Cascale

HIGG FEM 2025

FEM 2025 Energy and Global Warming Calculations

Version fem2025-v0.0.32 · 11 September 2026

How the in-assessment Higg FEM 2025 energy and greenhouse gas calculations work: the answers they read, the energy densities and emission factors they apply, and the aggregates they produce.

Higg Index guidance · cascale.org

Contents

Scope

This document describes the calculations performed inside the Higg FEM 2025 assessment itself: the energy, emissions, wastewater and refrigerant values a facility and its verifier see on the platform and that are exported with the assessment.

These totals are the FEM's own simplified methodology. They are not a GHG Protocol inventory, and they are neither purely location-based nor purely market-based. They are designed to be completed consistently from a facility's utility and fuel records and to be comparable across facilities and years; they should not be read as scope 1 and scope 2 figures. The main departures from the GHG Protocol Corporate Standard and Scope 2 Guidance are:

- **No scope split and no dual reporting.** `totalGHGemissions` combines fuel combustion, company vehicles, refrigerants, purchased electricity, steam, heating and cooling into one figure. The only split published is renewable versus non-renewable sources. No location-based and market-based pair is produced.
- **Electricity mixes location and market conventions.** Purchased electricity (and chilled water) uses a single IEA country grid factor, a location-based figure. Purchased renewables are a contractual instrument and are given an emission factor of 0, or the facility's reported generation mix, which is market-based treatment: in a location-based inventory those MWh would carry the grid factor. Unbundled Energy Attribute Certificates go the other way and never reduce any total. Self-declared supplier factors are collected but not used.
- **Biogenic CO2 is inside the totals.** Biomass, biogas, biodiesel, ethanol and the biomass fractions of fabric and municipal waste carry full combustion CO2e factors, so their biogenic CO2 is counted alongside fossil CO2. The GHG Protocol reports biogenic CO2 outside the scopes and counts only the CH4 and N2O of biomass combustion in scope 1.
- **Secondary energy is modelled, not supplier-reported.** Purchased steam reported by mass, district heating and chilled water are converted with assumed generation efficiencies (0.8, 0.8 and a coefficient of performance of 3) and default factors (coal for steam and district heating, the grid for chilled water), so their MJ approximate the energy consumed at the generator rather than the energy delivered by the supplier, and their emissions are not the supplier's.
- **Refrigerant use is treated as emitted.** The quantity of refrigerant reported as used in the year is multiplied by its global warming potential; there is no leak-rate or mass-balance method.
- **Wastewater methane is outside the totals.** Biogenic emissions from wastewater treatment are reported separately as `biogenicCO2e` and are not added to `totalGHGemissions`, although wastewater CH4 is a scope 1 emission.
- **Single CO2e factors.** Each source is MJ multiplied by one kg CO2e per MJ factor on an IPCC AR6 basis. There is no gas-by-gas breakdown, no process emissions, and hydrogen is 0 regardless of how it was produced.

The GHG Protocol aligned figures (scope split, location and market-based pairs, biogenic memo items, attributed secondary sources and data-quality flags) are produced from the same answers by the Higg Assessment Model (HAM) and documented in the HAM guidance. Consumers who need inventory-grade numbers should use those. Where the two differ, the HAM guidance is the reference for HAM outputs and this document is the reference for the values inside FEM.

Answer values referenced in this document (for example `yes` and `no`) are the option indices stored with the assessment, not the display text shown to the facility.

Production and Domestic Energy Use

Data Collection

Data about production and domestic energy use is collected in the Energy section of FEM separated by facility type except in the case that a facility operates as and only as both a Finished Product Processing and Finished Product Assembler *and* Finished Product Processing represents 5% or less of the total production volume of the facility *and* the facility cannot track the energy use of the two facility types separately. In that case the Finished Product Processing energy use is reported as a part of the Finished Product Assembler facility type data. In the case that the two are combined `energyseparate` will have a value of `no`.

Domestic energy use is either reported as a part of production use, in the case that a facility cannot separate the energy usage, or separately.

You can determine whether a facility is reporting energy values split between domestic and production or combined by looking at the ref_id `ensourcetracksepdomprod` an answer of `no` means the facility is reporting combined (row 3 in the table below) and `yes` means separated (rows 1 and 2 in the table below). Because a facility will never report using both methods they may safely be summed without risk of double counting.

Raw energy use is reported in the follow ref_ids:

Scope	Usage	Unit of Measure
Domestic	ensourcequantdomestic[1]	ensourceunitdomestic[1]
Production	ensource[2]quantprod[1]	ensource[2]unitprod[1]
Domestic & Production	ensource[2]quant[1]	ensource[2]unit[1]

Where the wildcards `[1]` and `[2]` represent the energy source and facility type which may be any of the following values:

Index	Kind	Reference	Value
1	Energy Source	ensourceelectricpurch	Purchased Electricity
1	Energy Source	ensourcesteampurch	Purchased Steam
1	Energy Source	ensourcechilledwater	Purchased Chilled Water
1	Energy Source	ensourcedistrictheating	Purchased Heating (District Heating)
1	Energy Source	ensourcebiodiesel	Biodiesel
1	Energy Source	ensourcebiogas	Biogas
1	Energy Source	ensourcemicrohydro	Mini or Micro-Hydro (Onsite)
1	Energy Source	ensourcepurchrenew	Purchased Renewables
1	Energy Source	ensourcesolarphoto	Solar Photovoltaic (electricity) (Onsite)
1	Energy Source	ensourcesolarthermal	Solar Thermal (Onsite)
1	Energy Source	ensourcewind	Wind (Onsite)
1	Energy Source	ensourcecng	CNG - Compressed Natural Gas
1	Energy Source	ensourcecoal	Coal - commercial mix
1	Energy Source	ensourcecoalwaterslurry	Coal Water Slurry
1	Energy Source	ensourcediesel	Diesel
1	Energy Source	ensourcefabricwaste	Fabric Waste
1	Energy Source	ensourcefueloil	Fuel Oil - Blended
1	Energy Source	ensourcelng	LNG - Liquid Natural Gas

Index	Kind	Reference	Value
1	Energy Source	ensourcelpg	LPG - Liquid Petroleum Gas
1	Energy Source	ensourcenaturalgas	Natural Gas
1	Energy Source	ensourcepetrol	Petrol/Gasoline
1	Energy Source	ensourcepropane	Liquid Propane
1	Energy Source	ensourcebiomasscert	Biomass - Sustainably Sourced with certification
1	Energy Source	ensourcebiomassgen	Biomass - Without sustainably sourced biomass certification
2	Facility Type	finalProductAssembly	Finished Product Assembler
2	Facility Type	finishedProductProcessing	Finished Product Processing (Product Printing, Product Painting, Embroidery & Embellishments, Buffing & Polishing, Moulding etc.)
2	Facility Type	printingProductDyeingAndLaundering	Finished Product Processing (Product Dyeing, Product Laundering and Product Finishing)
2	Facility Type	hardComponentTrimProduction	Component / Sub-Assembly Manufacturing (incl Packaging)
2	Facility Type	materialProduction	Material Production
2	Facility Type	rawMaterialProcessing	Raw Material Processing
2	Facility Type	rawMaterialCollection	Raw Material Collection & Bulk Refining

So the raw value for energy usage of coal water slurry in Raw Material Collection & Bulk Refining for production would be found in either the ref_id `ensourcerawMaterialCollectionquantprodensourcecoalwaterslurry` or `ensourcerawMaterialCollectionquantensourcecoalwaterslurry` the former if `ensourcetracksepdomprod` is `yes` and the latter if it is `no` and, in that case, combined with domestic energy use but it is never the case that the energy usage can be found under both ref_ids.

Conversion to MJ

All domestic and production energy sources are converted into MJ from the reported unit in calculations with the ref_id form of

Scope	Usage
Domestic	ensourcequantdomestic[1]_mj
Production	ensource[2]quantprod[1]_mj
Domestic & Production	ensource[2]quant[1]_mj

The wild cards `[1]` and `[2]` are the energy source and facility type as above.

Energy units (kWh, MJ, mmBTU, BTU, Joule) convert directly. Mass and volume units are converted to MJ using the following energy densities which, where possible, represent the lower heating value (LHV) of the source and, regardless, use either the best available energy density or a proxy deemed as sufficiently representative. The source and conversion formula behind each density are recorded with the value in Cascale's shared reference data, which is published with the Higg Assessment Model, and are left out here for space:

Density Kind	Reference	Name	Density
Volumetric (MJ per liter)	biodiesel	Biodiesel	35.6645
Gravimetric (MJ per kg)	biodiesel	Biodiesel	40.7719
Volumetric (MJ per liter)	biogas	Biogas	0.0220
Gravimetric (MJ per kg)	biogas	Biogas	19.1304

Density Kind	Reference	Name	Density
Volumetric (MJ per liter)	cng	CNG - Compressed Natural Gas	0.0383
Gravimetric (MJ per kg)	cng	CNG - Compressed Natural Gas	52.2257
Volumetric (MJ per liter)	coal	Coal - commercial mix	22.3889
Gravimetric (MJ per kg)	coal	Coal - commercial mix	24.8766
Volumetric (MJ per liter)	coalwaterslurry	Coal Water Slurry	18.0000
Gravimetric (MJ per kg)	coalwaterslurry	Coal Water Slurry	15.0000
Volumetric (MJ per liter)	diesel	Diesel	38.2903
Gravimetric (MJ per kg)	diesel	Diesel	45.5837
Volumetric (MJ per liter)	fabricwaste	Fabric Waste	8.7027
Gravimetric (MJ per kg)	fabricwaste	Fabric Waste	21.7568
Volumetric (MJ per liter)	fueloil	Fuel Oil - Blended	38.7416
Gravimetric (MJ per kg)	fueloil	Fuel Oil - Blended	46.1209
Volumetric (MJ per liter)	lng	LNG - Liquid Natural Gas	24.5909
Gravimetric (MJ per kg)	lng	LNG - Liquid Natural Gas	53.9279
Volumetric (MJ per liter)	lpg	LPG - Liquid Petroleum Gas	25.6419
Gravimetric (MJ per kg)	lpg	LPG - Liquid Petroleum Gas	46.6216
Volumetric (MJ per liter)	naturalgas	Natural Gas	0.0382
Gravimetric (MJ per kg)	naturalgas	Natural Gas	55.1867
Volumetric (MJ per liter)	petrol	Petrol/Gasoline	34.6537
Gravimetric (MJ per kg)	petrol	Petrol/Gasoline	46.2050
Volumetric (MJ per liter)	propane	Propane	25.6419
Gravimetric (MJ per kg)	propane	Propane	46.6216
Volumetric (MJ per liter)	biomasscert	Biomass - Sustainably Sourced with certification	3.0000
Gravimetric (MJ per kg)	biomasscert	Biomass - Sustainably Sourced with certification	15.0000
Volumetric (MJ per liter)	biomassgen	Biomass - Without sustainably sourced biomass certification	3.0000
Gravimetric (MJ per kg)	biomassgen	Biomass - Without sustainably sourced biomass certification	15.0000

Sources without a listed energy density (purchased electricity and the onsite renewable electricity sources) may only be reported in energy units.

The exceptions to the table are `districtheating`, `steampurch`, `chilledwater`, `diesel` and `biodiesel`.

District heating may be reported in energy or volume units. For volume units the energy density is calculated from the difference between the temperature of the heated water received at the facility and the temperature of the water exiting, `ensourcedistrictheatingrectemp` and `ensourcedistrictheatingexittemp` (°C), as `(rectemp − exittemp) × 0.0041868 MJ/l` (`districtheating_mj_per_liter`). Whatever the reporting unit, the result is divided by an assumed generation and distribution efficiency of 0.8, so 1 MJ of district heating consumed is reported as 1.25 MJ.

Purchased steam may be reported in energy or mass units (volume is not allowed). For mass units the energy density in MJ/kg is read from steam tables using the reported pressure and temperature of each steam source (`ensteampressure`, `ensteampressureuom`, `ensteamtemp` on the rows `one`, `two`, `three` of the steam source table) and divided by the same 0.8 efficiency; the per-source densities are combined into `steam_mj_per_kg` weighted by each source's share `ensteamsourcepct`. `steam_is_vapor` checks that every reported pressure and temperature pair can be steam at all. Steam reported directly in energy units is taken as reported, without the efficiency adjustment.

Purchased chilled water may only be reported in energy units. The reported energy is divided by an assumed coefficient of performance of 3.0, so 1 MJ of chilled water consumed is reported as 1/3 MJ.

Diesel and biodiesel blends are separated so that the reported MJ represent only diesel and only biodiesel rather than the blends as delivered. If `endieselmix` is `yes`, `enbiodieselpercent` is the percentage of biodiesel in the facility's diesel and that share of the diesel quantity is moved to biodiesel. If `enbiodieselmix` is `yes`, `enbiodieselmixpercent` is the percentage of biodiesel in the facility's biodiesel and the remainder is moved to diesel. The moved quantity is converted with the density of the fuel it is moved to.

Restated: the reported MJ for the secondary sources district heating, purchased steam (mass units) and chilled water include an assumption about generation efficiency, and this carries through every aggregate that reports energy for those sources.

Conversion to kg CO2e

The kg CO2e emitted through the use of all domestic and production energy sources is calculated and reported with the ref_id form of

Scope	Usage
Domestic	ensourcequantdomestic[1]_kgco2e
Production	ensource[2]quantprod[1]_kgco2e
Domestic & Production	ensource[2]quant[1]_kgco2e

The wild cards `[1]` and `[2]` are the energy source and facility type as above.

Each kg CO2e value is the corresponding MJ value multiplied by a single emission factor. The default factors are the FEM 2025 values of Cascale's shared reference data, which also records the source of each factor and is published with the Higg Assessment Model. The table lists every source that appears in FEM 2025, including the sources that can only be selected as part of a purchased renewables, EAC, steam or biomass mix:

All emission factors are kg CO2e per MJ

Reference	Value	kg CO2e / MJ	Used for
agresidue	Residues from agricultural processes	0.1019	biomass mix
biodiesel	Biodiesel	0.0710	facility, vehicle, purchased renewables mix, EAC mix, steam mix
biogas	Biogas	0.0547	facility, vehicle, purchased renewables mix, EAC mix, steam mix
biomasscert	Biomass - Sustainably Sourced with certification	0.1139	facility, steam mix
biomassgen	Biomass - Without sustainably sourced biomass certification	0.1139	facility, steam mix
chilledwater	Purchased Chilled Water	Country grid factor	facility
cng	CNG - Compressed Natural Gas	0.0562	facility, vehicle, steam mix
coal	Coal - commercial mix	0.0953	facility, steam mix
coalwaterslurry	Coal Water Slurry	0.0953	facility, steam mix
crops	Dedicated crops	0.1019	biomass mix
diesel	Diesel	0.0744	facility, vehicle, steam mix

Reference	Value	kg CO2e / MJ	Used for
districtheating	Purchased Heating (District Heating)	0.0953	facility
electricpurch	Purchased Electricity	Country grid factor	facility, vehicle
ethanol	Ethanol	0.0722	vehicle
fabricwaste	Fabric Waste	0.1312	facility, steam mix
forestresidue	Residues from forests	0.1139	biomass mix
fueloil	Fuel Oil - Blended	0.0777	facility, steam mix
geotherm	Geo thermal	0.0000	purchased renewables mix, EAC mix, steam mix
hydro	Hydro	0.0000	purchased renewables mix, EAC mix, steam mix
hydrogennr	Hydrogen -Non- Renewable Source	0.0000	vehicle
hydrogenr	Hydrogen - Renewable Source	0.0000	vehicle
lng	LNG - Liquid Natural Gas	0.0562	facility, vehicle, steam mix
lpg	LPG - Liquid Petroleum Gas	0.0632	facility, vehicle, steam mix
microhydro	Mini or Micro-Hydro	0.0000	facility, purchased renewables mix, EAC mix
mill	Residues from sawmills and paper mills	0.1139	biomass mix
muniwaste	Municipal Solid Waste	0.0978	steam mix
naturalgas	Natural Gas	0.0562	facility, steam mix
petrol	Petrol/Gasoline	0.0696	facility, vehicle, steam mix
propane	Propane	0.0632	facility, vehicle, steam mix
purchrenew	Purchased Renewables	0.0000	facility
renewablepurch	Purchased Renewables (electricity)	0.0000	vehicle
renewother	Other Renewable Source	0.0000	purchased renewables mix, EAC mix
renewunknown	Source Unknown	Country grid factor	purchased renewables mix, EAC mix
solarphoto	Solar Photovoltaic	0.0000	facility, vehicle, purchased renewables mix, EAC mix
solarphoto_onsite	Solar Photovoltaic	0.0000	EAC mix
solarthermal	Solar Thermal	0.0000	facility, steam mix
solidwood	Solid wood	0.1139	biomass mix
steampurch	Purchased Steam	0.0953	facility
wind	Wind	0.0000	facility, vehicle, purchased renewables mix, EAC mix

The exceptions are `electricpurch`, `chilledwater`, `purchrenew`, `steampurch`, `biomasscert` and `biomassgen`, whose emissions are calculated with a factor other than a single default.

`electricpurch` and `chilledwater` use the facility's country grid emission factor (`country_ef`, selected by `sitecountry`). The country grid emission factors are updated when possible for each FEM cadence, are licensed from IEA, and may not be disclosed by Cascale. Facilities may still report a self-declared electricity factor in `enghgefelecpurchwquant`; since FEM 2024 it is collected but not used in any calculation.

Facilities reporting the use of `purchrenew`, `steampurch`, `biomasscert` or `biomassgen` may report the mix of sources used to generate that energy (`ensourcepurchrenewmix`, `ensteammix`, `ensourcebiomasscertmix`, `ensourcebiomassgenmix`, each with a percentage table). When the mix question is answered `yes` the emission factor is the percentage-weighted average of the factors in the table above for the reported sources (`purchrenewmix_ef`, `steampurchmix_ef`, `biomass_cert_ef`, `biomass_gen_ef`); the unknown-source renewable (`renewunknown`) contributes the country grid factor. Otherwise the default from the table is used: 0 for purchased renewables, 0.0953 for steam (coal) and 0.1139 for biomass. The zero factor for purchased renewables is the FEM's market-style treatment of contracted renewable electricity (see Scope): the same MWh would carry the country grid factor in a location-based inventory. In FDM 2025 the biomass mix questions are not asked, so FDM always applies the default biomass factor.

Vehicle Energy Use

Raw vehicle energy use is reported in the ref_ids `ensourcequantvehicle[1]` for the quantity and `ensourceunitvehicle[1]` for the unit of measure. The wildcard `[1]` is the energy source as found in the following table:

Reference	Value
envehicleelectricpurch	Purchased Electricity
envehiclebiodiesel	Biodiesel
envehiclebiogas	Biogas
envehicleethanol	Ethanol
envehiclehydrogenr	Hydrogen - Renewable Source
envehiclerenewablepurch	Purchased Renewables (electricity)
envehiclesolarphoto	Solar Photovoltaic (electricity)
envehiclewind	Wind (electricity)
envehiclecng	CNG - Compressed Natural Gas
envehiclediesel	Diesel
envehiclehydrogennr	Hydrogen -Non- Renewable Source
envehiclelng	LNG - Liquid Natural Gas
envehiclelpg	LPG - Liquid Petroleum Gas
envehiclepetrol	Petrol/Gasoline
envehiclepropane	Liquid Propane

The MJ used and kg CO2e emissions are calculated as per the "Production and Domestic Energy Use" section with the ref_id formats `ensourcequantvehicle[1]_mj` and `ensourcequantvehicle[1]_kgco2e`. The wildcard `[1]` represents the energy source.

The following special cases modify the MJ calculations:

Diesel and biodiesel blends are separated as for facility use. If `endieselvechicle` is `yes`, `endieselvechiclemix` is the percentage of biodiesel in the vehicle diesel and that share is moved to biodiesel; if `enbiodieselvehicle` is `yes`, `enbiodieselvehiclemix` is the percentage of biodiesel in the vehicle biodiesel and the remainder is moved to diesel. (The ref_ids `endieselvechicle` and `endieselvechiclemix` are spelled as shown.)

Petrol and ethanol blends are separated the same way. If `enpetrolvehicle` is `yes`, `enpetrolvehiclemix` is the percentage of ethanol in the petrol and that share is moved to ethanol; if `enethanolvehicle` is `yes`, `enethanolvehiclemix` is the percentage of ethanol in the ethanol source and the remainder is moved to petrol. The reported percentages are volume shares: when the quantity is reported in mass or

volume units they are applied directly, and when it is reported in energy units they are first converted to an energy share using an ethanol-to-petrol energy density ratio of 0.666.

Vehicle energy sources use the same energy densities and emission factors as production/domestic sources. Several sources are reported for vehicles only and have the following values:

Energy Density

Density Kind	Reference	Name	Density
Volumetric (MJ per liter)	ethanol	Ethanol	23.4122
Gravimetric (MJ per kg)	ethanol	Ethanol	29.6666
Gravimetric (MJ per kg)	hydrogenr	Hydrogen - Renewable Source	141.9162
Gravimetric (MJ per kg)	hydrogennr	Hydrogen -Non- Renewable Source	141.9162

Emission Factor

Reference	Value	kg CO2e / MJ
ethanol	Ethanol	0.0722
hydrogennr	Hydrogen -Non- Renewable Source	0.0000
hydrogenr	Hydrogen - Renewable Source	0.0000
renewablepurch	Purchased Renewables (electricity)	0.0000

Note: FEM reports on emissions from scope 1 and 2 only so the scope 3 emissions for hydrogen are not in scope.

Wastewater Treatment

Biogenic carbon emissions from wastewater treatment expressed in terms of kg CO2e may be found in the aggregate calculation under the ref_id `biogenicCO2e`. It is the sum of `wwTreatmentCO2e`, calculated for the facility's biological treatment as a whole, and `wwProcessCO2e`, the sum over the reported biological sub-processes. `biogenicCO2e` is not included in any of the GHG totals described under Aggregates.

The US EPA reference for estimating biogenic emissions (Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories, 2010, chapter 3) is the source of the method, which was introduced in FEM 2023 and is unchanged in FEM 2025.

The following emission formulas are used:

CO2 Emission Formula:

$CO2 = 10^{-6} \times Qww \times OD \times EffOD \times CFCO2 \times [(1-MCFww \times BGCH4)(1-\lambda)]$

CH4 Emission Formula:

$CH4 = 10^{-6} \times Qww \times OD \times EffOD \times CFCH4 \times [(MCFww \times BGCH4)(1-\lambda)]$

Where

- CO2 = CO2 emission rate (Mg CO2/hr)
- CH4 = CH4 emission rate (Mg CH4/hr)
- 10^-6 = Units conversion factor (Mg/g)
- QWW = Wastewater influent flow rate (m3/hr)
- OD = Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD5 or COD (mg/L = g/m3)
- EffOD = Oxygen demand removal efficiency of the biological treatment unit
- CFCO2 = Conversion factor for maximum CO2 generation per unit of oxygen demand

- 44/32 = 1.375 g CO2/ g oxygen demand
- CFCH4 = Conversion factor for maximum CH4 generation per unit of oxygen demand
- 16/32 = 0.5 g CH4/ g oxygen demand
- MCFWW = methane correction factor for wastewater treatment unit, indicating the fraction of the influent oxygen demand that is converted anaerobically in the wastewater treatment unit
- BGCH4 = Fraction of carbon as CH4 in generated biogas (default is 0.65)
- λ = Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process).

The defaults for MCFww and λ are taken from Table 3-1 of the EPA reference:

Wastewater Treatment Processes	MCF	λ	Assumptions	Additional Values
Aerated treatment process (e.g., activated sludge system), well managed	0	0.65	assume that the treatment plant is well managed	MCFWW = 0 λ = 0.65 CFCO2 = 1.375 g CO2/ g oxygen demand CFCH4 = 0.5 g CH4/ g oxygen demand
Anaerobic treatment process (e.g., anaerobic reactor)	0.8	0.1		MCFWW = 0.8 λ = 0.1 CFCO2 = 1.375 g CO2/ g oxygen demand CFCH4 = 0.5 g CH4/ g oxygen demand
Facultative lagoon, shallow (< 2 m deep)	0.2	0	assume that manufacturing facilities will not have lagoons that are more than 2 m deep	MCFWW = 0.2 λ = 0 CFCO2 = 1.375 g CO2/ g oxygen demand CFCH4 = 0.5 g CH4/ g oxygen demand
AR6 CH4 GWP (Feedback Included) - Non Fossil Origin	27.2			

The inputs are the annual discharged volume `wwtrack[1]amt` (m3) and the BOD5 concentrations before and after treatment `wwbiological[1]pretreat` and `wwbiologicalp[1]posttreat` (mg/L), where the wild card `[1]` is the wastewater type (`domestic`, `industrial` or `combined`). Sub-processes are reported on the rows `sub1` to `sub10` of the biological sub-process table with their type `wwprocessindicate`, and BOD5 before and after the sub-process, `wwprocesspretreat` and `wwprocessposttreat`.

For a given facility the treatment type used to assign values from the table above (`wwTreatmentApplicability`) is determined by applying the following logic to the values given for `wwbiologicalp[1]process`:

Facility Selection	Treatment Type
Aerobic; Anaerobic; Facultative	Facultative
Aerobic; Anaerobic	Anaerobic
Facultative; Anaerobic	Anaerobic
Aerobic; Facultative	Facultative
Otherwise	Selected Option

For sub process calculations the process type given by the facility is used.

The per-treatment-type constants used by the calculations are the bracketed terms of the formulas multiplied by the conversion factors, in g per g of oxygen demand: aerobic 0.61875 CO2 and 0 CH4, anaerobic 0.594 CO2 and 0.234 CH4, facultative 1.19625 CO2 and 0.065 CH4 (`aerobicTreatmentIntensityCO2` and so on), with `methaneGWP` = 27.2.

Implementation note (September 2026). The current calculation departs from the formulas above in three ways, all under review: the discharged volume is multiplied by the BOD5 removal *fraction* `(pre – post) / pre` rather than by the removed BOD5 concentration `(pre – post)` in g/m3, so the oxygen-demand magnitude is not applied; the per-sub-process volumes divide by the post-treatment BOD5 rather than the pre-treatment BOD5; and the aerobic CO2 constant 0.61875 corresponds to a biomass yield of 0.55 rather than the 0.65 default (which would give 0.48125). Because `biogenicCO2e` is not part of any GHG total, only that reported value is affected.

Refrigerants

Refrigerant use is reported in the Air Emissions section of FEM. Usage information can be found in the following ref_ids:

Kind	Reference
Usage	airrefrig[1]quant
Unit of Measure	airrefrig[1]uom

The wildcard `[1]` represents the refrigerant being reported on. The possible values may be found in the emission factor table for refrigerants that follows. FEM 2025 offers the 127 refrigerants below; earlier cadences offered a longer list.

To calculate the kg of CO2e emissions due to refrigerant usage (`airrefrig[1]quant_kgco2e`) the quantity of refrigerant used is converted to kg and then multiplied by the global warming potential (IPCC AR6 unless noted in the shared reference data) found in the following table. `totalRefrigerantEmissions` is the sum over all refrigerants.

Reference	Value	kg CO2e per kg
r10	R-10 (PCC)	2200
r11	R-11 (CFC)	5560
r12	R-12 (CFC)	11200
r12B1	R-12B1 (H)	1930
r12B2	R-12B2 (H)	216
r13	R-13 (CFC)	16200
r13B1	R-13B1 (H)	7200
r14	R-14 (PFC)	7380
r20	R-20 (HCC)	16200
r21	R-21 (HCFC)	160
r22	R-22 (HCFC)	1960
r22B1	R-22B1 (H)	380
r23	R-23 (HFC)	14800
r30	R-30 (HCC)	11.2
r31	R-31 (HCFC)	79.4
r32	R-32 (HFC)	771
r40	R-40 (HCC)	5.54
r41	R-41 (HFC)	135
r50	R-50 (HC)	27.9
r110	R-110 (PCC)	

Reference	Value	kg CO2e per kg
r111	R-111 (CFC)	
r112	R-112 (CFC)	4620
r113A	R-113a (CFC)	3930
r114	R-114 (CFC)	9430
r114A	R-114a (CFC)	7420
r115	R-115 (CFC)	9600
r120	R-120 (HCC)	
r121	R-121 (HCFC)	58.3
r121A	R-121a (HCFC)	
r122	R-122 (HCFC)	56.4
r122A	R-122a (HCFC)	245
r122B	R-122b (HCFC)	772
r123	R-123 (HCFC)	90.4
r123A	R-123a (HCFC)	395
r123B	R-123b (HCFC)	90.4
r124	R-124 (HCFC)	597
r124A	R-124a (HCFC)	2070
r125	R-125 (HFC)	3500
r130A	R-130a (HCC)	128
r131	R-131 (HCFC)	30
r131A	R-131a (HCFC)	181
r132	R-132 (HCFC)	122
r132A	R-132a (HCFC)	70.4
r133A	R-133a (HCFC)	388
r134	R-134 (HFC)	1260
r134A	R-134a (HFC)	1530
r140	R-140 (HCC)	2
r140A	R-140a (HCC)	161
r141	R-141 (HCFC)	46.6
r141A	R-141a (HCFC)	46.6
r141B	R-141b (HCFC)	860
r142A	R-142a (HCFC)	175
r142B	R-142b (HCFC)	2300
r143	R-143 (HFC)	353
r143A	R-143a (HFC)	4470
r150	R-150 (HCC)	1
r152A	R-152a (HFC)	164
r160	R-160 (HCC)	0.481
r161	R-161 (HFC)	4.84
r170	R-170 (HC)	0.437
r221	R-221 (HCFC)	110
r222	R-222 (HCFC)	500
r225	R-225 (HCFC)	1560

Reference	Value	kg CO2e per kg
r232	R-232 (HCFC)	690
r234Ba	R-234ba (HCFC)	260
r235Cc	R-235cc (HCFC)	1560
r244	R-244 (HCFC)	3360
r290	R-290 (HC)	20
r400	R-400 (CFC)	
r401A	R-401A (HCFC)	16
r401B	R-401B (HCFC)	14
r401C	R-401C (HCFC)	19
r402A	R-402A (HCFC)	2100
r404A	R-404A (HFC)	4728
r405A	R-405A (HCFC)	5328
r406A	R-406A (HCFC)	1943
r407A	R-407A (HFC)	2262
r407C	R-407C (HFC)	1908
r407D	R-407D (HFC)	1748
r407E	R-407E (HFC)	1672
r407F	R-407F (HFC)	1965
r408A	R-408A (HCFC)	3000
r409A	R-409A (HCFC)	1600
r410A	R-410A (HFC)	2256
r410B	R-410B (HFC)	2404
r411A	R-411A (HCFO)	14
r412A	R-412A (HCFC)	2286
r413A	R-413A (HFC)	2183
r417A	R-417A (HFC)	2508
r418A	R-418A (HCFC)	1741
r420A	R-420A (HCFC)	1548
r421A	R-421A (HFC)	2812
r421B	R-421B (HFC)	3409
r422A	R-422A (HFC)	3359
r422B	R-422B (HFC)	2700
r422D	R-422D (HFC)	2917
r425A	R-425A (HFC)	1638
r427A	R-427A (HFC)	2397
r430A	R-430A (HFC)	125
r434A	R-434A (HFC)	3654
r438A	R-438A (HFC)	2425
r440A	R-440A (HFC)	185
r500	R-500 (HCFC)	8100
r506	R-506 (HCFC)	0
r507A	R-507[A] (HFC)	3300
r508B	R-508B (HFC)	10350

Reference	Value	kg CO2e per kg
r510A	R-510[A] (HC)	0
r511A	R-511[A] (HC)	0
r600	R-600 (HC)	0.006
r600A	R-600a (HC)	0
r601A	R-601a (HC)	20
r631	R-631	
r717	R-717	
r718	R-718	
r728	R-728	
r740	R-740	
r744	R-744 (CO2)	1
r1112A	R-1112a (CFO)	
r1120	R-1120 (HCO)	
r1132A	R-1132a (HFO)	1.7
r1141	R-1141 (HFO)	0.02
r1218	R-1218 (PFO)	
r1233Zd	R-1233zd (HCFO)	
r1234Yf	R-1234yf (HFO)	
r1270	R-1270 (HO)	20
re134	R-E134 (HFC)	840
re143A	R-E143a (HFC)	5810

Empty values result in a value of 0 kg CO2e per kg of refrigerant.

Purchased Renewables and EACs

Energy Attribute Certificates (EACs) are reported in the FEM Energy section (`ensourcepurcheac` and its children). None of the aggregate calculations documented here account for them: EACs do not reduce any MJ or kg CO2e total, in contrast to purchased renewables, which do (see Scope).

Two calculations expose the EAC data for consumers who apply their own market-based accounting. `eac_mj` is the retired quantity `ensourcepurcheacmwh` converted to MJ (× 3600). `eac_avoided_ghg` is the kg CO2e the retired certificates would offset: the share of the facility's purchased electricity MJ that the EACs cover (`eac_mj / ensourceelectricpurchtotal`) multiplied by the purchased electricity emissions (`ensourceelectricpurchtotalghg`), less the emissions of the certificates' own generation mix (`eacmix_ef × eac_mj`, where `eacmix_ef` is the percentage-weighted factor of the reported EAC sources and is 0 unless biodiesel, biogas or an unknown source is reported). It is 0 when no purchased electricity is reported.

Aggregates

Note: No aggregate calculations documented here incorporate biogenic emissions from wastewater or account for EACs reported in the FEM Energy Section (`ensourcepurcheac` and its children).

Aggregates Existing Prior to FEM 2023

`ensource[1]total`

Total MJ of energy across all facility types, domestic and vehicle usage from the source represented by the wild card `[1]`. Vehicle usage is included where the same source exists for vehicles (for example `ensourcedieseltotal` includes `ensourcequantvehicleenvehiclediesel_mj`).

`ensource[1]totalghg`

Total kg CO2e of energy across all facility types, domestic and vehicle usage from the source represented by the wild card `[1]`.

`totalRenewableEmissions`

Total kg CO2e across all facility types, domestic and vehicle usage from the renewable energy sources: biodiesel, biogas, both biomass sources, mini/micro-hydro, purchased renewables (facility and vehicle), solar photovoltaic, solar thermal, wind, ethanol and renewable hydrogen.

`totalNonRenewableEnergyEmissions`

Total kg CO2e across all facility types, domestic and vehicle usage from the non-renewable energy sources: purchased electricity, chilled water, district heating, steam, CNG, coal, coal water slurry, diesel, fabric waste, fuel oil, LNG, LPG, natural gas, petrol, propane and non-renewable hydrogen. Does not include refrigerants.

`totalRefrigerantEmissions`

Total kg CO2e of emissions from refrigerants.

`totalNonRenewableEmissions`

`totalNonRenewableEnergyEmissions` plus `totalRefrigerantEmissions`.

`totalGHGemissions`

Total kg CO2e emissions from all energy sources (renewable and non-renewable) and refrigerants.

Aggregates Added in FEM 2023

`domestic_total_mj`

Total MJ of energy used for domestic purposes. Only has a value if the facility reported production and domestic usage separately.

`domestic_total_kgco2e`

Total kg CO2e of emissions from energy used for domestic purposes. Only has a value if the facility reported production and domestic usage separately.

`vehicle_total_mj`

Total MJ of energy used by vehicles.

`vehicle_total_kgco2e`

Total kg CO2e of emissions from vehicles.

`[2]_mj`

Total MJ of energy used across all sources for the facility type represented by the wild card `[2]`. Does not include domestic or vehicle usage.

`[2]_total_mj`

Total MJ of energy used across all sources for the facility type represented by the wild card `[2]`. Includes domestic and vehicle usage divided evenly across the facility's reported facility types (`energy_adjusted_facility_type`, which drops the Finished Product Processing types when `energyseparate` is `no`).

`[2]_normalized_mj`

Total MJ of energy used per unit produced across all sources for the facility type represented by the wild card `[2]`. Includes domestic and vehicle usage divided evenly across each facility type. The unit total and unit of measure can be found in `sipfacilityannualprodvolquant[2]` and `sipfacilityannualprodvolunits[2]` respectively.

`[2]_kgco2e`

Total kg CO2e of emissions across all energy sources for the facility type represented by the wild card `[2]`. Does not include domestic or vehicle usage.

`[2]_total_kgco2e`

Total kg CO2e of emissions produced across all energy sources for the facility type represented by the wild card `[2]`. Includes domestic and vehicle usage divided evenly across each facility type.

`[2]_normalized_kgco2e`

Total kg CO2e of emissions per unit produced across all energy sources for the facility type represented by the wild card `[2]`. Includes domestic and vehicle usage divided evenly across each facility type. The unit total and unit of measure can be found in `sipfacilityannualprodvolquant[2]` and `sipfacilityannualprodvolunits[2]` respectively.

Aggregates Added in FEM 2024

No new aggregate calculations were added in FEM 2024.

Aggregates Added in FEM 2025

No new aggregate calculations were added in FEM 2025. One helper was added for data consumers:

`ghg_emissions_increase_from_2024_model_percent`

The percentage change in `totalGHGemissions` attributable to the FEM 2025 emission factor model changes (chilled water, district heating, steam, fabric waste, LPG, propane, petrol and unknown-source purchased renewables) if they were applied to the same answers under the FEM 2024 model. It does not include the effect of the annual grid factor update. See the FEM 2025 Energy Source Changes document.

Additional Aggregates

Additional aggregations may be found in exports and other reporting. They are documented in the data dictionary or report specific documentation as appropriate.