within a defined Biomethane Mass Balance Period.

F. 7.   A Biomethane Mass Balance Period shall be agreed between the Hydrogen Production Facility and the Delivery Partner for all biomethane Inputs, regardless of delivery mode. Within the chosen Biomethane Mass Balance Period, the quantity of biomethane claimed as Input shall not exceed the quantity evidenced as supplied, adjusted for Supply Chain Losses. A maximum three-month Biomethane Mass Balance Period shall apply. Projects may adopt a shorter balancing window where operationally feasible.

F. 8.   Positive balances may be carried forward to the next Biomethane Mass Balance Period (where more biomethane is evidenced entering the Mass Balance System over the Biomethane Mass Balance Period than is claimed for use as an Input to the Hydrogen Production Facility, after accounting for any Supply Chain Losses), provided that sufficient evidence is provided to the Delivery Partner.

F. 9.   Negative balances are not permitted (where less biomethane is evidenced entering the Mass Balance System, including carry over, over the Biomethane Mass Balance Period than is claimed for use as an Input to the Hydrogen Production Facility after adjusting for Supply Chain Losses).

F. 10.   For the purposes of calculating emissions associated with negative biomethane balances, the quantity of biomethane claimed as an Input corresponding to the shortfall shall be treated as unabated wholly fossil natural gas supplied via the National Transmission Network, as per the GHG Emission Intensity specified in the Data Annex.

F. 11.   A negative balance may only be avoided where a positive balance from a previous Biomethane Mass Balance Period has been formally carried forward in accordance with Paragraph F. 8 and is sufficient to cover the shortfall, after accounting for any applicable Supply Chain Losses.

Evidence Requirements

F. 12.   The Hydrogen Production Facility shall ensure that all biomethane claimed under the Standard complies with the applicable evidence requirements set out in Table 9.

F. 13.   Where biomethane Inputs have differing Environmental Characteristics, including GHG Emission Intensities, separate hydrogen Consignments shall be generated in accordance with Paragraph 7.4 – 7.5 of the Standard.

F. 14.   If information provided by the Hydrogen Production Facility is deemed to be insufficient by the Delivery Partner to evidence the requirements within Table 9, the biomethane Input shall be treated as wholly fossil natural gas. The GHG Emission Intensity applied shall be the combined upstream and combustion values from the Fuel GHG Emission Intensity and Fuel combustion CO_2 Emission Intensity tables of the Data Annex.

F. 15.   Any biomethane used as an Input to a Hydrogen Production Facility shall meet the relevant criteria set out in Annex E. Failure to comply with these criteria, where applicable to biomethane Inputs, shall result in the consequences set out in Annex E.

Table 9: Evidence requirements for biomethane supply

Criteria	Evidence Required
Eligible Biomethane Purchase Agreement (BPA)	A contract entered into with the Hydrogen Production Facility for the supply, physical delivery and Transfer of Title of the biomethane to the Hydrogen Production Facility from a biomethane producer or supplier. This contract must be signed and in effect prior to end of the relevant Biomethane Mass Balance Period (as defined in F. 7). This contract shall either be with: • A biomethane producer. • A licensed gas shipper or biomethane supplier. Multi-party contractual arrangements are permitted under the Eligible BPA. The contract shall clearly identify all parties involved, maintain traceability of physical delivery and Transfer of Title, reconciliation, and ensure compliance with the Standard's mass balance and sustainability requirements. Where the identity of the biomethane producer cannot be disclosed due to confidentiality provisions, the Delivery Partner may request alternative evidence to verify origin and compliance. The Eligible BPA shall contain terms that: • Provide information on the Biomethane Production Facility, including name and location (including country) and production type (i.e. production method, digestate storage, and CO_2 capture choices) and Feedstock(s) used for biomethane production and their country of origin. • Provide for the physical supply of biomethane to the Hydrogen Production Facility. • Enable the Hydrogen Production Facility to evidence any losses incurred between the biomethane producer or supplier and the Facility, including losses from transport, storage, or grid injection. • Enable the Hydrogen Production Facility to evidence the required metered data, invoices or statements, the GHG Emission Intensity (in gCO_2e/MJ_{LHV}) of the biomethane volumes supplied and compliance with Biomass Requirements in Annex E, for the relevant biomethane volumes. • Enable the Hydrogen Production Facility to evidence the existence of the above terms in any associated arrangements with biomethane producers or gas shippers/suppliers. An Eligible BPA shall not be an Excluded BPA (see Chapter 2).

	The BPA shall contain provisions that require the Biomethane Producer or supplier to either: • Not claim Biomethane Guarantees of Origin Certificates. • Transfer the Biomethane Guarantees of Origin certificates to the Hydrogen Production Facility, who shall cancel or retire them upon point of use at the Hydrogen Production Facility.
Transfer of Title for biomethane	The Transfer of Title for biomethane shall be to the Hydrogen Production Facility, either directly from the biomethane producer or via a supplier, provided that: • All evidence requirements in this Annex and the Biomass Requirements in Annex E are satisfied. • Traceability and reconciliation across the Biomethane Mass Balance Period are maintained. • Transfer of Title is documented in an Eligible Biomethane Purchase Agreement (BPA) or equivalent contractual evidence.
Transaction evidence	The Hydrogen Production Facility shall provide biomethane supply and/or settlement invoices or statements broken down per Biomethane Mass Balance Period showing that the total biomethane supplied (adjusted for Biomethane Supply Chain Losses as per Annex F. 16 - F. 18) matches or exceeds the total biomethane claimed by the Hydrogen Production Facility over that same period, using the following Equation 64: **Equation 64** $$\sum_i \{Biomethane\ Supply\ Invoices_i\ [MWh]$$ $$\times \left(1 - \%Biomethane\ Supply\ Chain\ Losses_{tot,i}\right)\}$$ $$\geq Facility\ metered\ biomethane\ consumption\ [MWh]$$ Where: • *Biomethane Supply Invoices* are the invoices or statements evidencing supply from a specific production Facility, i, within the Biomethane Mass Balance Period. Biomethane supply invoices or statements may be provided by the contracted biomethane supplier or shipper, rather than directly from individual Biomethane Production Facilities, provided the documentation enables reconciliation of volumes over the Biomethane Mass Balance Period and includes sufficient evidence to demonstrate compliance with the Standard. Where possible, this should include the identity of the production facilities and confirmation of any Biomethane Guarantees of Origin Certificate cancellation. • *%Biomethane Supply Chain Losses$_{tot,i}$* are the total multiplicative losses from all supply chain steps between a specific Biomethane Production Facility, i, and the Hydrogen Production Facility. • *Facility metered biomethane consumption* refers to the quantity of biomethane claimed to be consumed by the Hydrogen Production Facility within the Biomethane Mass Balance Period. Calculated as total metered gas consumption multiplied by

	the declared biomethane share. This includes biomethane supplied in gaseous or liquefied form, provided it is metered and used in accordance with the Standard.
Evidence of continuous biomethane supply	The Hydrogen Production Facility shall provide details of all transport modes, temporary storage and any other intermediate steps for the supply of biomethane through a Mass Balance System. • To demonstrate supply of biomethane, evidence of the following shall be provided: • Biomethane Production Facility name and location (including country). • Biomethane purchase point (i.e. contractual point of Transfer of Title). • Biomethane injection and extraction points, and quantities (kWh_{HHV}), with metered data and dated. • Booked capacity and quantities shipped across each Cross-Border Interconnection Point (where relevant). Virtual Reverse Flow is permitted where recognised at Cross-Border Interconnection Points and supported by documentation. • Pipeline exit point and quantities extracted (with metered data). For biomethane moved by non-pipeline transport, including road tankers, tube trailers, trains and ships, mass balance evidence for all movements of biomethane throughout the supply chain shall be provided to the Delivery Partner. Relevant evidence will depend on the specific transport mode and will be agreed with the Delivery Partner, but acceptable forms of evidence may include: • Metered data. • Bills of lading. • Weighbridge or other quantity receipts. • Delivery notes. The evidence detailed above shall be used to demonstrate that the quantity of biomethane evidenced as supplied within the Mass Balance System is at least equal to the quantity of biomethane claimed as an Input to a Hydrogen Production Facility within the Biomethane Mass Balance Period, as set out in this Annex.
Proof of sustainability	Hydrogen Production Facilities shall provide evidence of compliance with the relevant Biomass Requirements set out in Annex E by using one (or more) existing voluntary schemes. Voluntary schemes that may be used to provide evidence of compliance with the Sustainability Criteria are listed in the Data Annex under Sustainability Criteria. Where certificates are used to demonstrate compliance with the Sustainability Criteria or other Biomass Requirements set out in Annex E, these certificates shall accompany the biomethane throughout the supply chain in accordance with the chain of custody rules of the relevant certification scheme. Where certification via a recognised voluntary scheme is not available, the Hydrogen Production Facility shall use an alternative option for demonstrating compliance with the Sustainability Criteria, as set out in Annex E. 51 - E. 52. The Hydrogen Production Facility shall provide evidence that the biogenic Feedstock(s) used to produce the biomethane also comply with Annex E requirements.

Cancellation of Biomethane Guarantees of Origin Certificates	Biomethane Guarantees of Origin Certificates are certificates which evidence the origin and low carbon attributes of biomethane. Where such certificates are produced, the Hydrogen Production Facility shall provide evidence of cancellation or retirement within the relevant Biomethane Mass Balance Period. In the case that certificates are generated, they shall accompany the biomethane through the supply chain.
	The Delivery Partner may request Certificate reference numbers and registry confirmations to verify that the low carbon attributes have not been claimed elsewhere or reused.
Exemption from Eligible BPA where Biomethane Production Facility and Hydrogen Production Facility are owned by the same legal entity	For a Biomethane Production Facility that is owned by the same legal entity as the owner of the Hydrogen Production Facility, (including, the case where the generation asset is located on-site), an Eligible BPA is not required, but equivalent evidence shall be provided.
	In this case, metering data shall be provided to prove physical delivery of biomethane from the Biomethane Production Facility (as per the requirements set out in Table 9), along with any internal transaction evidence such as invoices, statements, or internal transaction logs, as well as the GHG Emission Intensity of the biomethane supplied and evidence of compliance with the Biomass Requirements in Annex E.
	Whilst a contractual arrangement may be exempt from the Eligible BPA requirements, such arrangement shall still not comprise an Excluded BPA.

Biomethane Supply Chain Losses

F. 16.   The GHG Emission Intensity of biomethane delivered to the Hydrogen Production Facility shall include the emissions from processing, T&S of biomethane and shall account for any process efficiencies or losses in the supply chain.

F. 17.   Where losses lead to fugitive emissions of biomethane during the supply chain, these emissions shall also be accounted for by taking into account the relevant GWPs of any emissions.

F. 18.   Where possible, supply chain emissions for biomethane should be reported from Measured Data. Where Measured Data is not available, conservative default loss factors from the Data Annex may be applied.

Cancellation of Biomethane Guarantees of Origin Certificates

F. 19.   Biomethane Guarantees of Origin Certificates are certificates which evidence the origin and low carbon attributes of biomethane.

F. 20.   Where Biomethane Guarantees of Origin Certificates are generated by a biomethane producer, these shall remain associated with the biomethane being claimed throughout the supply chain and be cancelled by the Hydrogen Production Facility, at the point of use, to ensure there is no double counting of the low carbon attributes.

F. 21.   Biomethane Guarantees of Origin Certificates shall not be considered acceptable evidence of compliance with the Biomass Sustainability Requirements set out in Annex E. However, certificates may be used, where appropriate, to demonstrate compliance with the relevant evidence requirements for biomethane supply set out in Table 9.

F. 22.   The Biomethane Producer or Supplier shall provide a statement confirming whether the biomethane is covered by a Biomethane Guarantees of Origin Certificate, and if so, that it is only covered by one scheme. If not currently covered, the Producer or Supplier shall confirm that the biomethane will not be retrospectively covered by any scheme.

F. 23.   The Biomethane Purchase Agreement (BPA) shall include provisions for the cancellation of Biomethane Guarantees of Origin Certificates. Cancellation of these certificates shall be undertaken by the Hydrogen Production Facility. Cancellation of such certificates shall occur in line with the relevant Biomethane Mass Balance Period. This may be demonstrated through the provision of cancellation statements or another form of evidence deemed acceptable by the Delivery Partner. Once cancelled, certificates shall not be traded or used for any other purpose.

F. 24.   The Biomethane Producer or Supplier may also be required to provide a Director's Certificate confirming that Biomethane Guarantees of Origin Certificates have either not been claimed, have been cancelled, or have been transferred and subsequently cancelled by the Hydrogen Production Facility. Only certificates demonstrably linked to physical biomethane volumes tracked through the supply chain, under the Mass Balance Period, shall be considered valid. Certificates generated under a book & claim model shall not be accepted for compliance purposes under this Standard.

F. 25.   For Hydrogen Production Facilities using biomethane as a Feedstock that generates a Discrete Consignment, failure to provide evidence that Biomethane Guarantees of Origin Certificates have been cancelled, by the end of the agreed relevant Biomethane Mass Balance Period, shall result in the corresponding volumes of hydrogen Consignment being treated as non-compliant with the Standard.

F. 26.   For Hydrogen Production Facilities using biomethane as a Fuel or other Input that does not generate a Discrete Consignment, failure to provide evidence that the Biomethane Guarantees of Origin Certificates have been cancelled by the end of the agreed relevant Biomethane Mass Balance Period, shall result in the GHG Emission Intensity of the Hydrogen Product being recalculated using unabated wholly fossil natural gas instead of biomethane for those volumes where certificates have failed to be cancelled, applying the Emission Intensity values specified in the Data Annex.

For the purposes of this Annex, all references to Guarantees of Origin Certificate cancellations relate specifically to Biomethane Guarantees of Origin, not Renewable Energy Guarantees of Origin certificates.

Annex G: Non-Typical Data for Input Energy

Overview

G. 1.   This Annex is used for calculating the GHG Emission Intensity of Input electricity, heat and/or steam when Typical Data is not available (in the Electricity generation GHG Emission Intensities table of the Data Annex). This calculation first relies on assessing the GHG Emission Intensity of the generated energy, which is set out in the sections below.

G. 2.   Any losses between the point of energy generation and the point of use within the Hydrogen Production Facility shall be accounted for in the Energy Supply Emission Category in Chapter 5, by deriving a delivered energy GHG Emission Intensity using Equation 65.

Equation 65

$$EI_{delivered\ energy} = \frac{EI_{generated\ energy}}{(1 - \%\ losses)}$$

Where:

- $EI_{delivered\ energy}$ = The GHG Emission Intensity of the delivered energy, in gCO_2e/MJ delivered.

- $EI_{generated\ energy}$ = The GHG Emission Intensity of the generated energy, in gCO_2e/MJ generated.

- Losses = Electricity Transmission and Distribution Losses as covered in Annex B, or thermal losses during transport of any heat/steam estimated and evidenced by the Hydrogen Production Facility.

G. 3.   Energy generation assets should not assume a GHG Emission Intensity calculated for a different purpose or under a different UK policy can be used directly within the Standard, as the System Boundaries, GWPs or GHG emissions included may be different. The Standard does not include certain bonuses or credits used in other UK policies, such as emissions savings from soil carbon accumulation via improved agricultural management, degraded land bonuses, manure bonuses, CO_2 capture and replacement, or credits for excess electricity from co-generation.

System Boundary for energy generation

G. 4. When calculating the GHG Emission Intensity of Input electricity, heat and/or steam as set out in Paragraph 5.34, the System Boundary shall start at different places depending on the classification of the original material that generates the Input energy (see Chapter 2 and Paragraphs 5.10 - 5.11 for relevant definitions and the classification approach):

- **Waste or Residue materials** shall start the generated energy GHG Emission Intensity calculations at the point of collection of the Waste or Residue Feedstock, with nil GHG emissions associated with the Feedstock up to the point of collection. The calculations therefore include collection, any pre-processing, storage and transport, up to and including the relevant energy generation asset.

- **Biomass materials that are not Wastes/Residues** shall start the generated energy GHG Emission Intensity calculations from the point of cultivation of the biomass. The calculations therefore include land preparation (including any direct land-use change, but excluding indirect land-use change), sowing of seeds/planting, application of fertilisers, pesticides, harvesting, collection, any pre-processing, storage and transport, up to and including the relevant energy generation asset.

- **Fossil materials that are not Wastes/Residues** shall start the generated energy GHG Emission Intensity calculations at the point of exploration. The calculations therefore include drilling/mining, development, extraction/production including any venting and flaring, maintenance and workovers, any purification/pre-processing, including any compression, liquefaction, storage and transport, up to and including the relevant energy generation asset.

- **Nuclear Fuel** shall start the generated energy GHG Emission Intensity calculations at the point of exploration. The calculations therefore include uranium ore mining, uranium processing and enrichment, nuclear Fuel rod production, storage and transport, up to and including the relevant energy generation asset.

- **Renewable energy generation** plants that do not consume a material, for example wind and solar farms, shall start the generated energy GHG Emission Intensity calculations at the energy generation Facility. Geothermal plants shall account for any increase in GHG emissions if energy generation operations increase previously naturally occurring vented emissions.

- **Electricity Storage Systems** discharging electricity shall use the Stored Electricity GHG Emission Intensity from Annex C as the generated energy GHG Emission Intensity.

- **Hydrogen or hydrogen-derived Fuels** used to generate energy (as an Input to a Hydrogen Production Facility) shall start the generated energy GHG Emission

Intensity calculations at the same point as given within the Standard, i.e. based on the original Feedstock/energy Input used to generate the hydrogen. This GHG assessment shall also include any efficiency losses and emissions incurred during conversion to hydrogen-derived Fuels, transport (nationally or internationally) and storage, and any re-conversion back to hydrogen, up to and including the relevant energy generation asset.

G. 5. Where CO_2 is captured by one of the processes within the scope of the generated energy GHG Emission Intensity calculations, including if CO_2 is captured from the energy generation asset, the emissions associated with energy Input and fugitive emissions up to the CO_2 T&S Network Delivery Point shall be included – for example, purification, trucking, compression, leaks. Any emissions after the CO_2 T&S Network Delivery Point shall not be included.

Generated energy GHG Emission Intensity calculation methodology

G. 6. Hydrogen Production Facilities should use the Typical Data GHG Emission Intensities for any Inputs to the energy generation asset already given within the Data Annex (such as Fuels and materials in the Fuel GHG Emission Intensity and Input Materials GHG Emission Intensities tables of the Data Annex respectively). If the required values for Inputs to the energy generation asset are not provided in the Data Annex, the Facility shall reference alternative reputable sources with a justification for their applicability, such as UK government conversion factors or peer reviewed academic literature for these generation Inputs.

G. 7. The total GHG emissions ($e_{energy\ generation}$) arising from generation of electricity, heat and/or steam, given in gCO₂e, shall be calculated using Equation 66:

Equation 66

$$e_{energy\ generation} = e_{ec} + e_l + e_{td} + e_p - e_{ccs}$$

Where:

- e_{ec}: the total GHG emissions, given in gCO₂e, from extraction of raw materials for the generation Inputs. This term includes extraction or cultivation processes, collection of raw materials, Waste, leakages and fugitive emissions during extraction, cultivation or collection, and the production, supply and use of chemicals, materials or energy Inputs in extraction, cultivation and collection. This term excludes the capture of CO_2 in the production of raw materials, and certified reductions of GHG emissions from venting or flaring at oil production sites (anywhere in the world).

- e_l: the total Greenhouse Gas emissions, given in gCO2e, from carbon stock changes caused by direct land-use change relating to the production of the energy generation Inputs (refer to Annex E for full guidance and the required calculations). This parameter does not apply to Waste or Residue Feedstocks used in energy generation, as these supply chains only start at the point of Feedstock collection and is also unlikely to apply to most fossil Fuel or nuclear supply chains. Emissions arising from the construction of the energy generation asset itself are out of scope.

- e_{td}: the total Greenhouse Gas emissions, given in gCO2e, from transport and distribution of the generation Input or prior raw or intermediate materials. This includes T&S of raw and semi-finished materials (excluding extraction/collection emissions covered under e_{ec}), distribution and storage of finished Feedstocks. This term excludes transmission and distribution of the generated electricity/heat/steam.

- e_p: the total Greenhouse Gas emissions, given in gCO2e, from processing the energy generation Input into the energy vector of interest (electricity, heat and/or steam), including any intermediate pre-processing. This term includes emissions from the production and supply of chemicals, materials and any other energy Inputs used in energy generation (but not the main energy generation Input which is covered in e_{ec}, e_l, e_{td} above); processing the energy generation Input itself (e.g., fossil CO_2 released); any compression and transport of captured CO_2 prior to CO_2 T&S Network Delivery Point that is not already reflected in the energy generation efficiency; wastes, leakages and Fugitive non-CO_2 emissions.

- e_{ccs}: the CO_2 saving from CO_2 Capture and Sequestration (CCS), given in gCO2e. This credit shall be limited to the CO_2 emissions avoided through the capture and sequestration of emitted CO_2 directly related to those processes given in Paragraph G. 3 above. This parameter excludes any savings already included under e_p. The CO_2 credit shall be claimed if the conditions of Paragraph 5.50 - 5.54 are met, substituting the energy generation asset for the Hydrogen Production within Paragraph 5.53.

Example: For cultivated biomass, chipped then gasified before biomethane is fed to a steam boiler, the following Inputs might be considered:

e_{ec} Diesel, electricity, seeds, fertilisers, chemicals used in planting, cultivation, harvesting and collection of perennial energy crops.

e_l Direct land use change from perennial energy crops planted on arable farmland.

e_{td} Diesel and electricity used in T&S of stems, T&S of biomass chips.

e_p Water, flue gas scrubbing chemicals at the steam boiler, along with diesel used in biomass chipping, and start-up heating Fuels, electricity and chemicals used in biomass gasification to biomethane.

e_{ccs} CO_2 captured and sequestered from the biomass gasification to biomethane asset.

> **Example:** For uranium ore to nuclear Fuel rods to electricity generation, the following Inputs might be considered:
> e_{ec} Diesel and electricity used in the extraction of uranium ore.
> e_{td} Diesel and electricity used in T&S of uranium ore, T&S of enriched uranium, and T&S of uranium Fuel rods.
> e_p Water, chemicals in power generation, along with electricity, water and chemicals used in uranium enrichment and nuclear Fuel rod production.
>
> **Example:** For fossil natural gas to combined heat and electricity generation, the following Inputs might be considered:
> e_{ec} Natural gas, electricity and diesel used in exploration, drilling and extraction.
> e_{td} Electricity and natural gas used in T&S of raw natural gas, and T&S of processed natural gas.
> e_p Water, flue gas scrubbing and CO_2 capture chemicals in power generation, along with electricity, water and chemicals used in natural gas processing.
> e_{ccs} CO_2 captured and sequestered from the combined heat & electricity generation asset – noting that this credit would be excluded if part of a Private Network.

G. 8.   If Co-Products are generated at the same time as the main intermediate products of interest from upstream pre-processing (for example, exported electricity is a Co-Product from a biomass pellet plant, or natural gas liquids are a Co-Product from natural gas processing), then the LHV Energy Allocation Method shall be used to apportion GHG emissions up to that point in the supply chain between the Products and Co-Products from the pre-processing, based on their LHV energy contents. These allocation rules and the derivation of Allocation Factors are detailed in Paragraphs 5.12 - 5.20.

GHG Emission Intensity for energy generation

G. 9.   Once the total GHG emissions have been determined for the generated energy ($e_{energy\ generation}$), the GHG Emission Intensity of the generated electricity/heat/steam shall be calculated using Equation 67, Equation 68, Equation 69 and Equation 70 as appropriate.

G. 10.   For electricity generation only:

Equation 67

$$EI_{elec\ generation} = \frac{e_{energy\ generation}}{P_{el}}$$

Where:

- $EI_{elec\ generation}$ = The GHG Emission Intensity of the generated electricity, in gCO_2e/MJ_e generated.

- $e_{energy\ generation}$ = The GHG emissions arising from the generation of electricity within the calendar month, in gCO_2e (using Equation 66).

- P_{el} = The (net) electrical Output, defined as the electricity exported from the electricity generation asset in MJ_e within the calendar month.

G. 11.   For heat or steam generation only:

Equation 68

$$EI_{heat\ generation} = \frac{e_{energy\ generation}}{P_h}$$

Where:

- $EI_{heat\ generation}$ = The GHG Emission Intensity of the generated heat or steam, in gCO_2e/MJ_{th} of Useful Heat generated.

- $e_{energy\ generation}$ = The GHG emissions arising from the generation of heat or steam within the calendar month, in gCO_2e (using Equation 66).

- P_h = The Useful Heat contained within the heat or steam export from the energy generation asset in MJ_{th} within the calendar month.

G. 12.   For combined electricity, heat and/or steam generation:

Equation 69

$$EI_{elec\ generation} = \frac{e_{energy\ generation}}{P_{el} + C_h \times P_h}$$

Equation 70

$$EI_{heat\ generation} = \frac{e_{energy\ generation} \times C_h}{P_{el} + C_h \times P_h}$$

Where:

- $e_{energy\ generation}$ = The GHG emissions arising from the generation of electricity, heat and/or steam within the month, in gCO_2e (using Equation 66).

- C_h = The Carnot Efficiency, that is, the fraction of useful energy in the Heat or Steam Product or Co-Product, as defined in Equation 8.

Annex H: Measured and Estimated Data

Overview

H. 1.   This Annex sets out the requirements for taking measurements of or estimating Activity Flow Data used to calculate GHG Emission Intensities (for Hydrogen Product and determining any Non-Typical Data), and to determine Standard Compliance during Hydrogen Production Facility operation. This Annex also covers the derivation of Lower Heating Values (LHVs), the location and specification of metering points, and the approach to allocating biogenic and fossil fractions within mixed Feedstocks. Schemes applying the Standard may have additional measurement and/or data requirements which apply to a Hydrogen Production Facility in their relevant contractual arrangements.

H. 2.   For all Hydrogen Production Facilities, the following requirements shall be met:

- Unless otherwise stated, Measured Data and Estimated Data shall be recorded per Reporting Unit, to calculate the GHG Emission Intensity for each Discrete Consignment.

- The Hydrogen Production Facility shall carry out a measurement uncertainty assessment of the relevant meters (see Table 11). The Facility shall undertake this once per year as a minimum and following any change in measurement equipment, including meter types.

Data Collection and Monitoring Procedure (DCMP) for all Pathways

H. 3.   A Hydrogen Production Facility shall have a DCMP in place and agreed with the Delivery Partner as part of the Monitoring, Reporting and Verification (MRV) Framework (as per Chapter 8). The DCMP may be updated from time to time by agreement between the Hydrogen Production Facility and the Delivery Partner. The DCMP shall as a minimum include suitable procedures for the following:

- Measuring or otherwise estimating the quantity of Inputs and Outputs in each Reporting Unit.

- Classifying Inputs and Outputs and reviewing each classification, covering the frequency of review.

- Determining the composition of any Inputs and Outputs, covering the frequency, sampling techniques and methodologies used.

- Calculating the LHV energy content of any Inputs and Outputs, covering the frequency, sampling techniques and methodologies used.

- Generating multiple Discrete Consignments from mixed Inputs, including any biogenic and fossil components, covering the frequency, sampling techniques and methodologies used.

- For Solid Carbon Output, determining the Solid Carbon End User Point, agreed time periods for Solid Carbon storage and the allocation method for Solid Carbon used in a Solid Carbon Permissible End Use.

Background methodologies

Method to calculate mass flow

H. 4.   The mass flow of an Input and Output material (including metered Feedstock Gas, hydrogen, CO_2, Fuel Supply via permanent connection, steam, water and oxygen) shall be calculated using Equation 71:

Equation 71

$$Mass\ flow\ (kg) = Mean\ mass\ flowrate\ \left(\frac{kg}{s}\right) \times Time\ period\ (s)$$

H. 5.   If a volumetric flowrate meter is used, the conversion of volumetric flowrate to mass flow shall be calculated using Equation 72:

Equation 72

$$Mass\ flow\ (kg) = Mean\ volumetric\ flowrate\ \left(\frac{m^3}{s}\right) \times Density\ \left(\frac{kg}{m^3}\right) \times Time\ period\ (s)$$

H. 6.   If a volumetric flowrate meter is used for a gas phase Input or Output, the Hydrogen Production Facility shall determine the gas density in units of kg/m^3, which depends on the gas temperature and pressure. To determine gas density, the Hydrogen Production Facility shall either use a densitometer or shall use an appropriate equation of state, for example, Peng Robinson or Soave-Redlich-Kwong (SRK). The Hydrogen Production Facility shall provide evidence to the Delivery Partner as to which equation of state is used, and why this is appropriate, which depends on the nature of the gas species.

H. 7.   Compositional analysis shall be used with metered flowrates using Equation 73 to calculate the quantity of pure CO2 injected into the CO2 T&S Network using the mass fraction of CO2 (refer to Paragraph H.9) within the CO2-rich Output material stream.

Equation 73

$$Pure\ CO_2\ flow\ (kg) =$$

$$CO_2\text{-}rich\ stream\ mass\ flowrate\ \left(\frac{kg}{s}\right) \times Mass\ fraction\ of\ CO_2 \left(\frac{kg_{CO2}}{kg}\right) \times Time\ period\ (s)$$

H. 8. Compositional analysis shall also be used for Solid Carbon Output: with weighed flow rates to calculate the quantity of pure Solid Carbon produced sequestered and un-sequestered using the mass fraction of Solid Carbon (refer to Paragraph H. 13) in the Solid Carbon Output using Equation 74 and Equation 75:

Equation 74

$$Pure\ solid\ carbon\ sequestered\ (kg) =$$

$$Impure\ solid\ carbon\ mass\ recieved\ at\ End\ User's\ site\ (kg)$$
$$\times\ carbon\ purity\ at\ Producer's\ site\ before\ transfer$$

$$Pure\ solid\ carbon\ unsequestered\ (kg) =$$

$$Pure\ solid\ carbon\ produced\ -\ pure\ solid\ carbon\ sequestered$$

Equation 75

$$Pure\ solid\ carbon\ produced$$
$$=\ Impure\ solid\ carbon\ mass\ after\ production\ (kg)$$
$$\times\ carbon\ purity\ after\ production$$

Method to calculate LHV of material streams

H. 9. Compositional analysis equipment, such as gas chromatography, samplers and online sensors, shall measure the composition of different species in Feedstocks, Input Fuels via a permanent connection, captured CO_2, Co-Products and Hydrogen Product streams, by mass fraction (kg/kg) or mole fraction (mol/mol). This only applies to continuous streams, rather than batched/intermittent streams. The frequency of this composition analysis shall be agreed with the Delivery Partner, depending on the variability of the stream measured. Mass fraction results shall be provided for every

species present. If composition values are measured in terms of mole fraction (mol/mol), these values shall first be converted to mass fractions using Equation 76.

Equation 76

$$Mass\ fraction\ of\ a\ species\ \left(\frac{kg}{kg}\right) =$$

$$\frac{Mole\ fraction\ of\ a\ species\ \left(\frac{mol}{mol}\right) \times Species\ molar\ mass\ \left(\frac{g}{mol}\right)}{\sum_i \left(Mole\ fraction\ of\ species_i\ \left(\frac{mol}{mol}\right) \times Species\ molar\ mass_i\ \left(\frac{g}{mol}\right) \right)}$$

H. 10.   Hydrogen Production Facilities that measure the composition data of an Input or Output (as per Table 10) shall derive the LHV of the material using Equation 77.

Equation 77

$$LHV\ of\ material\ stream\ \left(\frac{MJ}{kg}\right) =$$

$$\sum \left(Mass\ fraction\ of\ species\ \left(\frac{kg}{kg}\right) \times LHV\ of\ pure\ species\ \left(\frac{MJ}{kg}\right) \right)$$

- For any Inputs or Outputs where composition data is not measured, Hydrogen Production Facilities shall refer to the section on Sources of Data for Lower Heating Values in the Data Annex.

Method to calculate Process CO_2 emissions

H. 11.   Process CO_2 emissions ($E_{Process\ CO_2}$) shall be calculated using a mass balance approach for the Inputs and Outputs to the Hydrogen Production Facility, following Equation 78. This sums the carbon contents of all the fossil Inputs, then subtracts the total carbon content of all the fossil Outputs that are not CO_2 (e.g., fossil Solid Carbon, fossil Co-Products, Fugitive non-CO_2 emissions, other liquid or solid fossil Wastes/Residues). The net amount of fossil carbon is assumed to be generated as fossil CO_2, prior to any CO_2 capture.

H. 12.   If there are both biogenic and fossil Inputs to the Hydrogen Production Facility, it is assumed that the proportion of Input carbon atoms from fossil Inputs compared to the total Input carbon atoms also applies to all Outputs from the Hydrogen Production Facility, in which case, Equation 78 only includes the fossil proportion of the Outputs. Similarly, if there is an Input that is a mix of biogenic and fossil components, Equation 78 only includes the fossil share of the Input.

Equation 78

$$E_{Process\ CO2}(g_{CO2}) =$$

$$3664\left(\frac{g_{CO2}}{kg_C}\right) \times \left\{ \sum_{Fossil\ Inputs}\left(Carbon\ content\ of\ Input\left(\frac{kg_C}{kg}\right) \times Mass\ flow\ of\ Input\ (kg)\right) \right.$$

$$- \sum_{\substack{Fossil\ Outputs,\\ excluding\ CO2}}\left(Carbon\ content\ of\ Output\left(\frac{kg_C}{kg}\right)\right.$$

$$\left.\left. \times Mass\ flow\ of\ Output\ (kg)\right)\right\}$$

H. 13. The carbon content (kg_C/kg) of an Input or Output is the fractional mass of all carbon atoms in the Input or Output divided by the mass of the Input or Output, as given in Equation 79:

Equation 79

$$Carbon\ content\left(\frac{kg_C}{kg}\right) =$$

$$\sum_{all\ species}\left(\frac{Mass\ Fraction\ of\ each\ species\ \times 12.011\left(\frac{kg_C}{kmol}\right) \times Carbon\ atoms\ per\ species)}{Molecular\ mass\ of\ each\ species\left(\frac{g}{mol}\right)}\right)$$

Data type requirements

H. 14. Table 10 provides a breakdown by data types that Hydrogen Production Facilities shall use as a minimum for each Input and Output material. A Hydrogen Production Facility may provide Measured Data instead of Estimated Data or calculate the GHG Emission Intensity of an Input material using methodologies in the Standard instead of literature data or may provide compositional analysis data instead of literature data. Table 10 matches the list of Inputs and Outputs from Paragraph H. 9 that require compositional analysis.

Table 10: Minimum data type requirements for each Input and Output material

Input and Output Type	Activity Flow Data: Mass Flow	GHG Emission Intensity	Activity Flow Data: Composition
Feedstock	Measured Data (metered or weighed)	Typical Data or if unavailable, Non-Typical Data (literature)	Measured Data (compositional analysis of flow)
Fuels via a permanent connection	Measured Data (metered or weighed)	Typical Data or if unavailable, Non-Typical Data (literature)	Typical Data or if unavailable, Non-Typical Data (literature)
Fuels without a permanent connection	Estimated Data (invoices and mass balance)	Typical Data or if unavailable, Non-Typical Data (literature)	Typical Data or if unavailable, Non-Typical Data (literature)
Input Materials used continuously	Measured Data (metered) for water and oxygen. Otherwise, Estimated Data (invoices and mass balance)	Typical Data or if unavailable, Non-Typical Data (literature)	Estimated Data (literature)
Input Materials not used continuously	Estimated Data (invoices)	Typical Data or if unavailable, Non-Typical Data (literature)	Estimated Data (literature)
Co-Product gas with a permanent connection	Measured Data (metered)	N/A	Measured Data (compositional analysis of flow)
Co-Product gas without a permanent connection	Estimated Data (mass balance)	N/A	Measured Data (compositional analysis of samples)
Co-Product liquid with a permanent connection	Measured Data (metered or weighed)	N/A	Measured Data (compositional analysis of flow)
Co-Product liquid without a permanent connection	Estimated Data (mass balance)	N/A	Measured Data (compositional analysis of samples)
Co-Product solid	Measured Data (weighed)	N/A	Measured Data (compositional analysis of samples)
Wastes and Residues	Estimated Data (mass balance)	N/A	Estimated Data (literature)

Metering requirements

Meter locations for each Eligible Hydrogen Production Pathway

H. 15.   Hydrogen Production Facilities shall meter each connection of Inputs and Outputs indicated with a tick (✔) in Table 11 for the relevant Pathway (or shall source equivalent metering data for any Electricity Storage System not at the Hydrogen Production Facility). Failure to install a meter for these Inputs and Outputs shall result in non-compliance with the Standard, due to insufficient quality of evidence. If a given Input or Output is never used or produced by a Hydrogen Production Facility, a meter is not required to be installed. Further details regarding these meters are given in the sections below.

Table 11: Required meters for each Pathway

Meter	Electrolysis	Fossil / biogenic gas reforming (with CCS)	Gas splitting producing Solid Carbon	Biomass / Waste gasification
Hydrogen	✔	✔	✔	✔
Electricity	✔	✔	✔	✔
Electricity Storage System – import & export	✔	✔	✔	✔
Water	✔ if imported	✔ if imported	✔ if imported	✔ if imported
Feedstock Gas		✔	✔	✔ if gaseous Feedstock
CO_2 T&S Network Delivery Point		✔		✔
Oxygen		✔ if imported		✔ if imported
Heat and steam	✔ if imported or exported	✔ if imported or exported	✔ if imported or exported	✔ if imported or exported
Fuel	✔ if permanent connection	✔ if permanent connection	✔ if permanent connection	✔ if permanent connection
Co-Product		✔ if permanent connection	✔ if permanent connection	✔ if permanent connection

H. 16.   For reference, Table 12 shows how the meters referenced for each Pathway align within the Emission Categories within the Standard's GHG Emission Intensity Calculation Methodology, and the appropriate references within the Standard Document. Note Table 12 only lists meters and does not consider other measurement

approaches (such as Estimated Data) for other Inputs and Outputs contributing to these Emissions Categories.

Table 12: Meter identification for Emission Categories

Emission Category	Meter type	Reference
$E_{\text{Feedstock Supply}}$	Feedstock Gas meter	Paragraphs 5.21-5.25
$E_{\text{Energy Supply}}$	Electricity meter, Electricity Storage System meters, heat meter, steam meter, Fuel meter (for supply via permanent connection)	Paragraphs 5.26-5.34
$E_{\text{Input Materials}}$	Water meter, oxygen meter	Paragraphs 5.35-5.37
$E_{\text{Process } CO_2}$	Feedstock Gas meter, Fuel meter (for supply via permanent connection)	Paragraphs 5.38-5.39
$E_{\text{Fugitive non-}CO_2}$	No meter	Paragraphs 5.40-5.45
$E_{CO_2 \text{ Capture and Network Entry}}$	Electricity meter, Electricity Storage System meters, heat meter, steam meter, Fuel meter (for supply via permanent connection)	Paragraphs 5.46-5.49
$E_{CO_2 \text{ Sequestration}}$	CO_2 T&S Network Delivery Point meter	Paragraphs 5.50-5.54
$E_{\text{Solid C Distribution}}$	No meter	Paragraphs 5.55-5.62
$E_{\text{Solid C Sequestration}}$	No meter	Paragraphs 5.63-5.70
$E_{\text{Compression and Purification}}$	Electricity meters, heat meter, steam meter, Fuel meter (for supply via permanent connection)	Paragraphs 5.71-5.75
$E_{\text{Fossil Waste/Residue Counterfactual}}$	Feedstock Gas meter	Paragraphs 5.76-5.81
All Emission Categories, due to LHV Energy Allocation	Co-Product meter	Paragraphs 5.12- 5.20

Hydrogen meters

H. 17. A hydrogen meter shall be used immediately after onsite hydrogen Compression and Purification but before any onsite Hydrogen Storage, to account for the quantity of Hydrogen Product generated. If the hydrogen meter measures volumetric flows of Hydrogen Product, it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow and LHV of Hydrogen Product is explained in Paragraphs H. 4 - H. 8.

Electricity meters

H. 18.   All Hydrogen Production Facilities shall install electricity meters on each electricity import connection, each electricity export connection, as well as the electricity charge and discharge connection from any onsite Electricity Storage System. These electricity meters shall account for all electricity flow.

H. 19.   The electricity meters shall account for the gross number of kilowatt hours per Reporting Unit that are consumed by the Hydrogen Production Facility or exported by the Hydrogen Production Facility.

H. 20.   Hydrogen Production Facilities shall use only Gross Meters. Net Meters shall not be used.

Electricity Storage System meters

H. 21.   Electricity Storage Systems shall follow the requirements for electricity meters given in Paragraphs H. 18 - H. 20.

H. 22.   Figure 15 shows the location of meters required for all Hydrogen Production Facilities producing hydrogen using electricity from an Electricity Storage System. Meters 1 & 2 could be the same electricity meter depending on the locations of the generation asset and Electricity Storage System, and sources of electricity used to charge the Electricity Storage System. Meters 3 & 4 could be the same electricity meter depending on the locations of the Electricity Storage System and Hydrogen Production Facility, and Input sources of electricity used in Hydrogen Production Facility.

Figure 15: Schematic of the location of electricity meters for a Pathway using an Electricity Storage System.

- Meter (1) is the generation asset export electricity meter.

- Meter (2) is the Electricity Storage System import electricity meter.

- Meter (3) is the Electricity Storage System export electricity meter.

- Meter (4) is the Hydrogen Production Facility import electricity meter.

Water meter

H. 23.   A water meter shall be used if water is sourced from outside the site boundary for use by the Hydrogen Production Facility. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8.

H. 24.   The meter measuring water flow shall measure the mass or volumetric flowrate of imported water. Note that if a volumetric flowrate meter is used, the density of water can be assumed to remain a constant 997 kg/m^3 irrespective of water temperature or pressure.

Feedstock Gas meter

H. 25.   A meter shall be installed on all connections that import Feedstock Gas to the Hydrogen Production Facility.

H. 26.   Feedstock Gas meters shall measure the mass or volumetric flowrate of the Feedstock. If the Feedstock Gas meter measures volumetric flows of Feedstock Gas, it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8.

H. 27.   The Feedstock Gas composition shall be analysed at a frequency set out in the DCMP to determine carbon content using the methodology set out in Paragraph H. 13 and shall be used to calculate the LHV energy flow of Feedstock Gas as set out in Paragraph H. 9 - H. 10.

CO$_2$ T&S Network Delivery Point meter

H. 28.   A CO$_2$ meter is required for Pathways in which CO$_2$ is captured by the Hydrogen Production Facility and sent for geological sequestration. This meter is to be located at the point of entry into a CO$_2$ T&S Network, where the liability for the CO$_2$ is transferred. The method to calculate mass flow is explained in Paragraphs H. 4 -H. 8

H. 29.   The CO$_2$ T&S Network Delivery Point meter shall measure the mass or volumetric flowrate of CO$_2$-rich gas. If the CO$_2$ meter measures volumetric flows of CO$_2$, it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8.

H. 30.   Compositional analysis equipment shall measure the composition of different species within the CO$_2$-rich stream, including impurities, by mass fraction (kg/kg) at the CO$_2$ T&S Network Delivery Point. The mass fraction of CO$_2$ and the CO$_2$ T&S Network Delivery Point flowrate meter shall be used to calculate the quantity of pure CO$_2$ sent for sequestration as per Equation 73

H. 31.   The methodology to calculate the mass fractions of the CO$_2$-rich stream is provided in Paragraphs H. 4 - H. 8.

Oxygen meter

H. 32.   An oxygen meter is only required if oxygen is sourced from outside the Hydrogen Production Facility and transported onsite. This includes where the oxygen production occurs in an adjacent Facility that does not form part of the Hydrogen Production Facility. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8 and relevant GHG Emission Intensities are found in the Input Materials GHG Emission Intensities table of the Data Annex.

H. 33.   The oxygen meter shall measure the mass or volumetric flowrate of oxygen gas. If the oxygen meter measures volumetric flows of oxygen, it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8.

Heat and steam meter

H. 34.   The heat and steam meters shall account for heat and steam imported or exported by the Hydrogen Production Facility. If heat is transferred using steam, any heat and steam may be accounted using the same steam meter. If heat is transferred using a different heat transfer medium than steam, the flowrate of the heat transfer medium shall be metered separately to the steam meter. GHG Emission Intensities for imported steam and heat are to be calculated in line with Paragraphs 5.31 - 5.32.

H. 35.   The heat and steam meters shall measure the mass or volumetric flowrate of steam (or other heat transfer medium). If the steam meter measures volumetric flows of steam (or other heat transfer medium), it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8. The mass flowrate of steam or heat transfer medium shall be converted to an equivalent energy flow using a specific enthalpy of steam at the metered temperature and pressure.

Fuel meter (via permanent connection)

H. 36.   If a non-Feedstock Fuel is imported onsite using a permanent pipeline connection, a Fuel meter is required for each type of Fuel. Relevant GHG Emission Intensities for imported Fuel Supply are found in the Fuel GHG Emission Intensity table of the Data Annex.

H. 37.   The Fuel meter shall measure the mass or volumetric flowrate of Fuel. If the Fuel meter measures volumetric flows of Fuel, it shall also measure the temperature (°C) and pressure (kPa) of the material stream. The method to calculate mass flow is explained in Paragraphs H. 4 - H. 8.The mass flowrate of Fuel shall be converted to an LHV energy flow using the methodology in Paragraphs H. 9 - H. 10.

Other Co-Product meter

H. 38.　For any Co-Product exported via a permanent connection from the Hydrogen Production Facility, that has a non-zero LHV energy content and which is not covered by meters considered in the Paragraphs H. 15 - H. 37, a meter shall be installed at the point of export from the Hydrogen Production Facility. A meter is not required for Wastes or Residues.

H. 39.　The meter shall measure the mass or volumetric flowrate of the Co-Product. The method to calculate the LHV energy content of the Co-Product is explained in Paragraphs H. 9 - H. 10.

Measurement and Meter Failure

H. 40.　In the case of Measurement and Meter Failure for an Input or Output listed in Table 12 for the Pathway, the Hydrogen Production Facility shall record the time of failure. The affected Discrete Consignments shall be deemed non-compliant with the Standard, unless the Delivery Partner determines in its discretion that such Discrete Consignments can be treated as valid and agrees an alternative approach to determine the Discrete Consignment GHG Emissions Intensity. This may take into account the Materiality of the Input or Output for which there has been a Measurement and Meter Failure, including if the monthly Materiality assessment is typically based on the metered data.

Meter Failure of Electricity Storage System import electricity meter

H. 41.　If the Electricity Storage System import electricity meter fails, estimated data may be used to update the Stored Electricity GHG Emission Intensity Tracker of the Electricity Storage System. In this case, Hydrogen Production Facilities may use the Electricity Storage System export electricity meter, a known RTE, change in 30-minute SoC, SoH, Design Capacity supported by performance guarantees to estimate the Activity Flow Data (volume of electricity) into the Electricity Storage System using Equation 80.

Equation 80

$$Gross\ Import = \frac{Gross\ Export - \left(Ideal\ Capacity \times SoH \times \left(SoC_{final} - SoC_{initial}\right)\right)}{RTE}$$

H. 42.　Where there is missing data for two or more variables including Electricity Storage System import electricity meter, Electricity Storage System export electricity meter, RTE, change in 30-minute SoC, SoH or Design Capacity, it is not possible to estimate the Activity Flow Data (volume of electricity) into the Electricity Storage System. In this case, Hydrogen Production Facilities shall resort to the guidance for Measurement and Meter Failure in H. 40.

H. 43.   In the case of failure of the Electricity Storage System import electricity meter, the highest value between the GHG Emission Intensities among relevant specific generators used for charging and the 30-minute relevant grid average GHG Emission Intensity (GB or NI, depending on the Hydrogen Production Facility location) shall be used for Import EI (Annex C. 10).

Other Measurement Requirements

Calculating the biogenic and fossil components of mixed Feedstocks

H. 44.   Hydrogen Production Facilities shall determine the number of Discrete Consignments within each Reporting Unit and determine if there is any mixing of Inputs at the Facility or in the supply chain, including use of mixed biogenic and fossil Inputs. Hydrogen Production Facilities shall implement a system to track the individual biogenic and fossil Discrete Consignments and the associated sustainability information.

H. 45.   Samples taken shall be in sufficient quantities for analysis and be representative of the Feedstocks used. Standards are available which outline recognised good practice for extracting samples and forming composites for biomass and Waste Feedstocks. A sample of these standards can be found in Appendix 12 of the Renewables Obligation: Fuel Measurement and Sampling Guidance[30]. The frequency of sampling is to be agreed with the Delivery Partner on a case-by-case basis depending on the variability of the Inputs.

H. 46.   Hydrogen Production Facilities using biomass Feedstocks or Inputs shall evidence the mass and Lower Heating Value (LHV) energy content of each Feedstock entering the plant over the month. If a Feedstock is a mix of fossil and biogenic components, Hydrogen Production Facilities shall evidence the mass and LHV energy contents of the fossil and biogenic components, as these will be considered as two separate Feedstocks, each generating a Discrete Consignment.

H. 47.   The biogenic proportion of a mixed Feedstock can be calculated using Equation 81 and Equation 82:

Equation 81

$$Biogenic\ proportion = \frac{MJ_{LHV}\ of\ biogenic\ component}{MJ_{LHV}\ of\ total\ feedstock}$$

Equation 82

$$MJ_{LHV}\ of\ component =$$

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[30] https://www.ofgem.gov.uk/publications/renewables-obligation-fuel-measurement-and-sampling-guidance

$$kg \ of \ component \ as \ received \ \times LHV_{dry} \times (1 - \% \ moisture \ content \ of \ component)$$

H. 48.   Hydrogen Production Facilities shall measure the dry LHV of the components with reference to Paragraphs H. 9 - H. 10. The frequency of this Feedstock sampling and verified testing will have to be agreed with the Delivery Partner on a case-by-case basis, depending on the variability of the Feedstock.

Measuring solid Inputs and Outputs

H. 49.   Where a solid Input is a Feedstock, or a solid Output is Solid Carbon or is a Co-Product of the Hydrogen Production Facility, Hydrogen Production Facilities shall record the Activity Flow Data for the amount of solid Input and Output using weighing equipment. The frequency of measuring and reporting weights shall be agreed with the Delivery Partner as part of the DCMP. Similarly, analysis equipment, such as sampling or sensors shall measure the composition of different species within these solid Inputs and Outputs, including impurities, by mass fraction (kg/kg). The methodology to calculate mass fractions within a solid is provided in Paragraph H. 4 - H. 10 with specific guidance for Solid Carbon given in Paragraph H. 8.

Estimated Data requirements

H. 50.   For a Hydrogen Production Facility, the Activity Flow Data for Emission Sources that are neither metered nor sampled, shall be estimated through invoiced or contractual data from the relevant supplier or using a mass balance approach. Where relevant, equipment manufacturer performance guarantees or third party verified testing may also be used as Estimated Data. These Emission Sources may include:

- Chemicals and materials: Invoices shall be submitted to record the mass flow of chemicals (such as salts, solvents, acids) and a mass balance for any continuous use.

- Fuels without a permanent connection: Hydrogen Production Facilities shall provide Estimated Data for the amount of Fuels used, supported with invoices and mass balance for any continuous use.

- Catalyst: Invoices shall be provided to report the mass of each purchased catalyst.

- Leakage losses including venting of non-CO_2 GHG species (Paragraph 10.13) shall be estimated using a mass balance and mass composition to determine the flowrate of each Input and Output stream (such as changes in stock levels). The difference between the mass of each non-CO_2 GHG species in the Input and Output material streams are Fugitive non-CO_2 emissions that shall be converted to gCO_2e by multiplying with relevant GWPs (the GWP of GHGs table of the Data Annex).

- Using a mass balance and assuming complete combustion of flare material Input, the mass of N_2O and any other non-CO_2 GHG species produced shall be calculated and convert to gCO_2e by multiplying with relevant GWPs (the GWP of GHGs table of the Data Annex).

H. 51.   For Input Materials that are used continuously within the process but do not arrive via a permanent connection, invoices and Measured Data or Estimated Data (in this case, mass balanced) shall be submitted. For Input Materials that are not used continuously within the process and arrives in batches, invoices shall be used to estimate GHG emissions. An appropriate emissions allocation method shall be agreed with the Delivery Partner through the Data Collection and Monitoring Procedure, depending on how the Input is expected to be consumed, for example:

- Where the Input is consumed in proportion to hydrogen Output, the GHG Emissions resulting from the use of these Input Materials may be accounted per unit of Hydrogen Product based on the estimated or measured Activity Flow Data.

- Where the Input consumption is not directly linked to hydrogen Output, the GHG Emissions resulting from the use of these Input Materials may be allocated on a time basis, where emissions are distributed evenly across Reporting Units over a relevant period of consumption, based on the estimated or measured Activity Flow Data.

H. 52.   The method of measurement or estimation, including any supporting calculations, shall be recorded and justified for every Discrete Consignment and shall be checked against the available evidence (for example, invoices, contracts), as discussed in Chapter 8.

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