Cascale

HIGG FEM 2022

FEM 2022 Energy and Global Warming Calculations

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Reconstructed documentation of how the Higg platform calculated the FEM 2022 energy, greenhouse gas and refrigerant values, prepared in 2026 from the question definitions and the platform's stored results.

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> **About this document.** This guidance was prepared in 2026 as a good-faith effort to document how the Higg platform calculated the FEM 2022 energy, greenhouse gas, water, waste and refrigerant values. FEM 2022 predates the calculation model maintained by Cascale today: the platform applied its own conversion factors and emission factors and wrote the results back into the assessment as answers, where data consumers see them next to the facility's own answers. What follows is reconstructed from the FEM 2022 question and answer definitions, from those stored results across 21,187 assessments, and from the release history. It may not accurately describe all platform behaviour, in particular edge cases that leave no trace in the data. Statements derived from the data rather than from a specification are marked *observed*, with the number of filings behind them.

Scope

This document describes the energy, greenhouse gas and refrigerant values the Higg platform calculated for a FEM 2022 assessment and reported back to the facility, its verifier and data consumers. They are the FEM's own simplified footprint, not a GHG Protocol inventory, and they are neither purely location-based nor purely market-based:

- One `totalGHGemissions` figure combines fuel combustion, refrigerants, purchased electricity, steam and chilled water; the only split published is renewable versus non-renewable. There is no scope split and no location/market pair.
- Purchased electricity carries a single country grid factor (location-based); purchased renewables carry a factor of 0 (market-style treatment of contracted renewable electricity). Energy Attribute Certificates were collected in FEM 2022 but not used.
- Biogenic CO2 from biomass and biodiesel is inside the totals, at full combustion factors.
- Purchased steam and chilled water are counted at a fixed fuel-oil-type factor with no supplier data; refrigerant purchased or added is treated as emitted; wastewater emissions are not calculated at all in FEM 2022.
- Factors are single CO2e values per source on an IPCC AR4/AR5 basis (FEM 2023 moved to AR6); there is no gas-by-gas breakdown and no process emissions.

The Higg Assessment Model recomputes FEM 2022 answers on a GHG Protocol aligned basis with current factors; those results differ from the platform values described here by design and are documented in the HAM guidance.

Energy Data

Facilities first flagged each energy source they use (`yes`/`no`, one answer per source), then reported a quantity and a unit for each source they track. Energy is reported for the site as a whole: there is no split by facility type, domestic use or vehicle use in FEM 2022.

Source	Displayed as	Quantity and unit ref_ids	Energy density applied	Platform MJ total
`ensourcecoal`	Coal- commerical mix	`ensourcecoalquant` `ensourcecoalunit`	24.8765 MJ per kg	`ensourcecoaltotal`
`ensourcebiomassgen`	Biomass- general	`ensourcebiomassgenquant` `ensourcebiomassgenunit`	9.5947 MJ per kg	`ensourcebiomassgentotal`
`ensourcebiomasswood`	Biomass- wood	`ensourcebiomasswoodquant` `ensourcebiomasswoodunit`	20.3292 MJ per kg	`ensourcebiomasswoodtotal`

Source	Displayed as	Quantity and unit ref_ids	Energy density applied	Platform MJ total
ensourcenaturalgas	Natural Gas	ensourcenaturalgasquant ensourcenaturalgasunit	0.0382 MJ per litre	ensourcenaturalgastotal
ensourcelng	LNG- liquid natural gas	ensourcelngquant ensourcelngunit	23.6000 MJ per litre	ensourcelngtotal
ensourcediesel	Diesel	ensourcedieselquant ensourcedieselunit	38.4523 MJ per litre	ensourcedieseltotal
ensourcefueloil	Fuel oil- blended average	ensourcefueloilquant ensourcefueloilunit	39.7341 MJ per litre	ensourcefueloiltotal
ensourcelpg	LPG- liquid petroleum gas	ensourcelpgquant ensourcelpgunit	25.6349 MJ per litre	ensourcelpgtotal
ensourcepetrol	Petrol	ensourcepetrolquant ensourcepetrolunit	34.8300 MJ per litre	ensourcepetroltotal
ensourcepropane	Propane	ensourcepropanequant ensourcepropaneunit	25.3562 MJ per litre	ensourcepropanetotal
ensourcebiodiesel	Biodiesel	ensourcebiodieselquant ensourcebiodieselunit	35.6659 MJ per litre	ensourcebiodieseltotal
ensourcesolarphoto	Solar Photovoltaic	ensourcesolarphotoquant ensourcesolarphotounit	energy units only	ensourcesolarphotototal
ensourcewind	Wind	ensourcewindquant ensourcewindunit	energy units only	ensourcewindtotal
ensourcegeotherm	Geothermal	ensourcegeothermquant ensourcegeothermunit	energy units only	ensourcegeothermtotal
ensourcehydro	Hydro	ensourcehydroquant ensourcehydrounit	energy units only	ensourcehydrototal
ensourceelectricpurch	Electricity	ensourceelectricpurchquant ensourceelectricpurchunit	energy units only	ensourceelectricpurchtotal
ensourcemicrohydro	Micro-Hydro	ensourcemicrohydroquant ensourcemicrohydrounit	energy units only	ensourcemicrohydrototal
ensourcesolarthermal	Solar Thermal	ensourcesolarthermalquant ensourcesolarthermalunit	energy units only	ensourcesolarthermaltotal
ensourcesteampurch	Steam (purchased)	ensourcesteampurchquant ensourcesteampurchunit	2.8000 MJ per kg	ensourcesteampurchtotal
ensourcechilledwater	Chilled water	ensourcechilledwaterquant ensourcechilledwaterunit	energy units only	ensourcechilledwatertotal
ensourcepurchrenew	Purchased Renewables	ensourcepurchrenewquant ensourcepurchrenewunit	energy units only	ensourcepurchrenewtotal

The platform's MJ result for each source is stored as an answer under the ref_id in the last column.

Conversion to MJ

The platform held one energy density per source and multiplied the reported quantity by it after converting the quantity to the density's base unit: energy units are converted with the standard factors below and the density is not applied; mass units are converted to kilograms and volume units to litres. The density for each source is listed in the source table above; solid fuels and steam are per kilogram, liquid fuels and natural gas per litre.

Behaviour that follows from having a single density per source (*observed*):

- A mass unit reported for a liquid fuel, or a volume unit for a solid fuel, is converted through the same number as if one litre were one kilogram (for example LPG in kg → 25.63 MJ, the litre density; purchased steam in m³ → 2,800 MJ, that is 1,000 kg of water).

- LNG in m³ is converted at 23,600 MJ, the density of the liquid; a gaseous cubic metre would be about 38 MJ.
- Purchased steam by mass: 2.8 MJ per kg. Purchased electricity, chilled water, purchased renewables and the onsite renewables can only be reported in energy units.
- Natural gas has a litre-based density (0.0382 MJ per litre, so 38.23 MJ per m³), while its units also allow the US volume units (cu ft 1.08 MJ, CCF 108.25 MJ).

Energy units (all sources):

Unit	MJ
kWh	3.600000
MJ	1.000000
mmBTU	1055.055000
BTU	0.001055
Joule	0.000001

Mass units convert to kilograms and **volume units** to litres with the standard factors (g 0.001, lb 0.4535, oz 0.0283, ton (metric) 1,000, ton (short) 907.185; m³ 1,000, gal 3.7854, cu ft 28.3168, cu yard 764.554, CCF 2,831.68).

Energy densities implied by the stored totals (median of `total ÷ quantity` per unit, converted to the base unit; *observed*, with the number of filings that reported the source):

Source	MJ per kg (observed)	MJ per litre (observed)	Filings reporting the source
`biodiesel`		35.6659	166
`biomassgen`	9.5947		909
`biomasswood`	20.3292		1346
`coal`	24.8765		806
`diesel`		38.4523	9172
`fueloil`		39.7341	467
`lng`		23.6000	344
`lpg`		25.6349	3128
`naturalgas`		0.0382	5044
`petrol`		34.8300	4993
`propane`		25.3563	288
`steampurch`	2.8000		1659

Conversion to kg CO2e

Each source's emissions are its MJ total multiplied by a single factor held by the platform: `ensource[source]totalghg = ensource[source]total × factor`.

Factors applied (kg CO2e per MJ) — the values the platform held for FEM 2022, confirmed against the stored results:

Source	kg CO2e per MJ	Filings	Note
`biodiesel`	0.07004	166	
`biomassgen`	0.11391	909	
`biomasswood`	0.09000	1346	

Source	kg CO2e per MJ	Filings	Note
chilledwater	0.06293	95	
coal	0.09004	806	
diesel	0.07033	9172	
electricpurch	country grid factor	17587	varies by country
fueloil	0.07042	467	
geotherm	0.00000	10	
hydro	0.00000	702	
lng	0.05034	344	
lpg	0.05872	3128	
microhydro	0.00000	15	
naturalgas	0.05034	5044	
petrol	0.06679	4993	
propane	0.05982	288	
purchrenew	0.00000	941	
solarphoto	0.00000	2374	
solarthermal	0.00000	157	
steampurch	0.06293	1659	
wind	0.00000	159	

Purchased electricity is multiplied by a **country grid factor** (`ensourceelectricpurchtotalgwp`, kg CO2e per MJ, selected by the facility's `sitecountry` answer), licensed from IEA and updated by the platform between cadences. The factors the platform applied are not preserved outside the assessments themselves. Comparing the factor stored with each filing against the FEM 2022 country factors now held in Cascale's shared reference data (which were re-derived for the Higg Assessment Model), the platform's factor is on median 15% higher, and only 7% of filings are within 5% of the shared value, so the shared data cannot be used to reproduce FEM 2022 platform emissions.

The renewable sources (`solarphoto`, `wind`, `geotherm`, `hydro`, `microhydro`, `solarthermal`, `purchrenew`) carry a factor of 0. Purchased steam and chilled water carry a fixed fuel-oil-type factor of 0.0629; the facility could not report a supplier factor or a generation mix in FEM 2022.

Refrigerants

Refrigerant use is reported in the Air Emissions section in up to five entries (`airsourcerefrig1` … `airsourcerefrig5`): the refrigerant (`airsourcerefrig[n]`), the quantity added or used (`airsourcerefrig[n]quant`) and its unit (`airsourcerefrig[n]unit`: g, kg, lb, oz, ton (metric), ton (short)). The platform converted the quantity to kilograms (`airsourcerefrig[n]total`), looked up the refrigerant's global warming potential (`airsourcerefrig[n]totalgwp`) and multiplied (`airsourcerefrig[n]totalghg`); `totalRefrigerantEmissions` is the sum of the five entries. Observed to equal the sum of its components in 99% of 3,077 filings.

The GWP values below are the ones the platform stored with FEM 2022 filings (IPCC AR4 basis, blends as marketed). Only refrigerants that at least one facility reported can be recovered this way; 264 of the 344 refrigerants offered in FEM 2022 were never reported and their platform values are unknown (the FEM 2023 Energy Source Changes document lists FEM 2022 values for those that changed in FEM 2023, several of which were 0).

Refrigerant	kg CO2e per kg (GWP applied)	Filings
R-10 (PCC)	1730.00	50
R-11 (CFC)	4660.00	14
R-110 (PCC)	0.00	1
R-114 (CFC)	8590.00	3
R-115 (CFC)	7670.00	1
R-12 (CFC)	10200.00	26
R-120 (HCC)	0.00	1
R-122 (HCFC)	59.00	2
R-122a (HCFC)	258.00	1
R-123 (HCFC)	79.00	11
R-1233zd (HCFO)	0.00	1
R-1234yf (HFO)	0.00	1
R-123a (HCFC)	370.00	2
R-125 (HFC)	3170.00	1
R-12B1 (H)	1750.00	3
R-12B2 (H)	231.00	3
R-13 (CFC)	13900.00	4
R-130a (HCC)	0.00	3
R-132 (HCFC)	0.00	3
R-132a (HCFC)	0.00	1
R-133a (HCFC)	0.00	2
R-134 (HFC)	1120.00	99
R-134a (HFC)	1300.00	281
R-13B1 (H)	6290.00	2
R-14 (PFC)	6630.00	3
R-140 (HCC)	0.00	6
R-140a (HCC)	160.00	14
R-141 (HCFC)	0.00	5
R-141a (HCFC)	0.00	2
R-141b (HCFC)	782.00	5
R-142a (HCFC)	0.00	1
R-142b (HCFC)	1980.00	2
R-143 (HFC)	328.00	1
R-143a (HFC)	4800.00	2
R-152a (HFC)	138.00	2
R-161 (HFC)	4.00	1
R-20 (HCC)	16.00	23
R-21 (HCFC)	148.00	8
R-22 (HCFC)	1760.00	2066
R-221 (HCFC)	0.00	1
R-222 (HCFC)	0.00	2
R-22B1 (H)	376.00	4
R-23 (HFC)	12400.00	24

Refrigerant	kg CO2e per kg (GWP applied)	Filings
R-232 (HCFC)	0.00	1
R-290 (HC)	0.00	6
R-30 (HCC)	9.00	4
R-31 (HCFC)	0.00	1
R-32 (HFC)	677.00	625
R-40 (HCC)	12.00	6
R-400 (CFC)	0.00	1
R-401A (HCFC)	1129.92	44
R-402A (HCFC)	859.00	1
R-404A (HFC)	3942.80	145
R-406A (HCFC)	1501.00	1
R-407A (HFC)	2079.40	60
R-407C (HFC)	1624.21	152
R-407F (HFC)	1825.00	2
R-408A (HCFC)	3257.10	1
R-409A (HCFC)	1484.75	1
R-41 (HFC)	116.00	12
R-410A (HFC)	1923.50	1381
R-410B (HFC)	2048.15	7
R-411A (HCFO)	1555.18	3
R-417A (HFC)	1542.22	9
R-420A (HCFC)	0.00	6
R-421A (HFC)	0.00	2
R-422A (HFC)	2847.17	1
R-422B (HFC)	0.00	2
R-422D (HFC)	2473.17	1
R-427A (HFC)	2138.00	2
R-438A (HFC)	2265.00	6
R-440A (HFC)	0.00	2
R-50 (HC)	28.00	3
R-507[A] (HFC)	3985.00	8
R-511[A] (HC)	0.00	1
R-600 (HC)	0.00	9
R-600a (HC)	0.00	26
R-631	0.00	1
R-717	0.00	4
R-E134 (HFC)	1300.00	2

Totals

The platform stored these aggregates with each assessment. Their composition is *observed*: the share of filings in which the stored total equals the sum of the listed components within 0.5%.

`ensourcetotal` — total MJ across all energy sources. Observed to equal the sum of its components in 95% of 18,244 filings.

`totalNonRenewableEnergyEmissions` — kg CO2e from the non-renewable sources: purchased electricity, steam, chilled water, coal, natural gas, LNG, diesel, fuel oil, LPG, propane and petrol. Observed to equal the sum of its components in 97% of 18,077 filings.

`totalRenewableEmissions` — kg CO2e from the renewable sources including biomass and biodiesel: biodiesel, both biomass sources, solar photovoltaic, solar thermal, wind, geothermal, hydro, micro-hydro and purchased renewables. Observed to equal the sum of its components in 98% of 2,185 filings.

`totalRefrigerantEmissions` — kg CO2e from the five refrigerant entries.

`totalNonRenewableEmissions` — `totalNonRenewableEnergyEmissions` plus `totalRefrigerantEmissions`. Observed to equal the sum of its components in 99% of 18,090 filings.

`totalGHGemissions` — `totalNonRenewableEmissions` plus `totalRenewableEmissions`. Observed to equal the sum of its components in 100% of 18,102 filings.

`totalNormalizedGHGemissions` — `totalGHGemissions` divided by the annual production volume `sipfacilityannualprodvolquant` (in the unit the facility chose in `sipfacilityannualprodvolunits`). Observed to equal the sum of its components in 100% of 18,049 filings.

`ensourcetotalNonRenewable` and `ensourcetotalRenewable` — MJ by the same renewable / non-renewable split. Observed to equal the sum of its components in 97% of 18,080 filings.

The remaining few percent of filings whose totals do not add up were, as far as the data shows, assessments whose totals were not recomputed after a late edit; the platform did not publish a rule for them.

Cadence Notes

FEM 2022 is the FEM 2021 design with two changes that matter here: purchased steam reported by mass is converted at 2.8 MJ per kg instead of 1, and the Energy Attribute Certificate questions (`ensourcepurcheac`, `ensourcepurcheactypes`, `ensourcepurcheacmwh`, `ensourcepurcheaccert`) were added. The EAC answers were collected only; no FEM 2022 value is calculated from them. FEM 2022 was the last cadence on this calculation approach; FEM 2023 replaced it with the calculations documented in the FEM 2023 guidance, and the FEM 2023 Energy Source Changes document lists every factor that changed at that transition.

Not Calculated in FEM 2022

No wastewater treatment emissions, no vehicle energy, no domestic/production split, no facility-type split, no energy or emissions normalised per facility type, and no market-based figures were calculated. Baseline and target answers (`enbaseline…`, `en…target…`) were converted to MJ with the same densities but do not enter any total.