Department for
Energy Security
& Net Zero

Data Annex

Data required to calculate greenhouse gas emissions under the UK Low Carbon Hydrogen Standard

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1 Default data

1.1 Default data overview

The main guidance document for the standard breaks down the hydrogen emissions intensity calculation into the following emissions categories.

$$E_T = E_{feedstock\ supply} + E_{energy\ supply} + E_{input\ materials} + E_{process\ CO_2} + E_{fugitive\ non\text{-}CO_2} + E_{CO_2\ capture\ and\ network\ entry} - E_{CO_2\ sequestration} + E_{compression\ and\ purification} + E_{waste\ fossil\ counterfactual}$$

$$\text{Where } E_T = \text{Total emissions } gCO_{2e}$$

Default data is only provided for the Feedstock supply, Energy supply and Input materials categories, and is only provided for the following pathways:

- Steam Methane Reformation using UK natural gas with CO_2 capture and storage
- Auto Thermal Reformation using UK natural gas with CO_2 capture and storage
- Food waste biomethane directly connected to Auto Thermal Reformation with CO_2 capture and storage (if CO_2 capture and storage is not implemented, the default values provided for the pathway with CCS can still be used)
- Forestry residue gasification with CO_2 capture and storage (if CO_2 capture and storage is not implemented, the default values provided for the pathway with CCS can still be used)
- Biogenic and Fossil fractions of mixed refuse derived fuel (RDF) gasification with CO_2 capture and storage (if CO_2 capture and storage is not implemented, the default values provided for the pathway with CCS can still be used)
- Electrolysis using grid average electricity
- Electrolysis using wind/solar electricity
- Electrolysis using electricity from nuclear electricity

If electrolysis projects use different electricity sources to the list above, they may still be able to use the Input material category default data. If SMR/ATR projects use different gas feedstocks to the list above, they may still be able to use the Energy supply and Input material category default data. Gasification projects using different biomass or waste feedstocks to the list above cannot use default data, due to potentially significant changes in energy or material inputs. Any other pathway not listed above must use projected or actual data in their hydrogen emissions intensity calculations. A summary of which default values can be applied across which pathways is given below in Table 1. DESNZ may update this table over time.

Table 1: Ability to use default factors for different hydrogen production pathways

Production pathway	Feedstock supply	Energy supply	Input materials
UK grid natural gas to SMR with CCS	Yes	Yes	Yes
Other fossil natural gas to SMR with CCS	No		
Biomethane to SMR with/without CCS	No		
UK grid natural gas to ATR with CCS	Yes	Yes	Yes
Other fossil natural gas to ATR with CCS	No		
Food waste biomethane to ATR with/without CCS	Yes	Yes	Yes
Other biomethane to ATR with/without CCS	No		
Forestry residue gasification with/without CCS	Yes	Yes	Yes
Other biomass gasification with/without CCS	No	No	No
Biogenic fraction of mixed RDF waste gasification with/without CCS	Yes	Yes	Yes
Fossil fraction of mixed RDF waste gasification with/without CCS	Yes	Yes	Yes
Other waste gasification with/without CCS	No	No	No
Electrolysis using grid average electricity	NA	Efficiency	Yes
Electrolysis using wind/solar electricity		Yes	
Electrolysis using nuclear electricity		Yes	
Electrolysis using other electricity sources		No	
Other pathways not listed above	No	No	No

Default data is **not** provided for the Process CO_2 emissions, CO_2 capture and infrastructure, CO_2 sequestration, Fugitive non-CO_2 emissions and Waste fossil counterfactual emissions categories. These categories will always have to be projected by projects (and later reported with actual data).

For the Compression and purification category, the Energy supply default data provided already accounts for the emissions associated with reaching the theoretical minimum pressure and purity under the standard (3 MPa and 99.9 vol% purity). However, if projected or actual data for the Energy supply category is being used, and the hydrogen output pressure or purity is below the theoretical minimum, the data and methodology provided in Data Annex section 2 should be used to calculate the theoretical added emissions. Similarly, if default data for the Energy supply category is being used, but the hydrogen output pressure or purity is above the theoretical minimum, the data and methodology provided in Data Annex section 2 should be used to calculate the added emissions.

The standard guidance has been developed into a hydrogen emissions calculator (HEC) to support hydrogen producers in checking their likely compliance against the standard. The default data provided below, and the theoretical compression & purification calculations, are already built into the HEC.

1.1.1 Conservative factor

To ensure that the default data provided is conservative, the central scenario values taken from DESNZ modelling have each been multiplied by a factor of 1.4 to derive the default values presented in this Annex. The exceptions are Feedstock supply emissions for natural gas taken from the UK gas grid, and Energy supply emissions for grid average electrolysis, neither of which were multiplied by the conservative factor.

All default data for electricity inputs to production pathways have been derived assuming an estimated 2025 UK grid electricity GHG intensity of 35.2 gCO_2e/MJ_e delivered (UK Green Book). The exception is electrolysis using grid average electricity, where the projected grid average GHG intensity in the relevant year (from the UK Green Book, as given in the 'Assumptions' tab of the Hydrogen Emissions Calculator) should be divided by a default electrolysis LHV efficiency of 58.6%, without any conservative factor applied.

1.2 Default data tables

DESNZ will update the following default data values over time to respond to industry developments and changes in the relevant input emissions intensities that were used to derive these default data values.

1.2.1 Feedstock supply

Feedstock supply emissions cover the GHG emissions arising from feedstock extraction, cultivation, harvesting, collection, pre-processing, storage and transportation. Depending on the production pathway, this term could include fossil natural gas, biomethane, solid biomass feedstocks and waste feedstocks. Note that upstream supply for the food waste biomethane pathway includes the emissions from food waste collection through AD biogas production up to the point of biomethane delivery to the reformer plant via direct pipeline connection. Counterfactual emissions for waste fossil feedstocks are considered separately to this emissions category.

Table 2: Default data for Feedstock supply

Production pathway	Emissions intensity (gCO_2e/MJ_{LHV} hydrogen)
UK grid natural gas to SMR	8.59
UK grid natural gas to ATR	8.04
Food waste biomethane to ATR	5.17
Forest residue gasification	7.96
Biogenic fraction of mixed RDF waste gasification	3.93
Fossil fraction of mixed RDF waste gasification	3.93
Electrolysis	NA

1.2.2 Energy supply

Energy supply emissions are the GHG emissions associated with the supply of electricity, steam, heat and fuels for hydrogen production (but excluding usage associated with directly converting feedstock to hydrogen which are separately considered under the Process CO_2 emissions category).

Table 3: Default data for Energy supply

Production pathway	Emissions intensity (gCO_2e/MJ_{LHV} hydrogen)
SMR	0.74
ATR	4.16

Forestry residue gasification	0
Biogenic fraction of mixed RDF waste gasification	8.63
Fossil fraction of mixed RDF waste gasification	8.63
Electrolysis using grid average electricity	Use the UK grid factor in the relevant year divided by 58.6% LHV electrolysis efficiency
Electrolysis using wind/solar electricity	0.00
Electrolysis using nuclear electricity	8.59

1.2.3 Input materials

Input materials emissions refers to upstream emissions associated with any input materials (except those covered in Feedstock supply and Energy supply emissions categories) to a system. This could include inputs such as oxygen, water, salts, catalysts, solvents, acids, alkali solutions, etc.

Table 4: Default data for Input materials

Production pathway	Emissions intensity (gCO_2e/MJ_{LHV} hydrogen)
SMR	0.38
ATR	0.39
Forestry residue gasification	1.56
Biogenic fraction of mixed RDF waste gasification	3.37
Fossil fraction of mixed RDF waste gasification	3.37
Electrolysis	0.10

2 Theoretical pressure and purity calculations

2.1 Compression of hydrogen

Hydrogen producers with an actual or projected output pressure of less than 3MPa are required to calculate the theoretical added emissions associated with theoretical compression up to 3MPa. DESNZ may update the theoretical compression method outlined in this section in the future in line with industry developments, along with more regularly updating the relevant emissions intensities.

If using default data and final output H_2 is below or equal to 3MPa

If default Energy supply category data is being used, the emissions associated with hydrogen compression to 3MPa have already been accounted for within the Energy supply category, and the formulae below do not need to be used.

If using projected or actual data for H_2 output pressure below or equal to 3MPa

If projected or actual Energy supply category data is being used, and the hydrogen output pressure p_0 is less than 3MPa, the formulae below should be used to calculate the additional theoretical GHG emissions required to achieve an outlet pressure of p_1 = 3 MPa, to add to the projected or actual GHG emissions result.

If projected output H_2 pressure is above 3MPa

For hydrogen producers with a projected hydrogen output pressure p_1 greater than 3MPa, the total emissions associated with compression to the outlet pressure must be accounted for.

If producers need to use default Energy supply category data in this case (if projected or actual data is unavailable), they can use the formulae below to calculate the theoretical additional GHG emissions associated with raising the hydrogen pressure p_0 from the 3 MPa already included within the Energy supply default data to their actual outlet pressure p_1.

If actual output H_2 pressure is above 3MPa

Hydrogen producers should report all actual emissions associated with actual compression and do not need to use the equations below.

2.1.1 How to calculate emissions associated with theoretical compression

The carbon emissions from energy use for compression are calculated as follows:

$$C = A \times B \times \frac{1000g}{120\ MJ_{LHV}}\ (1)$$

Where:

C = GHG emissions from electricity use for compression, in $gCO_2e/MJ_{LHV}\ H_2$

A = Electricity required to compress hydrogen (with losses), $kWh_e/kg\ H_2$

B = Electricity source emissions factor, $kgCO_2e/kWh_e$, selecting the factor relevant to your process from Table 5 (for wind/solar or nuclear electricity this must be a demonstrable input).

Compression energy, A, is calculated as follows:

$$\mathrm{A} = \frac{\mathrm{W}}{3.6 \times \eta}\ (2)$$

Where W is the specific compression power defined in equation 3, and η is the adiabatic efficiency, which can be taken from Table 5.

$$W = \left[\frac{n}{n-1}\right] \times p_0 \times V_0 \times \left[\left(\frac{p_1}{p_0}\right)^{\frac{(n-1)}{n}} - 1\right] \quad (3)$$

Where W is the specific compression power defined in equation 4, n is the adiabatic coefficient, p_o and p_1 are the respective inlet and outlet pressures and V_0 is the input specific volume (of hydrogen). These terms are defined in Table 5.

$$V_0 = k \times {p_0}^{\alpha}\ (4)$$

Where α is the power law exponent and k is a constant. This equation uses a line of best fit derived from hydrogen density data[1]. The values of α and k should be taken from Table 6, using the temperature closest to the compressor inlet temperature. For example, a hydrogen production outlet temperature of 40°C should use the α and k values for 50°C.

2.2 Purification of hydrogen

Hydrogen producers with actual hydrogen purity of less than 99.9% by volume are required to calculate the theoretical emissions associated with theoretical purification up to 99.9% by volume. DESNZ may update the theoretical purification method outlined in this section in the future in line with industry developments, along with more regularly updating the relevant emissions intensities.

[1] https://h2tools.org/hyarc/hydrogen-data/hydrogen-density-different-temperatures-and-pressures, data source NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 8.0

To utilise this equation to calculate the emissions associated with purification, the emissions associated with compression to a minimum of 3MPa must have already been accounted for either theoretically using the steps in section 2.1.1 or based on actual emissions.

The following purification equations assume a minimum starting pressure of 3MPa is input into pressure swing absorption (PSA) equipment.

If Energy supply category default data is being used, the emissions associated with purification to 99.9% by volume have already been accounted for.

2.2.1 How to calculate emissions associated with theoretical purification

The carbon emissions from energy use for purification are calculated as follows:

$$E = P_c \times B \times \frac{1000g}{120\ MJ_{LHV}}$$

Where:

E = GHG emissions from electricity use for purification $gCO_2e/MJ_{LHV}\ H_2$.

P_C = Electricity required to purify hydrogen of 3MPa or higher to a purity of 99.9% (with losses), $kWh_e/kg\ H_2$, as found in Table 5.

B = Electricity source emissions factor, $kgCO_{2e}/kWh_e$, selecting the factor relevant to your process from Table 5 (for wind/solar or nuclear electricity this must be a demonstrable input).

2.3 Compression and purification terms, units and data

Table 5: Terms and units for Compression and purification calculations

Term	Provided value	Units	Definition
W	Equation 3	MJ/kg	Specific compression power
p_o	Section 2.1	MPa	Input pressure
p_1	Section 2.1	MPa	Output pressure
V_0	Equation 4	m^3/kg	Input specific volume
n	1.41	-	Adiabatic coefficient
η	60%	%	Adiabatic efficiency
α	From Table 6	-	Power law exponent

k	From Table 6	-	Constant
P_C	0.0013	kWh_e/kgH_2	Purity correction factor (assuming starting pressure ≥ 3MPa)
B(2025 grid average)	0.127	$kgCO_2e/kWh_e$	GHG factor of electricity source
B(nuclear)	0.014	$kgCO_2e/kWh_e$	GHG factor of electricity source
B(wind/solar)	0.0	$kgCO_2e/kWh_e$	GHG factor of electricity source

This data is not conservative as this is a theoretical calculation.

Table 6: Line of best fit parameters for equation 4 at specific temperatures

Temperature (°C)	k	α
0	1.1651	-0.935
25	1.2691	-0.939
50	1.373	-0.943
75	1.4767	-0.946
100	1.5804	-0.949
125	1.6839	-0.952

3 Actual data for natural gas upstream emissions

3.1 UK gas network

Given the complexity of calculating upstream emissions associated with natural gas drawn from the UK gas network, for the calculations of projected and actual data, projects may use a figure of 6.29 gCO_2e/MJ_{LHV} natural gas. DESNZ will update this figure on a regular basis.

4 Waste fossil feedstock counterfactual

4.1 Fossil fraction of RDF counterfactual

DESNZ may update the counterfactual outlined in this section in the future based on the development of the UK waste industry and other relevant UK policies.

The current counterfactual for the fossil fraction of Refuse Derived Fuel (RDF) should be an Energy from Waste (EfW) plant that produces only electricity at 22% net electrical LHV efficiency, without useful heat sales and without any CO_2 capture. An illustration of the change in emissions between the counterfactual and hydrogen production scenario is given in Figure 1. The current counterfactual is focused only on the waste fossil feedstock CO_2 emissions emitted (and displaced utility), but not any non-CO_2 emissions arising from conversion of the waste fossil feedstock in the counterfactual, nor any change in other inputs used in the counterfactual (e.g. fossil heating oil use for plant start-up), nor any change in the upstream waste fossil feedstock supply chain.

The displaced electricity is assumed to be supplied by UK grid average electricity, with the annual average emissions intensity taken from either the latest DESNZ publication[2] if the hydrogen plant has started operations, or from the latest UK Green Book projections[3] for the relevant year of operations if the hydrogen plant is yet to start operations. Updates to either dataset (e.g. to the Company conversion factors in around June) are expected to be implemented immediately for new consignments or new projections from that date forwards.

[2] Government conversion factors for company reporting of greenhouse gas emissions, Full set workbook, summing kgCO2e/kWhe factors for UK electricity generation and UK electricity Transmission & Distribution, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting
[3] Green Book Supplementary Guidance, Data Tables 1-19, Table 1, Column I (industrial consumption-based grid average), https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

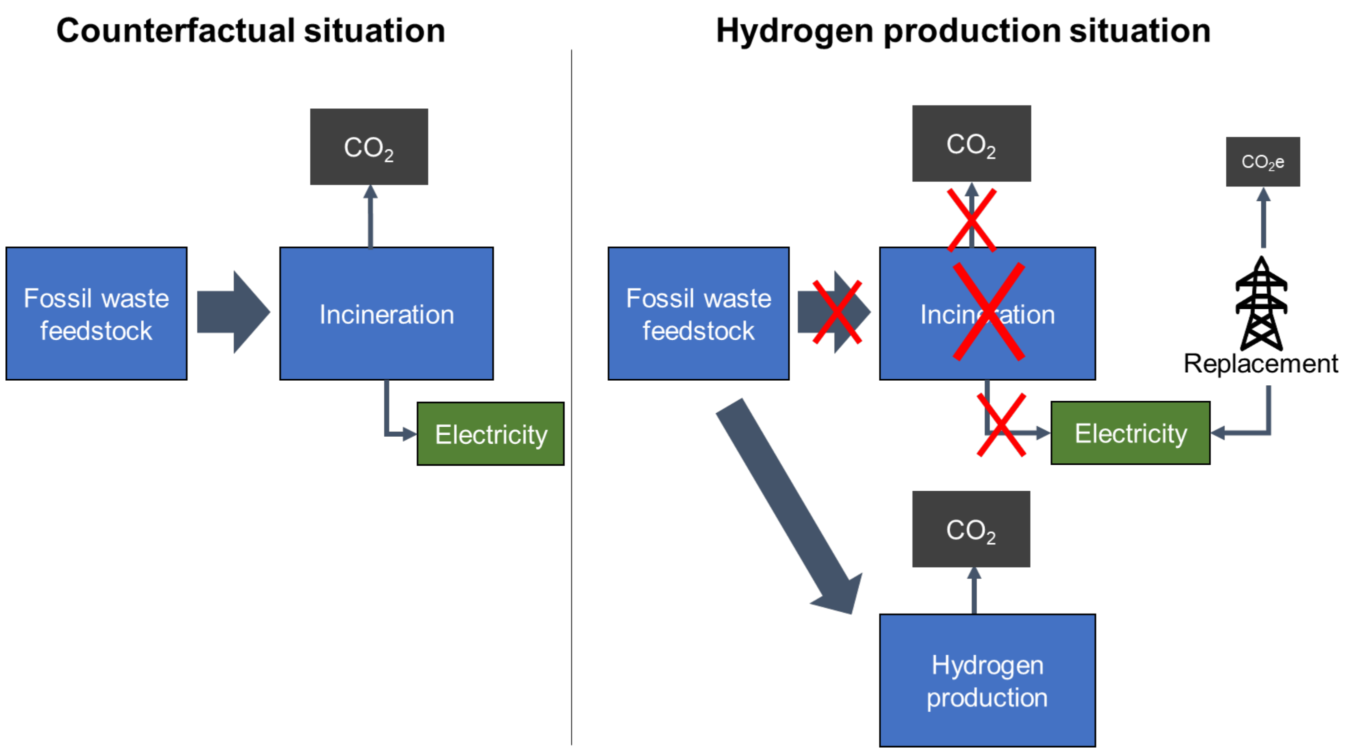

Figure 1: Simplified description of the fossil fraction of RDF counterfactual methodology

If hydrogen is generated via electrolysis using electricity generated in a specific EfW plant, then instead of the generic EfW counterfactual assumption above, the counterfactual should instead be taken as the specific EfW plant. This means the hydrogen producer should use the electricity and heat efficiencies from the specific EfW plant to calculate the displaced electricity (and any heat), along with the emissions intensity of the grid electricity (and any replacement natural gas for heating) in the relevant year of operations. In this particular case, the presence/absence of any CO_2 capture at the specific EfW plant will not impact the overall hydrogen emissions intensity, as it appears in both the counterfactual and hydrogen production situations (it is only the electricity that is being diverted). Any CO_2 sequestered from the EfW plant will show up as a lower electricity intensity in the Energy supply emission category, but will also lead to the $E_{waste\ fossil\ counterfactual\ CO2\ emitted}$ term being smaller, meaning these two changes will cancel each other out in this particular case.