Department for
Business, Energy
& Industrial Strategy

UK Low Carbon Hydrogen Standard

Guidance on the greenhouse gas emissions and sustainability criteria

2022

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Executive Summary

To support the implementation of the UK Hydrogen Strategy and Energy Security Strategy, the UK Low Carbon Hydrogen Standard ('the standard') defines what constitutes 'low carbon hydrogen' at the point of production. The standard sets out in detail the methodology for calculating the emissions associated with hydrogen production and the steps producers are expected to take to prove that the hydrogen they produce is compliant. The intent of the standard is to ensure new low carbon hydrogen production supported by government makes a direct contribution to GHG emission reduction targets under the Climate Change Act.

Hydrogen producers proving compliance with the standard are required to:

- meet a GHG emissions intensity of $20gCO_2e/MJ_{LHV}$ of produced hydrogen or less for the hydrogen to be considered low carbon.

- calculate their greenhouse gas (GHG) emissions up to the 'point of production', accounting for the following emissions components:

$$E_T = E_{feedstock\ supply} + E_{energy\ supply} + E_{input\ materials} + E_{process} + E_{fugitive\ non\text{-}CO2} + E_{CCS\ process\ and\ infrastructure} - E_{CO2\ sequestration} + E_{compression\ and\ purification}$$

- account for the emissions associated with meeting a theoretical minimum pressure level of 3MPa and a theoretical minimum purity of 99.9% by volume at the production plant gate, in the emissions calculations.

- include emissions associated with capture, compression, transport, and storage of CO_2 in the emissions calculation: while some of the associated infrastructure may be located outside the point of production, the related emissions were generated through the hydrogen production and are considered within the scope of the standard.

- account for the use of electricity:

    - Using actual data to demonstrate that the electrolyser is operating at the same time as the electricity input source.

    - Evidencing hydrogen producers have exclusive ownership of the electricity used to cover the amount of electrolytic hydrogen produced.

- set out a risk mitigation plan for fugitive hydrogen emissions including:

    - Risk Reduction Plan: Produce a plan demonstrating how fugitive hydrogen emissions at the production plant shall be minimised.

    - Risk Plan: Provide estimates of expected rates of remaining fugitive hydrogen emissions by the plant. (Noting that these are not accounted for in the GHG emissions calculation above).

    - Risk Monitoring: Prepare a monitoring methodology for fugitive hydrogen.

- and meet additional requirements for the use of biogenic inputs, where relevant and as appropriate for the feedstock source and classification:

    - demonstrate compliance with the land, soil carbon and forest criteria.

    - satisfy the minimum waste and residue requirement.

    - report on estimated indirect land-use change (ILUC) GHG emissions (noting that these are not accounted for in the GHG emissions calculation above).

This document describes the methodology to calculate GHG emissions associated with the production of low carbon hydrogen in the UK and sets out the specific criteria for several hydrogen production pathways:

- Electrolysis.
- Natural gas reforming (with carbon capture and storage).
- Biomass/waste conversion to hydrogen (with/without carbon capture and storage).

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1. Introduction

The Prime Minister's Ten Point Plan for a Green Industrial Revolution[1] committed to focus on driving innovation, boosting export opportunities, and generating green jobs and growth across the country to level up regions of the UK. To build on this, government published the Net Zero Strategy[2], setting out a long-term plan to deliver our legally binding targets under the Climate Change Act. Both documents pointed to the role of low carbon hydrogen in meeting our emission reduction targets while generating economic growth in the UK. The Energy Security Strategy set out the UK's ambition for up to 10GW of low carbon hydrogen production capacity ambition by 2030 subject to affordability and value for money.

As we look to grow the UK's nascent hydrogen economy, we must consider the range of methods that could be used to produce hydrogen. Often badged with broad labels such as 'blue' or 'green', hydrogen production can encompass a wide variety of feedstocks, energy inputs and processes, all with different GHG emissions intensities. There is, however, no single understanding or formal definition of what is actually meant by 'low carbon' hydrogen in the UK.

To support the implementation of the UK Hydrogen Strategy and Energy Security Strategy, the UK Low Carbon Hydrogen Standard ('the standard') defines what constitutes 'low carbon hydrogen' up to the point of production. The intent of the standard is to ensure new low carbon hydrogen production supported by government makes a direct contribution to our GHG emissions reduction targets. The standard was developed following a public consultation and multiple engagement sessions with experts from stakeholder groups, such as the Hydrogen Advisory Council and its Low Carbon Hydrogen Standard Working Group.

This guidance document sets out detail on the methodology for calculating emissions. It aims to assist hydrogen producers in their GHG emissions reporting, sets out an approach for considering fugitive hydrogen emissions, and sets out biomass sustainability criteria under the standard.

This document should be used as guidance for the GHG emissions intensity and biomass sustainability criteria for government schemes and policies that apply the standard.

[1] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
[2] https://www.gov.uk/government/publications/net-zero-strategy

2. Terminology

The following terminology will be used throughout this document:

- **Actual data:** Historical data measured or calculated by producers based on the hydrogen production process.
- **Allocation:** Partitioning the input or output flows of a process or a production pathway between the production pathway under study and one or more other production pathway(s). An example would be the partitioning of input emissions between hydrogen and other co-product outputs of a multifunctional process.
- **Carbon/GHG Intensity:** Lifecycle emissions of greenhouse gases from the supply chain. It is expressed in units of carbon dioxide equivalents per mega joule of hydrogen at lower heating value (gCO_2e/MJ_{LHV}).
- **Carnot Efficiency:** The maximum theoretical efficiency that a heat engine may have operating between two given temperatures. It is used in the energy allocation process when heat is a co-product.
- **Emissions Component:** Parts of the production process for which emissions are required to be calculated. These are emissions from feedstock supply, energy supply, input materials, process, fugitive non-CO_2, carbon capture processing, and CO_2 sequestration. See section 6.4 for more details.
- **Co-products:** Desirable secondary goods, other than the hydrogen product, that are generated during the manufacturing process and can be sold or reused profitably.
- **Energy allocation:** The energy allocation approach assigns upstream and process emissions to all products and co-products according to the proportion of the total output energy that they each have, as measured on a lower heating value basis.
- **Default data**: Data provided for use by production pathways where actual data or projected data is unavailable. Default data will be provided on a component basis and will be conservative, based on expected values multiplied by a factor of 1.4.
- **Delivery partner**: Where a government scheme applies the standard as eligibility criteria and requires compliance with the standard, delivery partners may be used to collect and assess data from projects to prove compliance with the standard.
- **Greenhouse gas, GHG:** Gases in the atmosphere, both naturally occurring and generated from human activity, that cause global warming. These gases can absorb infrared radiation (net heat energy) emitted from Earth's surface and re-radiate it back to the Earth's surface. Greenhouse gases considered in this methodology are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF_6).
- **Global Warming Potential, GWP:** For any Greenhouse Gas (GHG), the Global Warming Potential (GWP) is the amount of carbon dioxide (CO_2) that would cause an

equivalent amount of global warming as the selected GHG over a given time period. This measures the radiative forcing (causing global warming) 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 (CO_2). The GWP of fossil CO_2 is assigned a value of 1.

- **Hydrogen Emissions Calculator HEC:** A tool for hydrogen producers to use to test whether the hydrogen in their facility is likely to comply with the GHG requirements of the standard.
- **Input:** Raw materials, intermediate products, co-products, or energy flow that enters a unit process.
- **Life Cycle Assessment, LCA:** Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system as defined by the system boundary.
- **Lower Heating Value, LHV:** A measure of the energy content of a fuel. Specifically, it is the amount of heat released in the combustion of a specified quantity of the fuel, not including the latent heat of vaporisation of any water vapour in the combustion products (also known as Net Calorific Value).
- **Output:** Product, co-product, material or energy flow that leaves a unit process.
- **Power Purchase Agreement (PPA):** A Power Purchase Agreement (PPA) is usually a long-term contract under which a business agrees to purchase electricity directly from an electricity generator.
- **Production pathway:** A production process used to make hydrogen.
- **Projected data:** Future data projected by hydrogen producers based on the design and expected performance of the facility.
- **Renewable electricity:** Electricity generated by a renewable non-fossil energy source e.g. wind, solar, geothermal, wave, tidal and hydropower**.**
- **Renewable Electricity Guarantee of Origin (REGO):** Each Renewable Energy Guarantee of Origin (REGO) certificate represents the ‘energy attribute’, associated with 1MWh of renewable energy generated.
- **Reporting party:** The ‘project’ or ‘operator of the hydrogen production facility’ responsible for reporting the emissions associated with hydrogen production.
- **Scope 1 emissions[3]:** A production pathway’s direct GHG emissions.
- **Scope 2 emissions:** GHG emissions associated with the generation of electricity outside of the hydrogen production facility, heating/cooling, or steam purchased for own consumption.

[3] https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf"

- **Scope 3 emissions:** A production pathway's indirect GHG emissions other than those covered in scope 2. In the case of this standard, partial scope 3 emissions shall be covered which includes upstream emissions only, not downstream emissions from hydrogen distribution and use.
- **System boundary:** defines which processes in the product's (i.e. the hydrogen's) life cycle that should be included in the life cycle assessment.

3. Scope

The guidance document should be used by hydrogen producers seeking support from government schemes and policies that apply the standard.

There are numerous pathways to produce hydrogen from various primary energy sources. This document describes the methodology to calculate GHG emissions associated with the production of low carbon hydrogen in the UK only and sets out specific criteria for several hydrogen production pathways in the annexes. Our analysis suggests that each of the listed technology pathways has the potential to produce hydrogen with GHG emissions complying with the standard. Inclusion on this list does not, however, guarantee the hydrogen shall comply with the standard – producers will need to design and operate their hydrogen production facilities to ensure the standard is met in practice, and on an ongoing basis, where it is required by the criteria of the scheme the project applies for. The initial hydrogen production pathways considered by BEIS in the design of the standard are set out below (with more detail in the annexes):

- Electrolysis.
- Natural gas reforming (with carbon capture and storage).
- Biomass/waste conversion to hydrogen (with or without carbon capture and storage).

This is not an exhaustive list and other pathways may also be able to meet the standard GHG emissions threshold and criteria where it is required by the criteria of a scheme or policy. Further hydrogen production pathways that can meet the requirements under the standard including the GHG emissions threshold, may be added to this standard guidance document through regular review points. Production pathways that are not included in this list but have the ability to demonstrate compliance with the standard are invited to submit this to BEIS for analysis, with the full methodology clearly outlined. Following sufficient scrutiny, we may then consider potential inclusion of these production routes in future standard publications, aligned with the wider review points. BEIS will need to model the likely GHG emissions from the pathway proposed and develop further detail on the methodology for inclusion as an annex.

Production pathways for consideration should submit evidence that the pathway meets the standard methodology and GHG threshold to the Hydrogen Production team at hydrogenproduction@beis.gov.uk.

4. GHG emissions threshold

To demonstrate compliance with the low carbon hydrogen standard, producers of low carbon hydrogen must be able to report a GHG emissions intensity of 20gCO_2e/MJ_{LHV} of produced hydrogen or less.

5. Normative references

The emissions accounting methodology is intended to apply to all hydrogen production pathways equally, based on international standards on GHG accounting. The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- ISO 14040 Environmental Management Life Cycle Assessment Principles and Framework.
- ISO 14044 Environmental Management Life Cycle Assessment Requirements and Guidelines.
- ISO 14067[4] Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.
- GHG Protocol A Corporate Accounting and Reporting Standard. Revised Edition.

[4] Referring to ISO 14067, the following criteria shall be applied:

a. the product category definition and description of the investigated pathways are identical;
b. the declared unit is identical;
c. the system boundary is equivalent;
d. the description of data is equivalent;
e. the criteria for inclusion of inputs and outputs are equivalent;
f. the data quality requirements (e.g. coverage, precision, completeness, representativeness, consistency and reproducibility) are the same;
g. assumptions especially for the delivery stage are the same;
h. specific GHG emissions and removals are treated identically;
i. the following criteria shall be applied for the life cycle inventory and LCIA phase:
    a. the methods of data collection and data quality requirements are equivalent;
    b. the calculation procedures are identical;
    c. the allocation of the flows is equivalent;
    d. the applied GWPs are identical.

6. Assessing the GHG emissions intensity of low carbon hydrogen

6.1. GHG accounting and reporting system boundary

The GHG calculation methodology described in this guidance is based on a 'point of production' system boundary, including Scope 1, Scope 2, and partial Scope 3 emissions. Partial Scope 3 emissions considered include associated impacts from the raw material acquisition phase, raw material transportation phase and hydrogen generation phase.

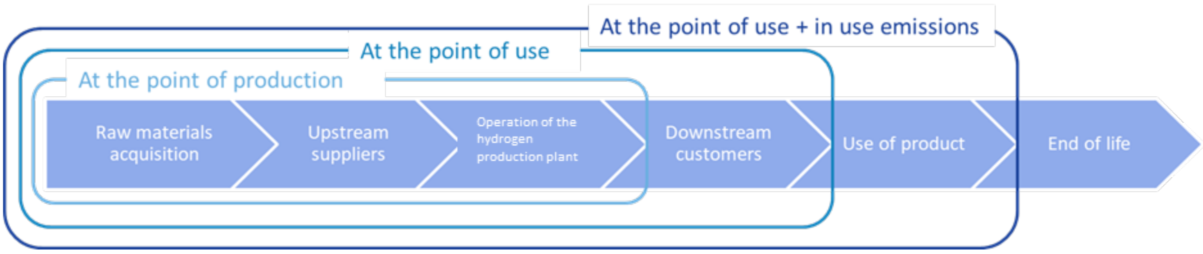

Figure 1: "Point of Production" system boundary adopted for this document

The emissions from the construction, manufacturing, and decommissioning of the capital goods (including hydrogen production plant, vehicles etc.), business travel, employee commuting, and upstream leased assets are not within scope. Excluding these emissions ensures consistency with GHG reporting for other energy vectors. Should the international or national reporting requirements change in future, the standard shall be updated to include these emissions.

If storage is integrated within the hydrogen production plant, then emissions associated with the energy consumption related to the operation of storage facilities within the plant shall be included. Buffer storage may be required to facilitate plant operation or accumulate batches short term ready for dispatch. If storage is shared with other producers and/or users, then energy allocation shall be used to allocate the emissions to the hydrogen producer (see section 6.4.11).

6.2. Units

GHG contributions are defined in terms of grams of carbon dioxide equivalent per megajoule of produced hydrogen at lower heating value (gCO_2e/MJ_{LHV}).

6.3. Applied global warming potential factors

Greenhouse gases considered in this methodology are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF_6). The global warming potential (GWP) of the various GHGs are expressed in CO_2e. The impact of the global warming potential of the GHGs shall be assessed over a period of 100 years. This is in line with current international and domestic carbon accounting practices.

Table 1 shows the GWP factors of CO_2, CH_4, N_2O, HFCs and SF_6 for a period of 100 years according to the Fifth Assessment Reports (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The GWP factors measure the radiative forcing (causing global warming) 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 (CO_2).

Table 1: Global warming potential (GWP) of various GHGs [IPCC 2018], without climate feedback in CO_2e (g/g).

AR5 CO_2e (g/g) without climate feedback	
GHG	**GWP factor (in CO_2e g/g)**
CO_2	1
CH_4	28
N_2O	265
SF_6	23,500
Hydrofluorocarbons (HFCs)	
HFC-23	12,400
HFC-32	677
HFC-41	116
HFC-125	3,170
HFC-134	1,120

HFC-134a	1,300
HFC-143	328
HFC-143a	4,800
HFC-152	16
HFC-152a	138
HFC-161	4
HFC-227ea	3,350
HFC-236cb	1,210
HFC-236ea	1,330
HFC-236fa	8,060
HFC-245ca	716
HFC-245fa	858
HFC-365mfc	804
HFC-43-10mee	1,650

6.4. Emissions accounting

An overview of the GHG emissions accounting methodology applied to each production pathways is summarised below. This section breaks down the emissions categories to be accounted for under the standard, providing detail on the emissions that are likely to incur within those categories.

Emissions include all Scope 1 and 2 and partial Scope 3 emissions calculated at the “point of production” boundary as defined in section 6.1. This includes GHG emissions (in

gCO_2e/MJ_{LHV}) from the hydrogen production pathways according to impacts arising from feedstock extraction, collection and transportation, and the impacts of hydrogen production processing facilities (including emissions from fuel and electricity use).

The final accounted emissions shall be the total emissions less any CO_2 captured and permanently stored in geological storage as set out in section 6.4.10.

The equation below shows the breakdown of the emissions are within the scope of the standard into its components (emissions categories). Emissions data should be reported to the nearest $0.1gCO_2e/MJ_{LHV}$.

$$E_T = E_{feedstock\ supply} + E_{energy\ supply} + E_{input\ materials} + E_{process} + E_{fugitive\ non\text{-}CO2} + E_{CCS\ process\ and\ infrastructure} - E_{CO2\ sequestration} + E_{compression\ and\ purification}$$

Where E_T = Total emissions gCO_{2e}

When using actual data, the final emissions value per unit hydrogen E, in gCO_2e/MJ_{LHV}, shall be calculated by dividing the total emissions E_T in gCO_2e by the total hydrogen output from the plant P in MJ_{LHV}. The total hydrogen output P is defined as the quantity of hydrogen, in MJ LHV, that is produced and valorised by the plant. Any fugitive hydrogen should not be included in this value.

$$E = E_T / P$$

Default data is provided in gCO_2e/MJ_{LHV}.

6.4.1. Feedstock Supply Emissions

$$E_{feedstock\ supply} = \sum_i E_{feedstock\ supply\ emissions,i}$$

Where $E_{feedstock\ supply\ emissions}$ is the sum of the GHG emissions arising from feedstock extraction, cultivation, collection, harvesting, pre-processing, storage and transportation and could cover the following feedstock inputs (depending on the production pathway):

- **Natural gas:** includes extraction, processing and transportation.

To account for natural gas inputs, producers should use the average UK gas network value provided in the Data Annex if they are connected to the UK gas network or actual data they have generated in all other cases.

- Upstream emissions for natural gas provided directly from a facility should be provided via the methodology set out in Annex B.
- Upstream emissions for natural gas imported directly from an international transmission system should be provided via the methodology and requirements in Annex B.

- **Biomass feedstocks:** includes 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 should be included, and indirect land use change should be reported separately – further guidance on emissions related to land-use change can be found in Annex C. Impacts related to avoided emissions (e.g. avoided landfill methane emissions) are not included.
- **Waste feedstocks (with fossil or biogenic content):** includes emissions from collection, sorting, pre-processing and transport to the point of hydrogen production.

If a producer uses a certain input (e.g. natural gas) both as the feedstock and as a fuel to their processing plant, these should always be combined and considered as only a feedstock.

Additional feedstock streams may be considered on a case-by-case basis and should be fully accounted for using the broad methodology for feedstock supply emissions.

Electrolysis pathways will have no feedstock supply emissions due to the lack of time resolved emissions data; only energy supply emissions (including electricity) and input materials emissions (including water) are included below.

6.4.2. Energy supply

$$E_{energy\ supply} = E_{electricity\ supply} + E_{steam\ supply} + E_{heat\ supply} + E_{fuel\ supply}$$

Electricity supply

$$E_{electricity\ supply} = \sum_{i} E_{electricity\ supply\ emissions,i}$$

Where $E_{electricity\ supply\ emissions}$ is the emissions of carbon dioxide, methane and nitrous oxide (as applicable), associated with supply of electricity within the hydrogen production process measured in grams CO_2e. This includes (but is not limited to) emissions associated with electricity used for the production and drying processes. Full details on the reporting requirements and evidence needed to calculate electricity input emissions are included in Annex A.

- **Off-grid generation (via physically linked renewable or low carbon electricity generation):** Where evidence can be provided electricity used for hydrogen production is off-grid (e.g. using on-site physically linked renewable or low carbon electricity generation) and consumed in the hydrogen production process, then the emissions would be any scope 1 emissions resulting from generating that electricity. Following the product system boundaries, Scope 1 emissions from electricity use are considered to be zero if off-grid on-site renewable electricity is used.

- **Grid connected low carbon electricity via contractual link (such as PPA or wholesale procurement) :** Where evidence can be provided renewable or nuclear electricity has been used for hydrogen production (by meeting Annex A Technical Requirements; temporal correlation, low carbon generation sourcing attributes and energy attribute information) and the grid has only been used to transmit renewable or nuclear electricity with no further import, the emissions are assumed to be the actual emissions of the low carbon generation source in real time. Nuclear energy includes impacts from uranium extraction to nuclear electricity (and heat) production. Where the grid is used to transmit electricity, evidence will need to be provided that transmission and distribution losses have been considered in emissions calculations.

- **Grid imported electricity:** Grid imported emissions can be calculated using actual national grid average GHG intensity data per 30-minute settlement period. This figure should include the combustion emissions of generation on the UK grid, and transmission and distribution losses from generation to use. Upstream emissions of UK generation plants are not included due to a lack of time resolved upstream emissions data.[5] Further detail on how to account for grid imported electricity emissions is provided in Annex A.

Steam supply

$$E_{steam\ supply} = \sum_i E_{steam\ supply\ emissions,i}$$

Where $E_{steam\ supply\ emissions}$ is the emissions associated with supply of steam to the hydrogen production process. For steam supply (i.e. where steam is purchased from an entirely separate process or is purchased from a third party provider), GHG emissions should be accounted for by the supplier with an emission factor provided to the buyer by the supplier. Where the steam is derived from a separate process on the same site, the operator should calculate the emission factor. These factors need to be documented with complete data on fuel used, efficiency of conversion and all losses or leakages.

Heat supply

$$E_{heat\ supply} = \sum_i E_{heat\ supply\ emissions,i}$$

Where $E_{heat\ supply\ emissions}$ is the emissions associated with supply of heat to the hydrogen production process. For heat supply (i.e. where heat is purchased from an entirely separate process or is purchased from a third party provider), GHG emissions should be accounted for

[5] Feedstock emissions before these UK generation plants such as feedstock extraction, refining and transportation of fuels for electricity generation prior to the point of combustion are not included due to data availability, but will be included when considering any future methodology.

by the supplier with an emission factor provided to the buyer by the supplier. Where the heat is derived from a separate process on the same site, the operator should calculate the emission factor. These factors need to be well documented with complete data on fuel used, efficiency of conversion and all losses or leakages.

Fuel supply

$$E_{fuel\ supply} = \sum_{i} E_{fuel\ supply\ emissions,i}$$

Where $E_{fuel\ supply}$ refers to upstream GHG emissions associated with any input fuels to a system (other than the feedstock supply emissions and input material emissions considered separately). These fuels include (but are not limited to) coal, oil, diesel, natural gas, biomethane, biomass and wastes, provided these are not the main feedstock. Note that emissions from the combustion/use of fuels onsite are considered under either process emissions or fugitive non-CO_2 emissions categories. If the fuel used is also the main feedstock, then the emissions related to that fuel should all be accounted for under $E_{feedstock\ supply}$.

6.4.3. Input materials emissions in hydrogen production

$$E_{input\ materials} = \sum_{i} E_{input\ material\ emissions,i}$$

$E_{input\ materials}$ refers to upstream GHG emissions associated with any input materials to a system (other than the feedstock supply emissions and energy supply emissions considered separately), where their purpose is not to provide energy to the process. This could include key inputs such as gasifier oxygen, water, salts, catalysts, solvents, acids etc. Additional input streams may be considered as needed, pending materiality. This could include items such as chemicals used for water treatment.

All processing associated with system water input is assumed to occur within the facility boundaries and thus all emissions associated with the supply of water should be accounted for.

6.4.4. Process emissions in hydrogen production

$$E_{process} = \sum_{i} E_{process\ emissions,i}$$

Where $E_{process}$, is the sum of emissions of carbon dioxide generated from the hydrogen production process including use of feedstocks, fuels (solid, liquid and gaseous) and input materials in the hydrogen processing plant, prior to any CO_2 capture. This will include (but is not limited to) the conversion or otherwise use of feedstocks, fuels (solid, liquid and gaseous) and input materials in the hydrogen processing plant, prior to any CO_2 capture. This will include (but is not limited to) the CO_2 generated by combustion of coal, oil, diesel, natural gas, biomethane, biomass and wastes.

6.4.5. Fugitive non-CO_2 GHG emissions in hydrogen production

$$E_{fugitive\ non-CO_2} = \sum_i E_{fugitive\ non-CO_2\ emissions,i}$$

Where $E_{fugitive\ non\text{-}CO2}$ is the sum of operational emissions of methane, nitrous oxide, sulphur hexafluoride (SF_6), perfluorocarbons (PFC) and hydrofluorocarbons (HFCs) (as applicable), released as fugitive emissions from the hydrogen production process.

This includes all operational losses due to the technology deployed and plant management respectively, such as leakages and accidental losses, as well as other losses due to poor management of plant operations. Activities such as venting waste streams have to be included within assessments of fugitive emissions.

Emissions arising from the accidental release of specific non-CO_2 gases used across a number of industry activities are also included (e.g. hydrofluorocarbons (HFCs) used in industrial refrigeration and/or cooling systems, and sulphur hexafluoride (SF_6) used in electrical switchgear).

These fugitive emissions shall be calculated by producers through the recording of leakage rates based on the best available data, or changes in stock levels of the relevant substances as measured throughout the relevant consignment period. These are expected to be relatively minor emissions sources.

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, producers should already be recording their levels of fugitive emissions and look to reduce these through their facilities.

For most hydrogen producers, fossil fuels are provided by a third party, so fugitive emissions associated with the collection, purification, transmission and distribution of the fossil fuels shall be captured by the feedstock supply emissions.

Evidence shows that hydrogen behaves as an indirect greenhouse gas and therefore reducing the amount of hydrogen vented into the atmosphere during the production process or onsite storage is key. While hydrogen fugitive emissions are not expected be accounted for within the GHG emissions calculations at this stage, we expect producers to minimise and report on these fugitive hydrogen emissions and follow the guidelines set out below (see Section 8).

6.4.6. Emissions associated with carbon capture, storage process and operation of infrastructure

$$E_{CCS\ process\ and\ infrastructure} = \sum_i E_{CCS\ process\ and\ infrastructure\ emissions,i}$$

Where $E_{CCS\ process\ and\ infrastructure}$ includes GHG emissions impacts from CO_2 capture, compression, transport, and injection into geological storage (where not already considered within the processing plant energy supply emissions, fuel combustion emissions or input material emissions categories). Transportation of CO_2 to geological storage may include transport modes such as pipelines, trucks or ships and therefore involve emissions from the upstream supply and combustion of transport fuels that are not accounted for within the processing plant energy supply emissions.

Any fugitive CO_2 emissions from the capture, compression and transport should be accounted for by a reduction in the amount of CO_2 sequestered (compared to the amount of CO_2 generated and captured).

6.4.7. CO_2 sequestration

$$E_{CO2\ sequestration} = \sum_i E_{CO2\ sequestration\ emissions,i}$$

Where $E_{CO2\ sequestration}$ are emissions captured and permanently stored through use of carbon capture and storage technology. For emissions to be accounted for under this category, the following conditions need to be met:

- CO_2 emissions must be captured and stored permanently in geological storage. Avoided emissions (through a displacement or change in fossil fuel use) and carbon capture and utilisation of CO_2 does not meet this condition.
- Permanent storage assumes zero leakage once CO_2 emissions are sequestered.
- Any emissions accounted for under this category cannot be credited or claimed elsewhere (e.g. as a carbon credit). If credited elsewhere, the emissions sequestration benefit can no longer be included in the overall emissions calculation for the purposes of the standard.

- Any emissions accounted for under this category must be directly related to processes within the evaluation scope of the standard. Carbon offsets (or similar) from other processes cannot be claimed under the standard.

In practice all process emissions before storage, including fugitive CO_2 emissions, should be reported across the emission categories mentioned above, with all captured and stored CO_2 emissions reported under this category. Should CO_2 emissions sequestered be incorporated across other emissions categories (e.g. as a reduction in process CO_2), this should be clearly stated.

6.4.8. Compression and Purification of Hydrogen

$$E_{compression\ and\ purification} = \sum_i E_{compression\ and\ purification\ emissions,i}$$

Where $E_{compression\ and\ purification}$ is the emissions associated with the supply of electricity or fuel used to compress or purify hydrogen. The standard sets a theoretical minimum pressure level of 3MPa and a theoretical minimum purity of 99.9% by volume. Actual pressure and purity of hydrogen produced should be dictated by end use requirements. Emissions associated with hydrogen infrastructure after the hydrogen production gate (e.g. off-site liquefaction, hydrogenation into a hydrogen carrier) and transportation to the consumption location are considered outside of the scope of this standard.

For the purpose of GHG emissions reporting, hydrogen producers outputting hydrogen at or above the theoretical minimum(s) of 3MPa for pressure and 99.9% by volume purity, should account for the emissions from the electricity or fuel used to reach the output pressure and purity, this includes any GHG emissions that are removed through purification and vented or captured and abated.

Hydrogen producers outputting hydrogen below the theoretical minimum(s) of 3MPa pressure and 99.9% by volume purity, should account for the emissions associated with theoretical compression and/or theoretical purification to reach the theoretical minimum(s). The data and methodology required to do the theoretical calculations is provided in the Data Annex. Where the emissions associated with theoretical pressure and purity is calculated the actual pressure and purity values may be required by off-taker(s) and by scheme delivery partners.

Please note that the default data in the Data Annex already accounts for compression to 3MPa and purification to 99.9% by volume purity. The addition of theoretical compression and purification emissions for those using default data is only required if the projected final pressure or purity is greater than the minimum, in this case the calculation can be used starting from 3MPa or 99.9% to the actual expected pressure and purity output.

6.4.9. Emissions allocation for co-products

This section covers co-products from production routes where hydrogen is the main output in terms of economic value. Production pathways where hydrogen is a co-product (or by-product) of different industrial process (where it is not the main output) will be considered in future reviews of the standard.

Production pathways for hydrogen typically result in various waste materials, residue materials, by-products and co-products.

ISO 14044 and the GHG Protocol Product Life Cycle Accounting and Reporting Standard distinguish between the product which is being studied as part of the GHG inventory preparation and other co-product(s) which “have value as an input into another product’s life cycle” (GHG Protocol, 2011). Consequently, the total emissions resulting from the hydrogen production should be separated between the hydrogen and the number of co-products where these products are valorised (sold on). This allocation refers to the partitioning of the inputs or outputs of a process or product system between the product system under study and one or more other product systems. Waste and residue materials have no emissions allocated.

This methodology considers production methods where hydrogen is the main output and assumes co-products such as heat, or oxygen are not valorised. Should co-products be valorised, this should be evidenced, and emissions should be allocated to co-products using energy allocation.

Energy allocation

This method allocates emissions to co-products from the production process, in proportion to the lower heating value energy content of each co-product as compared to the total lower heating value energy content of all product and co-products combined.

Producers with heat or steam co-products using the energy allocation method are expected to use the Carnot efficiency for those co-products (in both the allocation numerator for that co-product output and in the allocation denominator for the sum of all products and co-products).

The useful part of the heat is found by multiplying its energy content with the Carnot efficiency, Ch, calculated as follows:

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

Where: Th =Temperature, measured in absolute temperature (kelvin), of the useful heat at the point of delivery. T0 = Temperature of surroundings, set at 273.15 kelvin (equal to 0°C).

If the excess heat is exported for heating of buildings, at a temperature below 150°C (423.15 kelvin), Ch can alternatively be defined as follows: Ch = Carnot efficiency in heat at 150°C (423.15 kelvin), which is: 0.3546.

7. Input use and resultant outputs

7.1. Mixed inputs

Hydrogen can be produced via a number of production pathways and using a number of feedstock or energy inputs. The inputs for one production pathway can have varying levels of upstream emissions associated with them. The treatment of input variability can be found in Annex A for electricity inputs, Annex B for natural gas inputs and Annex C for biomass and/or waste inputs. This section considers how the outputs associated with such inputs should be considered for compliance with the standard.

7.1.1. Consignment options

Hydrogen producers receiving support for produced hydrogen through funds or schemes requiring compliance with the standard may need to report the inputs for production pathways which may have different upstream emissions associated with them. Where that is the case the outputs from the production process using different inputs can be considered in two ways:

Discrete H_2 consignments (based on features of each single input):

- Hydrogen produced from a single measurable input with an identical set of environmental characteristics (as defined in 7.1.2) within a defined emissions assessment period shall be considered as a single consignment.
- Where a hydrogen production input is made in an upstream process from multiple feedstocks but supplied for hydrogen production as a single input with a single set of environmental characteristics this can be used to make a discrete consignment.
- Where two or more measurably different inputs are used in parallel during the defined emissions assessment period, separate discrete consignments associated with the defined emissions assessment period should be reported based on the hydrogen manufactured from each single measurable input.
- The emissions assessment period for discrete consignments will be:
    - 30 mins of production for electricity inputs
    - 1 day for production from natural gas, biomass, and waste inputs (based on the gas grid day 05:00-04:59, and assuming use of wholesale grid imported electricity)

Averaged H_2 consignments (based on multiple discrete consignments averaged)**:**

Averaging is designed to support the ambitious growth targets of the nascent hydrogen market by permitting the mixing of low carbon and higher carbon inputs, delivering a balance between transparency, flexibility and overall GHG emission reduction.

- The output hydrogen from two or more discrete consignments with the GHG emissions of the output averaged based on the CO_2e energy contents of the consignments shall be considered as an averaged consignment.
- In each calendar month period a maximum of one averaged consignment, that meets the GHG emissions threshold, can be considered as compliant under the standard. This shall be a minimum of two discrete consignments averaged, a maximum of all the discrete consignments produced in a month averaged, or any number of discrete consignments in between averaged.
- The discrete consignments do not need to be consecutive to be averaged.
- Only consignments produced in the reporting month can be included in the monthly averaged consignment.

For each calendar month, discrete consignments, one averaged consignment or a combination of consignment types (including maximum one averaged consignment), can be considered as being compliant with the standard assuming the guidance is complied with and the GHG emissions associated with each consignment meets the standard threshold.

See section 7.2 for reporting Mixed Outputs.

7.1.2. Environmental Characteristics

To be considered a discrete consignment the environmental characteristics of the input should be identical:

- Energy input.
- Energy generation process.
- Feedstock input.
- the feedstock form i.e., solid, liquid, gas.
- feedstock production process.
- country of origin.
- feedstock classification (e.g. biogenic waste, fossil waste, residue), where relevant.
- compliance with the additional sustainability and other criteria, for biogenic inputs.
- GHG emissions intensity of the input.

More detailed information on how these environmental characteristics apply to different inputs can be seen in the relevant annexes to this document.

7.1.3. Input specific requirements

Examples of inputs

- Wholesale grid imported electricity.
- Direct or Sleeved Power Purchase Agreement (PPA) with a renewable or low-carbon generator.
- Off-grid on-site connection to a renewable or low-carbon generator.
- Natural gas from the gas grid.
- Direct connection to natural gas extraction facility.
- Biomethane from a direct connection to an anaerobic digestion facility.
- Municipal solid waste.

This is a non-exhaustive list and an input being on this list does not mean that hydrogen produced from said input would automatically be compliant under the standard.

Electricity inputs

- All electricity inputs shall have a discrete consignment size of 30 minutes.
- Real time tracking of generation and consumption (temporal correlation) is required across all 30-minute consignments.
- Different types of discrete consignment will need to track carbon intensities in different ways:
    - Off-grid physical links must provide generation data matched to hydrogen production consumption per 30 mins.
    - Direct or sleeved PPA must provide generation data matched to hydrogen production consumption per 30 mins (accounting for all transmission and distribution losses).
    - Wholesale grid import must provide actual carbon intensity data per 30 minutes matched to consumption for hydrogen production (accounting for all transmission and distribution losses) using data provided by NGESO.
    - Where a mix of renewable, low carbon electricity and/or grid import are used this should be separated into individual discrete consignments within the 30-minute period with the % of each input clearly matched to hydrogen output volumes (and with all transmission and distribution losses factored in).

Example: for one 30-minute period 50MWh of hydrogen is produced using 20% wholesale grid imported electricity and 80% direct connection to a wind farm: this would result in two discrete 30-minute consignments.

1. 10MWh of hydrogen based on wholesale electricity grid GHG intensity.

2. 40MWh of hydrogen based on wind farm electricity GHG intensity.

These discrete consignments can remain as discrete consignments or be included as part of an averaged consignment. In each calendar month period a maximum of one averaged consignment that meets the GHG emissions threshold can be considered as compliant under the standard. This will be a minimum of two consignments averaged, a maximum of all the consignments produced in a month averaged or any number of consignments in between averaged.

Note, hydrogen producers using natural gas reformation process may choose to source low carbon electricity, in this case the discrete consignments should be 30 minutes following the guidance for electricity inputs.

Natural gas Inputs

- All natural gas inputs shall have a discrete consignment size of 1 day (05:00-04:59) based on the quantity of gas used via metering of the natural gas from the gas grid. This assumes the use of wholesale grid imported electricity.
- Natural gas from the UK gas network is considered as one input, daily usage should be metered.
- The average UK gas network value for upstream natural gas emissions should be applied for gas taken from the UK gas network, this value will be provided in the Data Annex.
- In all other cases, producers are expected to use actual data according to the methodology set out in Annex B.
- Where default data is used, 1 discrete consignment can be made each day based on the daily metered volumes of natural gas, the daily published calorific value (CV) for the gas delivered, and the default feedstock emissions provided.
- The feedstock emissions can be calculated and should be reported as daily discrete consignments.
- If multiple sources of fossil fuel based natural gas (e.g.: the UK gas network & direct connection) are used within a day this should be separated into individual discrete consignments within the daily period with the % of each input and the upstream emissions of feedstocks clearly matched to hydrogen output volumes.

Example: for one day period 750MWh of H_2 is produced using 40% UK gas grid and 60% imported Norwegian natural gas would produce two daily discrete consignments.

1. 300MWh of hydrogen based on average UK gas grid GHG intensity.
2. 450MWh of hydrogen based on imported Norwegian natural gas GHG intensity.

These discrete consignments can remain as discrete consignments or be included as part of an averaged consignment. For natural gas reformation processes using fossil fuel inputs, specifically sourced and evidenced, biogenic inputs cannot be averaged in the same consignment and should be considered as separate discrete consignments. In each calendar month period, a maximum of one averaged consignment, that meets the GHG emissions threshold, can be considered as compliant under the standard. This will be a minimum of two consignments averaged, a maximum of all the consignments produced in a month averaged or any number of consignments in between averaged.

Biomass & Waste inputs

- All biogenic inputs (including wastes and residues) and fossil waste inputs shall have a discrete consignment size of 1 day (05:00-04:59) as a default.
- Any consignment must be able to evidence compliance with all non-GHG criteria for all biogenic inputs. Any consignment of hydrogen which includes production from an input that is not compliant with the non-GHG criteria cannot be compliant with the standard.
- Where a mixed waste input has a biogenic and a fossil component (e.g. municipal solid waste), it should be considered as two distinct inputs to hydrogen production, split in line with the biogenic and fossil fractions of the waste. This would create two discrete daily consignments of hydrogen, despite the fact that the original waste input is mixed.
    - Having separated the biogenic and fossil fractions of a waste stream, the biogenic waste inputs can feed into a single discrete consignment, as can the fossil waste inputs, provided that each consignment has a single set of identical environmental characteristics.
- Biomethane inputs can be reported where there is sufficient evidence that biomethane has been / will be physically supplied to the hydrogen production facility (see Annex E for relevant guidance).
    - Biomethane inputs can be used to create daily discrete hydrogen consignments, with the environmental characteristics associated with the biomethane input, as evidenced by the biomethane supplier.
    - If the supplier provides biomethane produced from multiple inputs with different environmental characteristics, the biomethane input to hydrogen production should be considered as multiple distinct inputs, creating separate daily discrete

consignments of hydrogen, with the volume of each distinct input corresponding to the volume of hydrogen output.

- Hydrogen producers using biomethane reformation process may choose to source low carbon electricity, in this case the discrete consignments should be 30min following the guidance for electricity inputs.

Example: over a one-day period 600MWh of H_2 is produced by an SMR, using 90% biomethane via a direct connection to an anaerobic digestion facility and 10% natural gas from the UK gas grid. The biomethane is sourced from 50% food waste, and 50% (sustainably-sourced) maize crops. This would produce three daily discrete consignments.

1. 270MWh of hydrogen based on sustainable maize-derived biomethane GHG intensity.
2. 270MWh of hydrogen based on food waste-derived biomethane GHG intensity.
3. 60MWh of hydrogen based on average UK gas grid GHG intensity.

These discrete consignments can remain as discrete consignments or be included as part of an averaged consignment. In each calendar month period a maximum of one averaged consignment, that meets the GHG emissions threshold, can be considered as compliant under the standard. This will be a minimum of two consignments averaged, a maximum of all the consignments produced in a month averaged or any number of consignments in between.

Note: Natural gas reformation processes cannot process biogenic inputs with CCS to offset emissions associated with hydrogen produced from fossil fuels. – e.g. any biomethane processed will result in separate biogenic hydrogen consignments to the fossil hydrogen consignments.

Non GHG requirements for biogenic inputs

To comply with the standard, consignments of hydrogen derived from biogenic inputs must meet sustainability criteria in addition to satisfying the GHG emissions threshold. The relevant criteria vary according to the feedstock classification and source:

- By default, all hydrogen derived from biogenic inputs needs to satisfy the GHG emissions threshold and **land criteria.**
  - The **land criteria** prohibit the sourcing of biomass inputs for hydrogen production from land that has or previously had a certain status, to preserve biodiversity and carbon stocks.
- Hydrogen derived from residues and wastes from agriculture must also meet the **soil carbon criteria.**

- The **soil carbon criteria** ensure that monitoring or management plans are in place to address the impacts on soil quality and soil carbon of harvesting the biogenic input concerned.

- Hydrogen derived from any kind of forest biomass (including wastes and residues) must meet the **forest criteria**, instead of the land criteria.

  - The **forest criteria** ensure that 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.

- Hydrogen derived from wastes and residues not from agriculture, aquaculture, fisheries or forestry does not need to meet any criteria in addition to the GHG emissions threshold.

Hydrogen derived from any (mix of) biogenic input(s) must also demonstrate compliance with the **minimum waste and residue requirement**. This sets a minimum threshold (50%) for the proportion of hydrogen yield (by energy content) that must be derived from inputs classified as wastes or residues, for each facility producing hydrogen from a biogenic input.

Further details of these requirements (or "non-GHG criteria"), and demonstrating compliance with them, are provided in Annexes C and D.

7.2. Mixed Outputs

Hydrogen producers using CCS or other emission abatement processes to meet the standard GHG emission threshold need to account for the impact of the performance of the capture process, transportation, and storage of the CO_2. Reduced performance of any of these areas could result in higher emissions being associated with certain volumes of hydrogen. Further details are outlined for CCS enabled pathways in Annex B.

In cases of reduced emissions capture or unplanned transport and storage network outages, producers are expected to consider the change in their hydrogen emissions resulting from CO_2 being fully or partially vented. Where producers have to vent the CO_2 they have captured the CO_2 vented shall be considered as not having been captured for the purpose of calculating emission and producers are expected to reduce their reported capture rate to reflect this.

Daily discrete consignments based on upstream emissions can be divided into 30 minutes discrete consignments based on the averaged emissions associated with the 30 minute period resulting from such outages. Where 30 minute consignments are in use to account for low carbon electricity the electricity input and CO_2 capture transport and storage rate must both be accounted for over the 30 minute period. Where daily consignment(s) are divided into 30 minute discrete consignments the daily consignment(s) will no longer exist: instead, the output hydrogen from two or more 30 minute discrete consignments with the GHG emissions of the output can be averaged based on the LHV energy contents of the consignments over a maximum of a month or remain as discrete consignments. Each monthly discrete consignments and or one averaged consignment can be compliant with the standard assuming the GHG threshold is met.

7.3. Future for mixed inputs and mixed outputs

The discrete and averaged consignment approach is designed to support the ambitious growth targets of the nascent hydrogen market by permitting the mixing of low carbon and higher carbon inputs, delivering a balance between transparency, flexibility and overall GHG emission reduction. This is to provide hydrogen producers with the flexibility to build a low carbon hydrogen market in support of the UK's ambition for up to 10GW of low carbon hydrogen production capacity ambition by 2030 subject to affordability and value for money, as set out in the Energy Security Strategy. As the market grows, technology develops, and the UK energy infrastructure decarbonises, the need for both consignment options may cease to exist. This will be reviewed in the next update of the standard. Should either consignment method no longer be required, we will flag this in the standard update prior to removing the consignment option in the subsequent standard update.

8. Fugitive hydrogen emissions

Hydrogen itself does not adsorb infrared radiation and so is not a direct greenhouse gas. However, if released in significant quantities - 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, in turn, would increase the warming effect of methane released. This and other 'indirect' effects mean emissions of hydrogen have an impact on climate change.

BEIS commissioned work from the University of Cambridge to understand the climate impact of hydrogen emissions using modern climate models. 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 production process.

Work is still ongoing to narrow uncertainties for both the GWP impact and leakage rates from hydrogen production, but we expect GWP to be included to the emissions calculation in future. Producers are expected to apply best available techniques set out by government and its agencies. For now, we require producers to take the steps outlined below.

8.1. Specific requirements for hydrogen production plants

8.1.1. Risk Reduction Plan: Produce a plan demonstrating how fugitive hydrogen emissions at the production plant will be minimised.

A plan should be provided demonstrating how the hydrogen production plant will be designed and operated to ensure that fugitive hydrogen emissions are kept as low as reasonably practical. As a minimum, the plan should consider each emission type detailed in the guidance section below (that is relevant to the production plant type). All assumptions should be stated, and justification should be provided where sources of emissions have been deemed negligible.

The guidance below outlines some possible actions that could be taken to minimise fugitive hydrogen emissions.

8.1.2. Risk Plan: Provide estimates of expected rates of remaining fugitive hydrogen emissions by the plant.

Producers should provide an upfront estimate of expected annual fugitive hydrogen emissions from the production plant, in kgH_2/yr. The estimate should include a breakdown of different emissions types considered, and as a minimum should show consideration of each emission type described in the guidance section below (that is relevant to the production plant type). All assumptions should be stated, including where emissions have been considered to be negligible.

8.1.3. Risk Monitoring: Prepare a monitoring methodology for fugitive hydrogen.

A methodology for monitoring overall fugitive hydrogen emissions from the plant in operation should be provided. The methodology should account for each emission type identified in the Risk Plan described above. Emissions that have been identified as negligible in the Risk Plan do not need to be monitored

The plant operator may use their discretion in determining the monitoring methodology, provided they are able to account for all potential fugitive hydrogen streams. Approaches may include direct-monitoring of hydrogen streams (for example in vent ducts), or mass balance approaches to track overall flows of hydrogen.

8.2. Guidance: Sources of fugitive hydrogen at production plants

The following processes have been identified as being potentially significant sources of fugitive hydrogen at production plants - including compression and purification processes of hydrogen within the production facility and should be duly considered by plant developers when considering how to minimise fugitive hydrogen emissions. The list is not exhaustive and further significant sources may exist.

8.2.1. Process venting

Cold vents are likely to be the most significant source of fugitive hydrogen emissions at a hydrogen production plant:

- "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);
- Hydrogen may also be vented during plant start-up and shut-down when equipment is purged. The significance of this will depend on the frequency of plant start-ups and shut-downs.

8.2.2. Compressors

Hydrogen compressors are likely to be a source of fugitive hydrogen emissions and shall be considered when they are included within the production plant boundary. Fugitive emissions may arise due to:

- Permeation through seals.
- Compressor venting for maintenance (likely to be negligible, depending on frequency).

8.2.3. 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 within the production plant boundary:

- 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, unless actions are taken to re-use this hydrogen.

8.2.4. 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.

8.2.5. Leakage through pipework and joints (Negligible)

Hydrogen leakage through joints etc. is 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.

8.3. Guidance: Minimising fugitive hydrogen emissions

As a priority, plants should minimise all cold venting of hydrogen. This may be achieved by:

- Ensuring that hydrogen is fully separated from any vented streams (e.g. water vapour).
- Finding alternative uses for the hydrogen within the plant 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.

Hydrogen leakage throughout the plant 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 plants during commissioning.

9. Reporting Requirements

9.1. Evaluation cycle

The evaluation cycle for GHG emissions data is the time period for which the GHG emissions are quantified to represent the emissions from hydrogen production. The standard is designed to calculate GHG emissions on a consignment basis, to ensure each consignment can be considered as compliant with the standard by meeting the GHG Threshold and non GHG requirements. The data reporting requirements will depend on the scheme applying the standard. Specific reporting requirements will be set out under guidance for government schemes applying the standard, which will be available upon launch of these schemes.

It is recommended that compliant hydrogen is reported on a monthly basis with annual third-party verification.

9.2. Description of data

The methodology should use data that reduces bias and uncertainty by using the best quality data available.

9.2.1. Actual, Default and Projected Data

Hydrogen producers reporting compliance against the standard should report actual data based on the performance and emissions measured or calculated through the production of hydrogen. However, it is understood that in certain cases the use of 'actual data' may not be possible and in these specific circumstances projected data would be the second preference with default data available as a backup. Example circumstances include:

- On application for some government schemes, hydrogen producers may not yet have access to 'actual data' if production has not commenced at the time of application. In this case projects should use projected data with clear assumptions set out, or where there is a gap in projected data certain default data will be available in the Data Annex. This default data will be component based and conservative to encourage projects to move over to projected data as soon as possible. Default data will not be provided for process and fugitive non-CO_2 emissions as set out in the Data Annex. Actual data will be expected on the commencement of hydrogen production.
- Where the standard requires theoretical calculations for pressure and purity adjustments for hydrogen: the default data to facilitate this will be provided in the Data Annex, and this data will be representative.

Conservative default data will be based on the central estimates from modelling multiplied by 1.4. Default data will be provided in the Data Annex on a component basis in line with the emissions breakdown in the emissions accounting equation. For a given component, either only the default value must be used or only projected/ actual data. Hydrogen producers are expected to have projected or actual emissions for their process and any combustion, carbon capture or actual compression or purification so default data will not be provided for these components. This data will be updated alongside other revisions to the standard as necessary. The actual data submitted by projects will be used to ensure that the default data supplied is representative or conservative as required.

9.2.2. Data Quality

Data quality shall be characterised by both quantitative and qualitative aspects.

Characterisation should address the following:

- Time-related coverage: age of data and the minimum length of time over which data should be collected.
- Geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the partial carbon footprint study.
- Technology coverage: specific technology or technology mix.
- Precision: measure of the variability of each data value expressed (e.g. 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 population of interest (i.e. geographical coverage, time period and technology coverage).
- Consistency: qualitative assessment of whether or not the study methodology is applied uniformly to the various components of the sensitivity analysis
- Reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the partial carbon footprint study.
- Sources of the data.
- Uncertainty of the information.

9.2.3. Data Completeness

The standard will not set a materiality threshold. All reasonable efforts shall be taken to include all processes and flows that are attributable to the hydrogen production process, including Scope 1, 2 and partial Scope 3 emissions as outlined in section 6. If the actual or projected data is known, then it should be included. In practice, a lack of data or the cost of gathering data may be a limiting factor. If individual material or energy flows are found to be disproportionally costly or impossible to quantify or estimate for a particular unit process, these may be excluded and shall be reported as data exclusions. Data exclusions must be recorded with clear reasoning for the omission and reported through annual audit and verification processes. Once projects are operational, if significant evidence suggests that we should consider allowing regular omissions, a materiality threshold may be introduced in future.

10. Eligibility and Compliance

10.1. Eligibility and Compliance overview

The standard will be used to ensure that hydrogen production supported by government schemes and policies that apply the standard, such as the Net Zero Hydrogen Fund (NZHF) and Low Carbon Hydrogen Business Model (HBM), is sufficiently low carbon. Hydrogen producers receiving support from such schemes may be expected to prove ongoing compliance with the standard throughout the agreed period, set out in their funding contract. Further detail on the compliance and monitoring requirements will be published within the specific scheme guidance and/or contractual terms providing details for on-going due diligence, monitoring and evaluation of production, contract management and verification processes. The outlined requirements in this section are an example of the data and reporting requirements needed to prove eligibility or ongoing compliance with the standard.

Compliance may be checked at multiple points including at application, during study/construction stages, at build completion, and on an ongoing basis once hydrogen production begins.

The standard methodology will be developed into a user-friendly tool, the 'hydrogen emissions calculator' (HEC). This will support the application processes for the NZHF, HBM and possible future government schemes applying the standard, as producers would be able to check if their hydrogen production route would (likely) be standard compliant.

10.2. Compliance to assess eligibility for HBM and NZHF allocation

Proof of compliance with the standard will be required as eligibility criteria for the NZHF and HBM and possible future funding schemes. To prove eligibility for certain funding allocation rounds, hydrogen producers will be required to demonstrate through calculation and supporting evidence that hydrogen produced from their facility will be able to comply with the GHG emissions requirements and other requirements of the standard.

Hydrogen producers are expected to have projected data and clarity around selected inputs and their associated upstream emissions. However, it is understood that at eligibility stage there may be gaps in hydrogen producers' data and some default data will be provided by in the Data Annex to support those gaps. Whether default or project data is used, projects would be expected to clearly indicate which data type is being used and any assumptions made, with references to any supporting evidence.

10.3. Compliance during operation

Once the hydrogen production facility is up and running the hydrogen produced can be checked for compliance against the standard.

It is recommended that hydrogen producers receiving support or funding from government schemes applying the standard should prove ongoing compliance with the standard throughout the agreed period set out in the relevant scheme contract to receive funding. Hydrogen producers receiving government support will be expected to prove ongoing compliance with the standard version detailed in their contract throughout the agreed period set out in their contract to receive ongoing funding. We would not expect any changes to the standard to be applied retrospectively to hydrogen producers already awarded funding through the schemes applying the standard unless that is clearly set out in the contractual agreements. Further detail on the compliance and monitoring requirements will be published within the respective scheme guidance and contractual documents.

10.4. Reporting Requirements

It is recommended that hydrogen producers be required to report all the required information to demonstrate compliance with the standard along with any supporting evidence to back up the data reported. A user-friendly tool will be provided to applicants to government schemes applying the standard, which will lay out how the standard can be interpreted in an accessible way. A list of example data/documents that may be required as evidence or for verification is below:

- A scanned copy of the application unit's business license.
- The hydrogen production flow chart of the application unit.
- The main equipment list for hydrogen production.
- Supply agreements for feedstock, fuel, energy and input materials.
- The life cycle of hydrogen production and associated GHG emissions to point of production.
- List of raw materials for hydrogen production and their associated GHGs emissions.
- Energy/mass flow diagram.
- Energy metering system diagram.
- If hydrogen production facilities and equipment involve multiple locations, a list of production locations, processes, and processes of each facility should be maintained.
- Production date and production capacity information.

10.5. Verification process

Data submitted to prove eligibility or compliance with the standard should be subject to verification processes. Hydrogen producers are expected to ensure that all required data is reported fully and accurately to the best of their knowledge as required within the contractual arrangements of the relevant government scheme applying the standard.

10.5.1. Verification at eligibility

Producers should be prepared to provide evidence to back up any data or claims, should such a request be made.

10.5.2. Ongoing verification

For schemes or funds implementing the standard, a level of ongoing verification will be required which should take place at least annually and shortly after the start of operations. This could be done by third party data verification reports and/or independent audits as required within the contractual arrangements of the funding scheme.

Scheme delivery partners may also choose to implement spot check audits if there is a perceived inconsistency with any reporting.

The steps an onsite audit may take are outlined below.

On-site verification steps

- Site visits and surveys.
- Confirm the input and output information of the product system boundary and unit process.
- Confirm the completeness and standardisation of the data collection plan and data collection process.
- The accuracy of the level data and the consistency of the data source.
- Check whether the content of the hydrogen life cycle assessment report meets the requirements of this document, and whether the information is correct.
- On-site verification of hydrogen parameters generated by hydrogen production projects, such as hydrogen purity, hydrogen pressure, hydrogen production, etc. Hydrogen production projects should have equipment to measure these hydrogen parameters and have a calibration certificate within the validity period.