Department for
Energy Security
& Net Zero

Data Annex

Data for calculating Greenhouse Gas Emissions under the UK Low Carbon Hydrogen Standard

December 2023

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Introduction

DA.1. This document contains Typical Data, Default Data, and other useful conversion factors, which can be used towards determining compliance with the GHG Emission Intensity Threshold and other requirements which make up the Low Carbon Hydrogen Standard (the 'Standard'). It is intended to complement the contents of the Standard Document with supporting quantitative and qualitative data (or references to data sources) which are necessary or auxiliary to determining Standard Compliance. It will not introduce new policies, nor will it contradict the contents of the Standard Document.

DA.2. This document will be reviewed and updated on an annual basis (subject to relevant datasets being published). Updates will incorporate developments in the industry (for example, improving default efficiencies for Default Data values), changes in the referenced datasets, and/or changes to the most appropriate datasets to use. Updates to this document may happen outside of the annual cycle if required to accommodate the inclusion of a new Eligible Hydrogen Production Pathway.

DA.3. The updates in this version of the Data Annex shall be effective immediately. Future updates to the Data Annex shall be effective from a specified date in the updated Data Annex – this date will be the start of a calendar month and will be a minimum of 28 days from the date of publication of the updated Data Annex.

Global Warming Potentials (GWP)

DA.4. Table 1 shows the GWP values of CO_2, CH_4, N_2O, SF_6, NF_3, perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs) for a period of 100 years according to the 2018 Fifth Assessment Reports (AR5) of the Intergovernmental Panel on Climate Change (IPCC). These values shall be applied across all GHG emissions calculations under the Standard.

Table 1: IPCC AR5 Global Warming Potential (GWP) of GHGs without climate feedback[1]

GHG	GWP value (in gCO_2e/g)
CO_2 (fossil)	1
CO_2 (biogenic)	0
CH_4	28
N_2O	265
SF_6	23,500
NF_3	16,100
Perfluorocarbons (PFCs)	
PFC-14 (CF_4)	6,630
PFC-116 (C_2F_6)	11,100
PFC-218 (C_3F_8)	8,900
PFC-318 (c-C_4F_8)	9,540
PFC-31-10 (C_4F_{10})	9,200
PFC-41-12 (C_5F_{12})	8,550
PFC-51-14 (C_6F_{14})	7,910
PFC-91-18 ($C_{10}F_{18}$)	7,190
Trifluoromethyl sulphur pentafluoride (SF_5CF_3)	17,400
Perfluorocyclopropane (c-C_3F_6)	9,200
Hydrofluorocarbons (HFCs)	
HFC-23	12,400

[1] https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

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

Typical Data

DA.5. The Standard Document breaks down the Hydrogen Product GHG Emission Intensity calculation into the following Emission Categories.

Equation 1

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

Where E_T = total GHG emissions in gCO_2e over the Reporting Unit for the Discrete Consignment.

DA.6. Instructions on which emissions shall be included within the calculations for each of these Emission Categories are given in Chapter 5 of the Standard Document, whereby Activity Flow Data is combined with GHG Emission Intensities (or GWPs) for each Input and Output to the Pathway. The sections below provide the Typical Data and data sources that shall be used for these GHG Emission Intensities, along with any further guidance regarding Solid Carbon Permissible End Uses and identification of fossil Waste/Residue feedstock counterfactuals that are not given in the Standard Document.

DA.7. Guidance on whether Default Data can be used before a Hydrogen Production Facility is operational (instead of Projected Data) is given in Paragraphs DA.75-DA.87.

Feedstock Supply

DA.8. Pathways without feedstocks (e.g. electrolysis) have no emissions to report under the Feedstock Supply Emission Category. The emissions associated with any Input electricity derived from biomass or Waste Inputs shall be accounted for under the Energy Supply Emissions Category.

DA.9. Fossil gas reforming with CCS Pathways, or gas splitting with solid carbon Pathways that consume natural gas from the UK Gas Network, shall calculate the Feedstock Supply emissions for these Discrete Consignments using the natural gas GHG Emission Intensity value given in Table 9 (depending on whether withdrawing from the Transmission Network or Distribution Network), combined with the Activity Flow Data for their consumption of natural gas from the UK Gas Network.

DA.10. Pathways using biomass or Waste feedstocks shall calculate their Feedstock Supply emissions for the UK proportion of their supply chain, using the same GHG Emission Intensities for Inputs to this supply chain (such as energy and materials) as given in

Paragraphs DA.20-DA.45. For biomass and Waste feedstocks sourced from abroad, appropriate up-to-date national GHG Emission Intensities shall be sourced and evidenced for input energy and materials used within overseas segments of the supply chain.

Direct land use change (DLUC)

DA.11. For relevant biomass feedstocks, these DLUC calculations are carried out according to the methodology in Annex E of the Standard Document and included within the Feedstock Supply Emission Category result.

DA.12. Based on the location of the DLUC, climate, ecological zone and soil type can be taken from maps and data provided by the Joint Research Centre (JRC)[2].

DA.13. The Food and Agriculture Organisation of the United Nations (FAO)[3] provides similar information.

DA.14. In most cases, it is possible to find values for the different parameters required under Annex E of the Standard Document within the look-up tables in the Renewable Transport Fuel Obligation (RTFO) standard values[4].

DA.15. For C_{DOM} the value of 0 may be used, except forest land (excluding forest plantations) with more than 30% canopy cover.

DA.16. CF_B can be taken to be 0.47; CF_{DW} can be taken to be 0.5; CF_{LI} can be taken to be 0.4.

Indirect land use change (ILUC) – reporting purposes only

DA.17. The ILUC emissions values in Table 2 shall be used when reporting the estimated ILUC emissions associated with use of cereals and other starch-rich crops, sugars or oil crops. Note that the values provided are in gCO_2e/MJ_{LHV} biomass, so require conversion into gCO_2e/MJ_{LHV} Hydrogen Product values based on the usage of the biomass within the Pathway.

DA.18. ILUC emissions shall be reported as being zero for all other types of biomass.

[2] https://esdac.jrc.ec.europa.eu/projects/RenewableEnergy/
[3] https://www.fao.org/forest-resources-assessment/remote-sensing/global-ecological-zones-gez-mapping/en/
[4] https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-compliance-reporting-and-verification

Table 2: ILUC values of biomass groups

Biomass group	ILUC values (gCO_2e/MJ_{LHV} biomass)
Cereals and other starch-rich crops	12
Sugars	13
Oil crops	55

Crude oil supply

DA.19. Pathways that utilise crude oil as a feedstock may use the country-level values provided by Masnadi et al[5] as summarised in the Table 3 below to derive a weighted average GHG Emission Intensity for their crude oil mix.

Table 3: GHG Emission Intensity of crude oil imports

Country	GHG Emission Intensity (gCO_2e/MJ_{LHV})	Country	GHG Emission Intensity (gCO_2e/MJ_{LHV})
Afghanistan	8.3	Kuwait	6.9
Albania	23.7	Kyrgyzstan	9.4
Algeria	20.3	Latvia	8.9
Angola	7.5	Libya	11.0
Argentina	9.1	Lithuania	9.7
Australia	9.1	Malaysia	12.9
Austria	7.6	Mauritania	14.8
Azerbaijan	6.3	Mexico	9.9
Bahrain	5.0	Morocco	9.3
Barbados	9.3	Myanmar	20.2
Belize	8.8	Netherlands	3.9
Bolivia	9.0	New Zealand	8.2
Brazil	10.3	Niger	11.3
Brunei	5.7	Nigeria	12.6
Bulgaria	8.6	Norway	5.6

[5] https://www.science.org/doi/10.1126/science.aar6859

Cameroon	18.4	Oman	11.7
Canada	17.6	Pakistan	12.2
Chad	10.2	Papua New Guinea	8.5
Chile	11.2	Peru	10.9
China	7.0	Philippines	11.6
Colombia	8.3	Poland	8.2
Cote d'Ivoire	6.1	Qatar	6.5
Croatia	7.8	Republic of Congo	10.6
Cuba	9.0	Romania	7.4
Democratic Republic of Congo	29.2	Russian Federation	9.7
Denmark	3.3	Saudi Arabia	4.6
Ecuador	9.3	Serbia	7.7
Egypt	10.6	Spain	4.1
Equatorial Guinea	6.4	Sudan	14.9
France	7.5	Suriname	8.2
Gabon	13.2	Syria	29.8
Georgia	15.2	Tajikistan	9.4
Germany	7.7	Thailand	5.1
Ghana	5.2	Trinidad and Tobago	14.3
Greece	5.9	Tunisia	15.4
Guatemala	9.8	Turkey	8.4
Hungary	7.9	Turkmenistan	15.9
India	8.6	Ukraine	11.8
Indonesia	15.3	United Arab Emirates	7.1
Iran	17.1	United Kingdom	7.9
Iraq	14.1	United States	11.3
Italy	6.1	Uzbekistan	27.4

Japan	7.7	Venezuela	20.3
Jordan	6.3	Vietnam	8.8
Kazakhstan	9.7	Yemen	26.9

Energy Supply

DA.20. Energy Supply emissions cover the generation and supply of electricity, steam, heat, and fuels for hydrogen production.

Electricity

Electricity sourced from a specific generator via an Eligible PPA (or equivalent), or sourced from a Private Network and not linked to a specific generator, excluding grid import to the Private Network

DA.21. When calculating the emissions associated with the generation of electricity from a specific generator or from a weighted average of generators on a Private Network, the Typical Data electricity generation GHG Emission Intensity in Table 4Table 4 shall be used by the Hydrogen Production Facility (or Electricity Storage System).

DA.22. Note that values are not provided for biomass or Waste electricity generators. Given the diversity of supply chains and conversion efficiencies, the GHG Emission Intensities for biomass or Waste electricity generation shall be calculated following the methodology given in Annex G of the Standard Document. The same applies to combined heat and power generation, given the diversity of conversion efficiencies.

DA.23. If the Hydrogen Production Facility (or Electricity Storage System) is consuming electricity from an onsite or adjacent electricity generation asset, the generation GHG Emission Intensity values in Table 4 can be used directly as the delivered GHG Emission Intensity without any Transmission and Distribution Losses being applied. If the Hydrogen Production Facility (or Electricity Storage System) is sourcing electricity from the electricity generation asset via the Electricity Grid or via a Private Network, then any Transmission and Distribution Losses will need to be accounted for in the delivered GHG Emission Intensity, following Annex B of the Standard Document.

Table 4: Electricity generation GHG Emission Intensities (prior to any Transmission and Distribution Losses)

Generator	gCO_2e/kWh_e	gCO_2e/MJ_e	Sources and supporting notes
Onshore wind	0.0	0.0	JEC (2020) Well-to-tank report v5[6], WDEL1
Offshore wind	0.0	0.0	JEC (2020) Well-to-tank report v5, WDEL1
Solar	0.0	0.0	IPCC (2014) Technology-specific cost and performance parameters[7], Table A.III.2
Hydro-electric dam	0.0	0.0	IPCC (2014) Technology-specific cost and performance parameters, Table A.III.2
Run-of-river hydro	0.0	0.0	IPCC (2014) Technology-specific cost and performance parameters, Table A.III.2
Geothermal	0.0	0.0	IPCC (2014) Technology-specific cost and performance parameters, Table A.III.2, assuming geothermal power generation has not led to any increase in venting of geological CO_2. Any increase requires a GHG emissions factor to be calculated instead
Natural gas CCGT	471.6	131.0	JEC (2020) Well-to-tank report v5[8], GPEL1a
Oil	811.1	225.3	JEC (2020) Well-to-tank report v5, FOEL1
Coal	1,009.8	280.5	JEC (2020) Well-to-tank report v5, KOEL1
Nuclear	14.0	3.9	JEC (2020) Well-to-tank report v5, NUEL1

DA.24. Within the Standard Document, Annex B Paragraphs B.25-B.30 and Annex C Paragraphs C.27-C.31 require the cancellation of REGOs, which depends on the electricity generation source. The REGO Percentage of electricity generated from wind, solar, hydropower, tidal, wave, hydrothermal, aerothermal, geothermal and biogenic feedstocks will be between 100% and 0%, depending on whether the specific generator is registered with the REGO scheme and generates REGOs, and the proportion of the generation exported that generates REGOs. Any non-renewable electricity generation sources will not generate REGOs, and therefore have a REGO Percentage of 0%.

[6] https://publications.jrc.ec.europa.eu/repository/handle/JRC119036
[7] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf
[8] https://publications.jrc.ec.europa.eu/repository/handle/JRC119036

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

DA.25. For operational Hydrogen Production Facilities in Great Britain (GB) consuming electricity from the Electricity Grid that is not linked to a specific generator, the GHG Emission Intensity per Reporting Unit for GB from the National Grid ESO Dashboard[9] shall be used. These values already include Transmission and Distribution Losses.

DA.26. For operational Hydrogen Production Facilities in Northern Ireland (NI) consuming electricity from the Electricity Grid, 30-minute GHG Emission Intensities per Reporting Unit for NI from the EirGrid Smart Dashboard[10] shall be used. These values already include Transmission and Distribution Losses. Note that the EirGrid data gives GHG Emission Intensities every 15 minutes, therefore the 30-minute NI Electricity Grid GHG Emission Intensity shall be a simple arithmetic mean of two 15-minute periods (for example, the GHG Emission Intensity between 10:00-10:30 shall be a simple arithmetic mean of the two GHG Emission Intensities at 10:00 and 10:15 respectively).

DA.27. For Hydrogen Production Facilities, the REGO Percentage of electricity volumes from the Electricity Grid that are not linked to a specific generator shall be set as 0%.

DA.28. For pre-operational Hydrogen Production Facilities planning to consume electricity from the Electricity Grid, the Projected UK grid average electricity GHG Emission Intensity data in Table 5 shall be used. This data comes from the UK Government (2023) Green Book supplementary guidance[11]. These values already include Transmission and Distribution Losses, and so can be used directly by pre-operational Hydrogen Production Facilities in combination with their Projected grid average power consumption. Table 5 shall not be used once a Hydrogen Production Facility is operational, as grid electricity intensities that vary every 30 minutes are required to be used in emissions calculations instead.

Table 5: UK grid average electricity GHG Emission Intensity delivered to industrial consumers (after Transmission and Distribution Losses)

Year	gCO_2e/kWh_e	gCO_2e/MJ_e
2023	140.43	39.01
2024	145.96	40.55
2025	126.65	35.18
2026	94.59	26.28

[9] https://www.nationalgrideso.com/future-energy/our-progress-towards-net-zero/carbon-intensity-dashboard
[10] https://www.smartgriddashboard.com/#all/co2, selecting Northern Ireland drop-down option, selecting CO_2, selecting Month within CO_2 intensity over time, then View in Table, download .CVS
[11] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal Data Tables 1-19, Table 1, column I (for industrial consumption)

2027	70.49	19.58
2028	61.10	16.97
2029	51.62	14.34
2030	47.62	13.23
2031	40.01	11.11
2032	31.51	8.75
2033	25.01	6.95
2034	20.12	5.59
2035	19.41	5.39
2036	18.91	5.25
2037	17.67	4.91
2038	17.24	4.79
2039	16.21	4.50
2040	15.45	4.29
2041	14.72	4.09
2042	13.98	3.88
2043	8.80	2.44
2044	8.18	2.27
2045	7.60	2.11
2046	7.43	2.06
2047	5.14	1.43
2048	4.99	1.39
2049	3.17	0.88
2050	2.41	0.67

Electricity Curtailment Avoidance

DA.29. Where an operational Hydrogen Production Facility can evidence Electricity Curtailment Avoidance, the GHG Emission Intensity for this volume of electricity may use either the appropriate regional or national GHG Emission Intensity figure for the Reporting Unit. Evidence of Bid Offer Acceptances in GB is provided via Elexon's Balancing Mechanism Reporting Service[12] or National Grid Electricity System Operator's Data Hub[13], and in NI is provided by SEM-O Market Data[14].

DA.30. For Hydrogen Production Facilities in GB claiming a regional GHG Emission Intensity, the regional GHG Emission Intensity value to be used for the Reporting Unit shall be determined by the Distribution Network Operator licenced area in which the Hydrogen Production Facility BMU is located. These regional GHG Emission Intensities are only to be used for the volumes of electricity relating to Bid Offer Acceptance within the Balancing Mechanism – not any volumes involving contracted import of grid average electricity. GB regional electricity GHG Emission Intensity data is available using the National Grid approved "Carbon Intensity API"[15], and values already include Transmission and Distribution Losses. This regional 30 minute data shall be used for the relevant Reporting Unit once the Reporting Unit has passed – earlier forecast data for the Reporting Unit shall not be used (as this is updated every 30 minutes ahead of the Reporting Unit).

DA.31. For Hydrogen Production Facilities in GB claiming the national GHG Emission Intensity (instead of a regional GHG Emission Intensity), the average GHG Emission Intensity for the Reporting Unit for GB from the National Grid ESO Dashboard[16] shall be used. These values already include Transmission and Distribution Losses.

DA.32. For Hydrogen Production Facilities in NI, Northern Ireland will be treated as its own region for purposes of determining the GHG Emission Intensity of any Bid Offer Acceptance under the Balancing Market. Per Reporting Unit, 30-minute GHG Emission Intensities for NI from the Eir Grid Smart Dashboard[17] shall be used. These values already include Transmission and Distribution Losses. Note that this 30-minute GHG Emission Intensity shall be taken as a simple arithmetic mean of two 15-minute periods, for example, the GHG Emission Intensity between 10:00-10:30 is a mean of the two GHG Emission Intensities at 10:00 and 10:15 respectively.

DA.33. For Hydrogen Production Facilities in GB or NI, the REGO Percentage of any Bid Offer Acceptance electricity volumes shall be set as 0%.

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[12] https://www.bmreports.com/bmrs/?q=help/about-us
[13] https://www.nationalgrideso.com/data-portal
[14] https://www.sem-o.com/market-data/
[15] https://carbonintensity.org.uk/
[16] https://www.nationalgrideso.com/future-energy/our-progress-towards-net-zero/carbon-intensity-dashboard
[17] https://www.smartgriddashboard.com/#all/co2, selecting Northern Ireland drop-down option, selecting Month for CO2 intensity over time, then View in Table, download .CVS

Stored Electricity via an Energy Storage System

DA.34. Hydrogen Production Facilities shall either use the 30-minute Self Discharge Loss values in Table 6, or evidence the 30-minute Self Discharge Loss value for the Electricity Storage System from which they source their electricity, as per Annex C Paragraphs C.10-C.12 of the Standard Document.

Table 6: Conservative Self Discharge Loss values for Electricity Storage Systems

Electricity Storage System	Loss per 30 minutes
Lithium ion battery[18]	0.0027%
Lead acid battery[19]	0.0072%
Nickel cadmium battery[18]	0.013%
Nickel metal hydride battery[18]	0.015%
LSD-nickel metal hydride battery[18]	0.0027%
Zinc manganese battery[18]	0.00034%
Pumped storage hydroelectricity[19]	0.00042%
Compressed air energy storage[19]	0.021%
Liquid air energy storage[19]	0.021%
Flywheel[19]	7.5%
Gravity-based energy storage[20]	0%
Liquid CO_2 energy storage[21]	0.021%
Sensible heat energy storage[22]	0.021%
Latent heat energy storage[22]	0.021%
Thermochemical energy storage[22]	0.021%
Supercapacitor[22]	0.83%
Superconducting magnetic energy storage[19]	0.31%

DA.35. Hydrogen Production Facilities shall either use the Round Trip Efficiency values in Table 7, or evidence the Round Trip Efficiency of the Electricity Storage System from which they source their electricity, as per Annex C Paragraphs C.13-C.14 of the

[18] Umweltbundesamt Table 3, Page 20 https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/4414.pdf
[19] https://sei.info.yorku.ca/files/2013/03/Sauer2.pdf
[20] https://www.mdpi.com/1996-1073/16/2/825
[21] https://www.sciencedirect.com/science/article/pii/S2352152X22017704
[22] https://www.sciencedirect.com/science/article/pii/S1364032122001368

Standard Document. The Round Trip Efficiency values in Table 7 are calculated from charging and discharging losses, electrical equipment losses and from any cooling requirements.

Table 7: Conservative Round Trip Efficiencies for Electricity Storage Systems

Electricity Storage System	Round Trip Efficiency
Lithium ion battery[23, 24, 25]	70.9%
Lead acid battery[23,24,25]	44.3%
Nickel cadmium battery[23,24,25]	62.1%
Nickel metal hydride battery[23,24,25]	57.6%
Pumped storage hydroelectricity[26]	45.7%
Compressed air energy storage[26]	34.6%
Liquid air storage[26]	34.6%
Flywheel[27]	77.1%
Gravity-based storage[26]	62.8%
Liquid CO_2 storage[26]	62.8%
Sensible heat storage[22]	44.0%
Latent heat storage[26]	16.2%
Thermochemical storage[22]	25.4%
Supercapacitor[27]	81.8%
Superconducting magnet[28]	72.3%

Projected data for Transmission and Distribution Losses pre-operations

DA.36. Where pre-operational Hydrogen Production Facilities intend to claim the delivered GHG Emission Intensity of a specific generation asset (or Electricity Storage Systems) via an Eligible PPA, or where pre-operational Electricity Storage Systems intend to claim the delivered GHG Emission Intensity of an specific generation asset

[23] Heating and cooling loss of battery Figures 18 and 19 https://onlinelibrary.wiley.com/doi/epdf/10.1002/ecj.12221
[24] Cooling equipment COP efficiency Air chiller and water chiller https://www.sciencedirect.com/science/article/pii/S1876610214033372#:~:text=Under%20standard%20rating%20conditions%20at,6.39%20for%20water%2Dcooled%20chillers
[25] Battery Charging and Discharging Losses: Frontiers of Mechanical Engineering, Table 1, https://link.springer.com/article/10.1007/s11465-018-0516-8
[26] McKinsey (2023) Net-zero power: Long duration energy storage for a renewable grid, Exhibit 9, available at: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/net%20zero%20power%20long%20duration%20energy%20storage%20for%20a%20renewable%20grid/net-zero-power-long-duration-energy-storage-for-a-renewable-grid.pdf
[27] https://eprints.whiterose.ac.uk/154479/1/2016_05_05_MA_Modified_Manuscript_NotMarked.pdf
[28] https://www.arup.com/perspectives/publications/research/section/five-minute-guide-to-electricity-storage

via an Eligible PPA, Table 8 provides the projected Transmission and Distribution Losses that shall be used. These projected Transmission and Distribution Losses have been calculated as an average of the five National Grid Future Energy Scenarios[29], and are assumed to apply to GB and NI pre-operational facilities. These values shall not be used once Facilities or Electricity Storage Systems are operational.

Table 8: Projected Transmission and Distribution Losses for pre-operations

Year	Transmission Loss	Distribution Loss	Total T&D Loss
2023	2.3%	5.2%	7.4%
2024	2.2%	5.2%	7.3%
2025	2.2%	5.1%	7.2%
2026	2.2%	5.1%	7.2%
2027	2.1%	5.0%	7.0%
2028	2.1%	5.0%	7.0%
2029	2.1%	5.0%	7.0%
2030	2.1%	4.9%	6.9%
2031	2.1%	4.9%	6.9%
2032	2.1%	4.9%	6.9%
2033	2.1%	4.8%	6.8%
2034	2.1%	4.8%	6.8%
2035	2.1%	4.8%	6.8%
2036	2.1%	4.8%	6.8%
2037	2.1%	4.7%	6.7%
2038	2.1%	4.7%	6.7%
2039	2.1%	4.7%	6.7%
2040	2.0%	4.7%	6.6%
2041	2.0%	4.6%	6.5%
2042	2.0%	4.5%	6.4%

[29] National Grid FES 2022 Data Workbook, Tab ED1, 2023-2050 columns, using mean value of Rows 6-10 (total TWh demand), 111-115 (transmission TWh losses) and 116-120 (distribution TWh losses). https://www.nationalgrideso.com/future-energy/future-energy-scenarios/documents

2043	1.9%	4.4%	6.2%
2044	1.9%	4.3%	6.1%
2045	1.9%	4.3%	6.1%
2046	1.8%	4.2%	5.9%
2047	1.8%	4.2%	5.9%
2048	1.8%	4.1%	5.8%
2049	1.8%	4.1%	5.8%
2050	1.8%	4.0%	5.7%

Typical data for Transmission and Distribution Losses during operations

DA.37. If both the operational Hydrogen Production Facility and specific generation asset are located in GB, the Facility shall determine Transmission Loss Factors (TLFs) and Distribution Line Loss Factors (LLFs) using data from the Elexon Portal[30].

DA.38. If both the Hydrogen Production Facility and specific generation asset are based in Northern Ireland, the following sources shall be used:

- Transmission Loss Adjustment Factors (TLAFs) are available via Eir Grid[31].
- The Distribution Loss Adjustment Factors (DLAFs) are located in the NIE Networks Statement of Charges for use of the Distribution System (DuoS)[32].

Heat and steam

DA.39. Typical values for heat and steam generation GHG Emission Intensities are not provided and shall be calculated following the methodology given in Annex G of the Standard Document. This is because the input sources, conversion efficiencies and system configurations for steam and heat generation vary widely. Thermal losses during the supply of steam and/or heat from the generation asset to the Hydrogen Production Facility also need to be factored in to derive a delivered heat and/or steam GHG Emission Intensity (in gCO_2e/MJ_{th}) for use by the Hydrogen Production Facility.

DA.40. If there is Useful Heat or Useful Steam exported by generation asset for heating buildings at a temperature below 150°C (423.15 Kelvin), the Carnot Efficiency C_h used in Equation 59 of the Standard Document can be set as 0.3546. Similarly, if the Hydrogen Production Facility exports Useful Heat or Useful Steam for heating

[30] https://www.elexonportal.co.uk/registration/newuser
[31] https://www.eirgridgroup.com/customer-and-industry/general-customer-information/tlafs/
[32] https://www.nienetworks.co.uk/about-us/regulation/network-charges

buildings at a temperature below 150°C (423.15 Kelvin), the Carnot Efficiency C_h used in Equation 59 of the Standard Document can be set as 0.3546.

Fuel

DA.41. When calculating the emissions associated with the production and supply of fuels, the following fuel GHG Emission Intensities in Table 9 shall be used in conjunction with the fuel Activity Flow Data. These GHG Emission Intensities already consider representative transport emissions associated with delivery to a Hydrogen Production Facility site, and so do not need any adjustment for transportation.

Table 9: Fuel GHG Emission Intensity (production & supply, without combustion/conversion)

Fuel	gCO_2e/MJ_{LHV}	Sources and supporting notes
Diesel	17.5	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions[33], 100% Mineral Diesel
Petrol	18.3	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions, 100% Mineral Petrol
Natural gas (Transmission Network, 7-94bar)	8.7	UK National Statistics (2023) Energy Trends[34] for the mix of natural gas sources consumed in the UK; NSTA (2023)[35] for CO_2 intensities; NSTA (2023)[36], SPGlobal (2023)[37] and ThinkStep (2017) [38] for CH_4 intensities; ~0.13% own use of gas from National Grid (2023)[39]; ~0.1% Transmission Network losses from Boothroyd et al. (2018)[40]; natural gas 92% mol methane or 86% by mass from EA (2016) [41]; natural gas combustion factor from Table 11.
Natural gas (intermediate/medium pressure Distribution	9.2	As above, but also including ~0.43% leakage, 0.006% own use and 0.01% theft, from JOGT (2023)[42]; ~0.1% leakage and all above ground installation leakage attributed to medium pressure distribution, from JOGT (2022)[43]

[33] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1083855/ghg-conversion-factors-2022-full-set.xls
[34] https://www.gov.uk/government/statistics/gas-section-4-energy-trends
[35] https://www.nstauthority.co.uk/the-move-to-net-zero/net-zero-benchmarking-and-analysis/natural-gas-carbon-footprint-analysis/
[36] https://www.nstauthority.co.uk/media/bicn5tva/nsta-emissions-monitoring-report-2023-final-accessible.pdf
[37] https://www.spglobal.com/esg/insights/featured/special-editorial/greenhouse-gas-intensity-of-the-north-sea
[38] https://globallnghub.com/wp-content/uploads/attach_380.pdf
[39] https://www.nationalgas.com/balancing/unaccounted-gas-uag
[40] https://www.sciencedirect.com/science/article/pii/S0048969718306399
[41] Table 3: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/545567/Material_comparators_for_fuels_-_natural_gas.pdf
[42] https://www.gasgovernance.co.uk/index.php/shrinkage/aa2023
[43] https://www.gasgovernance.co.uk/sites/default/files/ggf/book/2022-03/2021-22%20Shrinkage%20and%20Leakage%20Model%20Review_FINAL%20REPORT.pdf

Network, 75mbar to 7bar)		
Natural gas (low pressure Distribution Network, up to 75mbar)	11.2	As above, but also including a further ~0.36% leakage and all interference damage attributed to low pressure distribution, a further 0.006% own use and 0.01% theft, from JOGT (2022)[44]
Marine gas oil	17.5	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Fuel oil	17.5	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Fossil methanol	28.2	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation[45]
Biomethanol	37.6	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Bioethanol	27.0	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Biodiesel FAME	13.5	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Biodiesel HVO	8.1	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions

[44] https://www.gasgovernance.co.uk/sites/default/files/ggf/book/2022-03/2021-22%20Shrinkage%20and%20Leakage%20Model%20Review_FINAL%20REPORT.pdf
[45] https://publications.jrc.ec.europa.eu/repository/handle/JRC115952

Input Materials

DA.42. When calculating the emissions associated with the provision of Input Materials, the following GHG Emission Intensities in Table 10 shall be used in conjunction with material Activity Flow Data. These GHG Emission Intensities include manufacture of the material, and based on the references provided, are assumed to also include transport to a Hydrogen Production Facility. The exceptions are for desalinated water, oxygen and nitrogen, where the values given are for manufacture by a co-located third party directly adjacent to the Hydrogen Production Facility, so transport emissions shall be calculated and added if required for these Inputs. Future versions of the Data Annex may provide more explicit transport assumptions for all the Input materials listed.

DA.43. The Table 10 factors do not consider emissions resulting from the combustion or conversion of these Input Materials within the Hydrogen Production Facility (these combustion/conversion emissions are to be covered within the Process CO_2 and Fugitive non-CO_2 Emission Categories).

DA.44. If using a material that is not listed in Table 10, the references given in the bullets below shall be consulted to source and evidence a suitable GHG Emission Intensity, or else a robust value from peer reviewed academic literature shall be evidenced, with justification for the applicability of the value chosen.

- UK Government conversion factors for Company Reporting[46]
- RTFO guidance[47]
- RTFO Carbon Calculator[48]
- RTFO carbon intensity templates[49]
- RED II text[50]
- JEC WTT v5[51]
- JRC updated input data for biofuel GHG default values[52]
- JRC updated data for solid/gaseous biogenic GHG default values[53]
- Biograce II biomass electricity, heating, cooling calculator (RED II compliant)[54]

[46] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023
[47] https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-compliance-reporting-and-verification
[48] https://www.gov.uk/government/publications/biofuels-carbon-calculator-rtfo
[49] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/947712/carbon-intensity-data-templates-2021.ods
[50] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
[51] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/jec-well-tank-report-v5
[52] https://op.europa.eu/en/publication-detail/-/publication/7d6dd4ba-720a-11e9-9f05-01aa75ed71a1
[53] https://publications.jrc.ec.europa.eu/repository/handle/JRC104759
[54] https://www.biograce.net/biograce2/

- Biograce I biofuels calculator (RED I compliant)[55]
- EcoInvent database of GHG emissions[56] (old values[57])
- IEA Net Zero Emissions by 2050 scenario[58]

Table 10: Input Materials GHG Emission Intensities (manufacture & supply, no combustion/conversion)

Material	gCO_2e/kg	Sources and supporting notes
Mains water	0.18	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Desalinated water from co-located third party, using grid power	1.15	IRENA (2012)[59] mid-point efficiency (3.5-5 kWh_e/m^3) for large-scale Reverse Osmosis of sea water with UK grid electricity factor; Shahabi et al. (2014) Environmental Life Cycle Assessment of seawater reverse osmosis desalination plant powered by renewable energy[60] for emissions associated with chemicals
Oxygen (liquid) from co-located third party, using grid power	51	Linde (2009)[61] assumes 245 kWh_e/tonne power usage in cryogenic separation, and UK grid electricity factor
Oxygen from co-located third party, using wind/solar	0	Nil intensity, due to nil intensity of input power
Nitrogen (gaseous) from co-located third party, using grid power	23	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation used for inputs of assuming 0.4 MJ_e/kg and UK grid electricity factor
Nitrogen (liquid) from co-located third party, using grid power	54	Wu et al. (2020)[62] for 0.258 kWh_e/kg power usage in cryogenic separation, and UK grid electricity factor

[55] http://www.biograce.net/home
[56] https://ecoinvent.org/the-ecoinvent-database/use-of-the-ecoinvent-database/
[57] https://web.archive.org/web/20190605065129/http://www.arb.ca.gov/fuels/lcfs/workgroups/lcfssustain/ISCC_EU_205_GHG_Calculation_and_GHG_Audit_2.3_eng.pdf
[58] https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf
[59] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2012/IRENA-ETSAP-Tech-Brief-I12-Water-Desalination.pdf
[60] https://www.sciencedirect.com/science/article/abs/pii/S0960148113006289
[61] https://ieaghg.org/docs/oxyfuel/OCC1/Plenary%201/Beysel_ASU_1stOxyfuel%20Cottbus.pdf
[62] https://www.sciencedirect.com/science/article/abs/pii/S0959652620330729

Nitrogen from co-located third party, using wind/solar	0	Nil intensity, due to nil intensity of input power
Sodium hydroxide (NaOH) solution	530	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Potassium hydroxide (KOH) solution	419	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Calcium oxide (CaO, pure)	1,193	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Calcium carbonate ($CaCO_3$, pure)	440	GHG Protocol (2005) Calculation Tools for Estimating GHG emissions from pulp and paper mills[63]
Sodium carbonate (Na_2CO_3, pure)	1,245	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Sodium hypochlorite (NaClO)	920	Winnipeg (2012)[64]
Sodium methoxide ($NaCH_3O$)	2,426	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Sodium bisulphite ($NaHSO_3$)	440	Winnipeg (2012)
Salt (NaCl)	8.3	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation used for inputs of power, diesel, natural gas heating and explosives. Input intensities for UK grid electricity, UK diesel, UK natural gas heating using 90% efficient boiler, ANFO emissions factor[65]
Hydrochloric acid (HCl) solution	1,061	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Sulphuric acid (H_2SO_4)	218	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Phosphoric acid (H_3PO_4)	3,125	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Boric acid (H_3BO_3)	720	Winnipeg (2012)

[63] https://ghgprotocol.org/sites/default/files/2023-03/Pulp_and_Paper_Guidance.pdf
[64] https://www.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_Appendix_H-WSTP_South_End_Plant_Process_Selection_Report/Appendix%207.pdf
[65] https://iaac-aeic.gc.ca/050/documents/p62225/104540E.pdf

Lubrication oils	947	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Cyclohexane	723	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Monoethanolamine (MEA)	3,400	Cuellar-Franca et al. (2016) A novel methodology for assessing the environmental sustainability of ionic liquids used for CO2 Capture[66]
Ammonia (NH_3) from unabated natural gas	2,288	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation used for inputs of power and natural gas. Input intensities for UK grid electricity factor, UK natural gas
Urea (CH_4N_2O) from unabated natural gas	1,640	JRC (2019) Definition of input data to assess GHG default emissions from biofuels in EU legislation
Activated carbon	5,270	Winnipeg (2012), using Mineral sources

Process CO_2 emissions

DA.45. To calculate the amount of CO_2 generated from the conversion/combustion of feedstock, or feedstock material also used as a fuel, Hydrogen Production Facilities shall use the methodology set out in Annex H of the Standard Document. The values in Table 11 shall not be used to calculate the amount of CO_2 generated from the conversion of feedstocks.

DA.46. When calculating the amount of CO_2 generated from the combustion of any non-feedstock fuels (prior to any CO_2 Capture), the following CO_2 Emission Intensities in Table 11 shall be used in conjunction with the fuel Activity Flow Data. Note that these factors do not include the input production and supply of these fuels to the hydrogen production site, which are considered in the Fuel Supply Emission Category.

DA.47. If using a fuel or material that is not listed in Table 11, the same references as in Paragraph DA.44 shall be consulted to evidence a suitable CO_2 Emission Intensity, or else a robust value from peer reviewed academic literature shall be evidenced, with justification for the applicability of the value chosen.

[66] https://pubs.rsc.org/en/content/articlepdf/2016/fd/c6fd00054a

Table 11: Fuel combustion CO_2 Emission Intensity (no production or supply emissions included)

Source	gCO_2/MJ_{LHV}	gC_{fossil}/kg	Sources and supporting notes
Diesel	74.4	864	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions, 100% Mineral Diesel
Petrol	70.7	856	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions, 100% Mineral Petrol
Natural Gas	56.7	703	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions, 100% Mineral Blend
Marine gas oil	75.0	875	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Fuel oil	77.8	881	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Fossil methanol	68.9	374	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions, using biomethanol Outside of Scopes
Biomethanol	0	0	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Bioethanol	0	0	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Biodiesel FAME	0	0	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions
Biodiesel HVO	0	0	UK government (2023) conversion factors for company reporting of Greenhouse Gas emissions

Fugitive non-CO_2 emissions

DA.48. No Typical Data is provided for this Emissions Category.

CO_2 Capture and Network Entry

DA.49. Pathways where the Inputs of energy and materials to operate CO_2 Capture and Sequestration equipment are not included in the above Emission Categories, and/or those Pathways where CO_2 is transported, purified, and/or compressed offsite prior to the CO_2 T&S Network Delivery Point shall calculate their emissions under this category using the same Typical GHG Emission Intensities given in Paragraphs DA.20-DA.45 used to calculate the emissions for Energy Supply and Input Materials Emission Categories.

CO_2 Sequestration

DA.50. All CO_2 sources (e.g. fossil, biogenic) are treated equally under this Emission Category, with 1 tonne of CO_2 meeting the requirements of Paragraph 5.49 of the Standard Document being given a credit of 1 tonne of CO_2 for this Emission Category.

Solid Carbon Distribution

DA.51. Pathways where solid carbon is collected, transported, stored, purified or densified offsite prior to its final use shall calculate their emissions under this Emission Category using the same Typical GHG Emission Intensities for Energy Supply and Input Materials as given in Paragraphs DA.20-DA.45.

DA.52. This term only applies to solid carbon generated from gas splitting Pathways and does not apply to other Pathways.

Solid Carbon Sequestration

DA.53. This Emission Category only currently applies to solid carbon generated from gas splitting Pathways and does not apply to other Pathways.

DA.54. For a gas splitting Pathway to be eligible under the Standard, all of the solid carbon generated shall be used in one of the following Solid Carbon Permissible End Uses:

- incorporated into concrete or cement for construction; or

- kept in inert underground storage (e.g. disused mines and bunkers, inert landfill, spent oil and gas wells).

DESNZ may consider adding further Solid Carbon Permissible End Uses in the future, based on any evidence submitted following Paragraphs 4.4-4.7 of the Standard Document.

DA.55. Solid Carbon arising from fossil Inputs meeting the requirements of Paragraph 5.57 of the Standard Document shall be assigned a nil sequestration credit for this Emission Category. Solid Carbon arising from biogenic Inputs meeting the requirements of Paragraph 5.57 of the Standard Document shall be assigned a sequestration credit of 3.664 gCO_2e/gC for this Emission Category (using the elemental carbon within the Solid Carbon, see Equation 64 of the Standard Document.

Compression and Purification of hydrogen

Compression of hydrogen

DA.56. 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 GHG Emission Intensities.

DA.57. **If using Projected or Measured Data for Energy Supply, and H_2 Output pressure is below 3MPa.** Paragraph DA.61 below shall be used to calculate the additional theoretical GHG Emission Intensity required to achieve an outlet pressure of p_1 = 3MPa, to add to the GHG Emission Intensity result.

DA.58. **If using Default Data for Energy Supply and H_2 Output pressure is below 3MPa**. The emissions associated with hydrogen compression to 3MPa have already been accounted for within the Energy Supply Default Data, so Paragraph DA.61 below shall not be used.

DA.59. **If using Projected or Measured Data for Energy Supply and H_2 Output pressure is above 3MPa.** The total emissions associated with compression to the outlet pressure shall be accounted for within the Energy Supply Emission Category, and Paragraph DA.61 below shall not be used.

DA.60. **If using Default Data for Energy Supply and H_2 Output pressure is above 3MPa.** If a pre-operational Hydrogen Production Facility is using Default Data for the Energy Supply Emission Category, they shall use Paragraph DA.61 below to calculate the theoretical additional GHG emissions associated with raising the hydrogen pressure p_0 from the 3 MPa already included within the Default Data to their expected outlet pressure p_1.

DA.61. The GHG emissions from energy use for (theoretical) compression shall be calculated as follows:

Equation 2

$$EI_{compression} = A \times B \times \frac{1kg}{120\ MJ_{LHV}}$$

Where:

- $EI_{compression}$ = Hydrogen Product added GHG Emission Intensity from electricity use for theoretical compression, in gCO_2e/MJ_{LHV} H_2.
- A = Electricity required to compress hydrogen (with losses), in kWh_e/kg H_2.
- B = Delivered electricity GHG Emission Intensity, in gCO_2e/kWh_e, adjusting for any Transmission and Distribution Losses. B shall be at least as large as the annual weighted average GHG Emission Intensity of the electricity sources consumed by the Hydrogen Production Facility (e.g. a nil GHG Emission Intensity cannot be assumed for B if the Facility only consumes grid average electricity). If grid average electricity is used as part of the annual weighted average mix of electricity sources being claimed under B, use Table 5 for the grid imported electricity volumes Table 5if the Hydrogen Production Facility is pre-operational, or if operational, use the annual average data from the latest Government conversion factors for company reporting[67] (30 minute grid GHG Emission Intensity data is not required for theoretical compression calculations).

Compression energy, A, is calculated as follows:

Equation 3

$$A = \frac{W}{3.6 \times \eta}$$

Where W is defined as the specific compression power, and η is the adiabatic efficiency, which can be taken from Table 12.

Equation 4

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

Where n is the adiabatic coefficient, p_o and p_1 are the respective inlet and outlet pressures, as defined in Table 12. V_0 is the input specific volume (of hydrogen), as defined below.

Equation 5Table

[67] Government conversion factors for company reporting of Greenhouse Gas emissions, Full set workbook, summing factors for UK electricity generation and Transmission & Distribution, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

$$V_0 = k \times p_0{}^{\alpha}$$

Where α is the power law exponent and k is a constant. The values of α and k shall be taken from Table 13 (derived using a line of best fit derived from hydrogen density data[68]), using the temperature closest to the compressor inlet temperature. For example, a hydrogen production outlet temperature of 40°C shall use the α and k values for 50°C.

Table 12: Terms and units for Compression and Purification calculations

Term	Provided value	Units	Definition
A	Equation 3	kWh_e/kg	Compression energy
W	Equation 4	MJ/kg	Specific compression power
p_o	Operator	MPa	Input pressure
p_1	Operator	MPa	Output pressure
V_0	Equation 5	m^3/kg	Input specific volume
n	1.41	-	Adiabatic coefficient
η	60%	%	Adiabatic efficiency
α	Table 13	-	Power law exponent
k	Table 13	-	Constant
P_C	0.0013	kWh_e/kgH_2	Purity correction factor (assuming starting pressure ≥ 3MPa)

Table 13: Line of best fit parameters for Equation 5 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

[68] 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

Purification of hydrogen

DA.62. 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 GHG Emission Intensities.

DA.63. Hydrogen producers with Measured hydrogen purity of less than 99.9% by volume shall calculate the theoretical emissions associated with theoretical purification up to 99.9% by volume. The following theoretical purification Equation 6 shall be used, and assumes a minimum starting pressure of 3MPa is input into pressure swing absorption equipment.

DA.64. To utilise Equation 6, the GHG emissions associated with compression to a minimum of 3MPa must have already been accounted for either in the Energy Supply Emission Category, or theoretically using Paragraphs DA.56 – DA.61.

DA.65. If Energy Supply Default Data is being used for a pre-operational Hydrogen Production Facility, the GHG emissions associated with purification to 99.9% (or higher) by volume have already been accounted for, and Equation 6 shall not be used.

Equation 6

$$EI_{purification} = P_c \times B \times \frac{1kg}{120\ MJ_{LHV}}$$

Where:

- $EI_{purification}$ = Hydrogen Product added GHG Emission Intensity from electricity use for theoretical purification, in $gCO_2e/MJ_{LHV}\ H_2$.
- P_C = Electricity required to purify hydrogen of 3MPa or higher to a purity of 99.9% (with losses), in $kWh_e/kg\ H_2$, as found in Table 12.
- B = as defined above in Paragraph DA.61.

Fossil Waste/Residue Counterfactual

Fossil fraction of RDF counterfactual

DA.66. 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.

DA.67. The current counterfactual for the fossil fraction of Refuse Derived Fuel (RDF) shall be an energy from waste (EfW) plant that produces only electricity at 22% net electrical Lower Heating Value (LHV) efficiency, without Useful Heat sales and without any CCS. The current counterfactual is focused only on the fossil Waste/Residue feedstock CO_2 emissions emitted (and displaced utility), but not any non-CO_2 emissions arising from conversion of the fossil Waste/Residue feedstock in the counterfactual, nor any change in other inputs used in the counterfactual (for example, fossil heating oil use for plant start-up), nor any change in the supply chain for fossil Waste/Residue feedstocks.

DA.68. The displaced electricity is assumed to be supplied by UK grid average electricity, with the annual average GHG Emission Intensity data from the latest Government conversion factors for company reporting[69] if the Hydrogen Production Facility has started operations, or from Table 5 for the relevant future year of operations if the Hydrogen Production Facility is yet to start operations. Note that 30 minute UK grid electricity intensity data is not required for counterfactual emissions calculations – only annual average data is required.

DA.69. 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 shall instead be taken as the specific EfW plant. This means the Hydrogen Production Facility shall use the electricity and heat efficiencies from the specific EfW plant to calculate the displaced electricity (and any heat), along with the GHG Emission Intensity of the grid electricity (and any replacement natural gas for heating) in the relevant year of operations. In this particular case, any CCS at the specific EfW plant will not impact the overall hydrogen GHG Emission Intensity, as CCS is used regardless of the destination of the diverted electricity.

Refinery Off-Gases (Residue) counterfactual

DA.70. DESNZ may update the counterfactual outlined in this section in the future based on the development of the UK refining industry, CO_2 T&S Networks and other relevant UK policies.

DA.71. If ROG is classified as a Residue with a counterfactual, the counterfactual for ROG shall be the unabated use of fossil natural gas. It is assumed that ROG and fossil natural gas would have the same LHV energy efficiency when converted in onsite furnaces to heat or in onsite boilers to steam regardless of where ROG-derived hydrogen is used. The natural gas supply GHG Emission Intensity in Table 9 (for Transmission Network withdrawals) shall be added to the natural gas CO_2 Emission Intensity in Table 11, and this combined intensity result (in gCO_2e/MJ_{LHV} natural gas) shall be assigned to the ROG at the start of the Pathway GHG Emission Intensity calculations (the same value in gCO_2e/MJ_{LHV} ROG). After conversion efficiency

[69] Government conversion factors for company reporting of Greenhouse Gas emissions, Full set workbook, summing factors for UK electricity generation and Transmission & Distribution, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

impacts, these high counterfactual GHG emissions will be largely, but likely not entirely, cancelled out by the CO_2 Sequestration Emission Category credit for reforming with CCS Pathways.

DA.72. If ROG is classified as a Co-Product, no counterfactual applies.

Default Data

Use of Default Data

DA.73. Prior to Hydrogen Production Facility operations commencing, if Projected Data is not available, Default Data can be used instead of Projected Data for a few of the Emission Categories. Default Data is only provided for the Feedstock Supply, Energy Supply and Input Materials Emission Categories, and is only provided for the following Pathways:

- Steam methane reformation (SMR) using UK natural gas with CCS
- Auto thermal reformation (ATR) using UK natural gas with CCS
- Food waste biomethane directly connected to autothermal reformation (ATR) with CCS (if CCS not implemented, the default values provided for the Pathway with CCS can still be used)
- Forestry residue gasification with CCS (if CCS 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 CCS (if CCS 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 nuclear electricity

DA.74. If pre-operational electrolysis Hydrogen Production Facilities plan to use different electricity sources to the list above, they may still use the Default Data for the Input Materials Emission Category (but not the Energy Supply Emission Category). If pre-operational fossil gas reforming with CCS Hydrogen Production Facilities plan to use different gas feedstocks to the list above, they may still use Default Data for the Energy Supply and Input Materials Emission Categories (but not the Feedstock Supply Emission Category). Pre-operational gasification Hydrogen Production Facilities using different biomass or Waste feedstocks to the list above shall not use Default Data, due to potentially significant changes in their Inputs. Prior to operations, any Pathway not listed above shall use Projected Data in their hydrogen GHG Emission Intensity calculations. A summary of which Default Data values can currently be applied across which pre-operational Pathway Emission Categories is given below in Table 14.

Table 14: Ability to use default factors for pre-operational Pathway Emission Categories

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	No, divide grid electricity GHG Emission Intensity by default electrolysis LHV efficiency (0.586 MJ_{LHV} H_2/MJ_e)	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

DA.75. Default Data is not provided for the Process CO_2 emissions, CO_2 Capture and Network Entry, CO_2 Sequestration, Solid Carbon Distribution, Solid Carbon Sequestration, Fugitive non-CO_2 emissions and Fossil Waste/Residue

Counterfactual Emission Categories. These Emission Categories will always have to be projected by pre-operational Hydrogen Production Facilities, and once operational shall use Measured Data.

DA.76. For the Compression and Purification category, the Energy Supply Default Data provided already accounts for the emissions that will be required to reach the theoretical minimum pressure and purity under the Standard (3 MPa and 99.9 vol% purity). However, if non-Default Data is being used for the Energy Supply category, and the hydrogen Output pressure or purity is planned to be below the theoretical minimum, the data and methodology provided in Paragraphs DA.56 – DA.61 shall be used to calculate the theoretical additional emissions. Similarly, if Default Data for the Energy Supply category is being used, but the hydrogen Output pressure or purity is planned to be above the theoretical minimum, the data and methodology provided in Paragraphs DA.56 – DA.61 shall be used to calculate the additional emissions.

DA.77. The Standard Document and Data Annex have been developed into a Hydrogen Emissions Calculator (HEC) to support pre-operational Hydrogen Production Facilities in checking their likely compliance against the Standard. The Default Data provided below, and the theoretical compression and purification calculations, are already built into the HEC.

DA.78. 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 Network, and Energy Supply emissions for grid average electrolysis, neither of which were multiplied by the conservative factor.

DA.79. All Default Data for electricity inputs to Pathways have been derived assuming an Estimated 2025 UK grid electricity GHG Emission Intensity of 35.2 gCO_2e/MJ_e. The exception is electrolysis using grid average electricity, where the projected grid average GHG Emission Intensity in the relevant future year (from Table 5) shall be divided by a default electrolysis LHV efficiency of 58.6%, without any conservative factor applied.

Default Data tables

DA.80. DESNZ will update the following Default Data values over time to respond to industry developments and changes in the relevant input GHG Emission Intensities that were used to derive these Default Data values.

Feedstock Supply

DA.81. Feedstock Supply emissions cover the GHG emissions arising from feedstock cultivation, harvesting, collection, pre-processing, storage, and transportation. Depending on the Pathway, this term could include fossil natural gas, uranium, biomethane, solid biomass feedstocks and Waste feedstocks.

DA.82. Note that Feedstock Supply for the food waste biomethane Pathway includes the emissions from food waste collection through to anaerobic digestion biogas production up to the point of biomethane delivery to the reformer plant via direct pipeline connection.

DA.83. Counterfactual emissions for Waste/Residue fossil feedstocks are considered separately to this Emissions Category.

Table 15: Default Data for Feedstock Supply

Production pathway	GHG Emission Intensity (gCO_2e/MJ_{LHV} Hydrogen Product)
UK grid natural gas to SMR	11.16
UK grid natural gas to ATR	11.45
Food Waste biomethane to ATR	5.16
Forest Residue gasification	7.94
Biogenic fraction of mixed RDF Waste gasification	3.92
Fossil fraction of mixed RDF Waste gasification	3.92
Electrolysis	NA

Energy Supply

DA.84. Energy Supply emissions are the GHG emissions associated with the supply of electricity, steam, heat, and fuels for hydrogen production (but excluding emissions associated with directly converting feedstock to hydrogen which are separately considered under the Process CO_2 Emissions Category).

Table 16: Default Data for Energy Supply

Production pathway	GHG Emission Intensity (gCO_2e/MJ_{LHV} Hydrogen Product)
SMR	0.74
ATR	4.16
Forestry residue gasification	0.00
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 from Table 5 divided by 58.6% LHV efficiency
Electrolysis using wind/solar electricity	0.00
Electrolysis using nuclear electricity	9.58

Input Materials

DA.85. Input Materials emissions refers to GHG emissions associated with the production and supply of any Input Materials (except those covered in Feedstock Supply and Energy Supply Emission Categories) to a system. This could include Inputs such as oxygen, water, salts, catalysts, solvents, acids, alkali solutions.

Table 17: Default Data for Input Materials

Production pathway	GHG Emission Intensity (gCO_2e/MJ_{LHV} Hydrogen Product)
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	0.11

Sustainability Criteria

DA.86. Voluntary schemes[70] that may be used to provide evidence of compliance with the relevant Sustainability Criteria are listed below. Note that the coverage of each is different, and one scheme may not cover all the Sustainability Criteria that a given Input is required to meet.

- Biomass Biofuels voluntary scheme (2BSvs)
- Bonsucro EU (formerly Better Sugar Cane Initiative (BSI)
- International Sustainability and Carbon Certification (ISCC)
- KZR INiG System
- Better biomass (formerly NTA 8080)
- Red tractor farm assurance combinable crops and sugar beet scheme (Red tractor)
- REDcert
- Roundtable on Sustainable Biomaterials EU RED (RSB EU RED)
- Scottish Quality farm assured combinable Crops (SQC)
- Trade Assurance Scheme for Combinable Crops (TASCC)
- Universal Feed Assurance Scheme (UFAS)

[70] These are the voluntary schemes that are recognised under the RTFO. Further information on the schemes can be found here: https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-voluntary-schemes/rtfo-list-of-recognised-voluntary-schemes

Useful References

Sources of data for Lower Heating Values

DA.87. The following references provide useful data on the Lower Heating Values (MJ/kg_{dry}) of various Inputs and Outputs, that for consistency purposes should be used within Activity Flow Data calculations for pre-operational Hydrogen Production Facilities, or if composition data for the Input or Output is not measured as per Annex H for operational Hydrogen Production Facilities:

- Renewable Transport Fuel Obligation (RTFO): compliance, reporting and verification[71]
- Greenhouse gas reporting: Conversion factors 2023[72]

Where LHV data for a particular Input or Output is not available in these references, the other references given in Paragraph DA.45 or peer reviewed academic literature may be consulted, with justification given for the applicability of the value chosen.

Unit conversions for pure hydrogen

DA.88. LHV to Higher Heating Value (HHV): To convert an LHV energy content of pure hydrogen into an HHV energy content of pure hydrogen, multiply the LHV amount of energy by 1.182 to obtain the HHV amount of energy.

DA.89. /MJ to /kWh: To convert from a per MJ H_2 measure to a per kWh H_2 measure, multiply the per MJ H_2 measure by 3.6.

DA.90. /MJ to /kg: To convert from a per MJ_{LHV} pure H_2 measure to a per kg pure H_2 measure, multiply the per MJ_{LHV} pure H_2 measure by 120.0 MJ_{LHV}/kg H_2. To convert from a per MJ_{HHV} pure H_2 measure to a per kg pure H_2 measure, multiply the per pure MJ_{LHV} H_2 measure by 141.8 MJ_{HHV}/kg pure H_2. Note that these values for MJ_{LHV} and MJ_{HHV} are for a pure hydrogen stream, while the Hydrogen Product will contain impurities.

[71] RTFO standard data, ODS file: https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-compliance-reporting-and-verification
[72] Conversion factors 2023: Full set (for advanced users) – updated 28 June 2023, Excel workbook: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

Table 18: Example conversion factors from 1.0 gCO_2e/MJ_{LHV} pure H_2

1.0 gCO_2e/MJ_{LHV} pure H_2 is equal to:
0.846 gCO_2e/MJ_{HHV} pure H_2
3.6 gCO_2e/kWh_{LHV} pure H_2
3,047 gCO_2e/MWh_{HHV} pure H_2
0.12 $kgCO_2e/kg$ pure H_2
0.12 $tCO_2e/tonne$ pure H_2

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