The transition from FEM 3.0 to FEM 4.0 for the FEM 2023 cadence will cause changes to kg CO2e and energy use totals calculated in FEM reporting that are not caused by changes in facility energy usage or emissions intensity.

For reporting use cases that rely on tracking energy and kg CO2e totals from FEM it is important to understand the causes of the changes so that the right adjustments, if any, can be made for the use case.

The document lays out potential sources of change at a level granular enough to allow FEM data consumers to understand and account for changes in the transition from FEM 3.0 to FEM 4.0 data.

Expected Size of Changes

This analysis ignores:

1. New energy sources and possibilities for facilities to report more granular/specific emission factors for others - both of which would be difficult to account for
2. Changes to refrigerant emissions which are discussed later

The average facility will see an increase in total kg CO2e emissions of slightly more than 2.5% because of changes between FEM 3.0 and FEM 4.0. The median facility sees an increase of slightly less than 1.5%.

The 10th percentile of facilities will see no change and the 90th percentile will see a 10% increase. The largest increase is about 30% and the largest decrease is about 24%.

Facilities using chilled water or purchased steam drive a large portion of the expected change. Without adjustment to those energy sources, the median change drops to less than 1%. Because facilities will set their energy density and emission factor for both sources the actual impact of modeling the emission factor as fuel oil is unpredictable but likely to be much lower than stated in this analysis.

In practice, facilities using large amounts of wood biomass will see the largest decreases and facilities using large amounts of generic biomass and natural gas will see the largest increases. The biomass shifts because of the roll up of the two sources into a single source in FEM 4.0 and natural gas because of an increase in the emission factor.

Stationary Source Energy Densities

For mass units the energy density is expressed in `MJ/kg`, and for volume units as `MJ/l`. Values in have been truncated to 4 decimal places and 1 for the Change % column

FEM22 Name	Unit	FEM22	FEM23	Change %
biomassgen	mass	9.5947	15	36.0
natgaslng	volume	23.6	24.59	4.0
natgaspropane	volume	25.3562	25.6419	1.1
natgaslpg	volume	25.6	25.6419	0.2
solarphoto	energy			0.0
wind	energy			0.0
geotherm	energy			0.0
hydro	energy			0.0
microhydro	energy			0.0
solarthermal	energy			0.0
purchrenew	energy			0.0
biomassbiodiesel	volume	35.6659	35.66	-0.0
coalother	mass	24.8765	24.8766	0.0
natgasng	volume	0.0382	0.0382	0.0
chilledwater	energy			0.0
diesel	volume	38.4523	38.2903	-0.4
petrol	volume	34.83	34.6537	-0.5
fueloilother	volume	39.7341	38.7416	-2.6
biomasswood	mass	20.3292	15	-35.5
steampurch	mass	2.8		

Notes

`steampurch` both has an energy density calculated from user input in FEM 2023 if reported in mass or volume units using the pressure and temperature of the steam.

`biomassother` and `biomasswood` have been replaced by a generic biomass energy source and the energy density is set in the middle of expected biomass sources.

Stationary Source Emission Factors

All emission factors in the following tables are expressed as `kgCO2e/MJ`

FEM22 Name	FEM22	FEM23	Change %	FEM22 Source	FEM23 Source
chilledwater	0.0629	0.0778	19.2	US EPA	Modeled as fuel oil
steampurch	0.0629	0.0778	19.2	US EPA	Modeled as fuel oil
biomasswood	0.0900	0.11	18.2	IPCC, 4AR & 5AR	IPCC, 6AR
natgasng	0.0503	0.0563	10.7	IPCC, 4AR & 5AR	IPCC, 6AR
natgaslng	0.0503	0.0563	10.7	IPCC, 4AR & 5AR	IPCC, 6AR
fueloilother	0.0704	0.0778	9.5	IPCC, 4AR & 5AR	IPCC, 6AR
petrol	0.0667	0.0729	8.5	IPCC, 4AR & 5AR	IPCC, 6AR
diesel	0.0703	0.0750	6.3	IPCC, 4AR & 5AR	IPCC, 6AR
coalother	0.0900	0.0950	5.3	IPCC, 4AR & 5AR	IPCC, 6AR
biomassbiodiesel	0.0700	0.0712	1.7	IPCC, 4AR & 5AR	IPCC, 6AR
purchrenew	0	0	0.0		
solarthermal	0	0	0.0		
microhydro	0	0	0.0		
hydro	0	0	0.0		
geotherm	0	0	0.0		
wind	0	0	0.0		

FEM22 Name	FEM22	FEM23	Change %	FEM22 Source	FEM23 Source
solarphoto	0	0	0.0		
natgaslpg	0.0587	0.0582	-0.9	IPCC, 4AR & 5AR	IPCC, 6AR
natgaspropane	0.0598	0.0582	-2.7	IPCC, 4AR & 5AR	IPCC, 6AR
biomassother	0.1139	0.11	-3.5	IPCC, 4AR & 5AR	IPCC, 6AR

Notes

Emission factors for `purchrenew`, `chilledwater`, and `steampurch` may be set by the facility in FEM 2023 either by directly setting the value or specifying the mix of energy sources used to create the secondary energy source.

Changed Refrigerant Emission Factors

The median facility *with reported refrigerant usage* (about 15% in a cadence) will see a more than 13% increase in the reported refrigerant kg CO2e because of increased global warming potential (GWP). The overwhelming bulk of the change is from refrigerants that were modeled as zero emissions in previous cadences because of a lack of data which now have reliable GWPs. The refrigerants modeled as zero emissions in FEM 2022 represented a small proportion of overall refrigerant use in FEM and most were completely unused leading to the increase in reported refrigerant kg CO2e being smaller than might otherwise be expected. Because many comparisons start from zero the change is expressed in absolute terms rather than as a percentage.

Name	FEM 22 GWP	FEM 23 GWP	Difference
R-10 (PCC)	1730	2200	470.0
R-11 (CFC)	4660	5560	900.0
R-12 (CFC)	10200	11200	1000.0
R-12B1 (H)	1750	1930	180.0
R-13 (CFC)	13900	16200	2300.0

Name	FEM 22 GWP	FEM 23 GWP	Difference
R-13B1 (H)	6290	7200	910.0
R-14 (PFC)	6630	7380	750.0
R-20 (HCC)	16	16200	16184.0
R-22 (HCFC)	1760	1960	200.0
R-23 (HFC)	12400	14800	2400.0
R-31 (HCFC)	0	79.4	79.4
R-32 (HFC)	677	771	94.0
R-112 (CFC)	0	4620	4620.0
R-113a (CFC)	0	3930	3930.0
R-114 (CFC)	8590	9430	840.0
R-114a (CFC)	0	7420	7420.0
R-115 (CFC)	7670	9600	1930.0
R-121 (HCFC)	0	58.3	58.3
R-122b (HCFC)	0	772	772.0
R-123b (HCFC)	0	90.4	90.4
R-124 (HCFC)	527	597	70.0
R-124a (HCFC)	0	2070	2070.0
R-125 (HFC)	3170	3500	330.0
R-130a (HCC)	0	128	128.0
R-131a (HCFC)	0	181	181.0
R-132 (HCFC)	0	122	122.0
R-132a (HCFC)	0	70.4	70.4
R-133a (HCFC)	0	388	388.0
R-134 (HFC)	1120	1260	140.0
R-134a (HFC)	1300	1530	230.0
R-E134 (HFC)	1300	840	-460.0
R-141b (HCFC)	782	860	78.0

Name	FEM 22 GWP	FEM 23 GWP	Difference
R-142a (HCFC)	0	175	175.0
R-142b (HCFC)	1980	2300	320.0
R-143a (HFC)	4800	4470	-330.0
R-E143a (HFC)	1	5810	5809.0
R-221 (HCFC)	0	110	110.0
R-222 (HCFC)	0	500	500.0
R-225 (HCFC)	0	1560	1560.0
R-232 (HCFC)	0	690	690.0
R-234ba (HCFC)	0	260	260.0
R-235cc (HCFC)	0	1560	1560.0
R-244 (HCFC)	0	3360	3360.0
R-401A (HCFC)	1129.92	16	-1113.9
R-401B (HCFC)	1236.34	14	-1222.3
R-401C (HCFC)	875.54	19	-856.5
R-402A (HCFC)	859	2100	1241.0
R-404A (HFC)	3942.8	4728	785.2
R-405A (HCFC)	0	5328	5328.0
R-406A (HCFC)	1501	1943	442.0
R-407A (HFC)	2079.4	2262	182.6
R-407C (HFC)	1624.21	1908	283.8
R-407D (HFC)	1487.05	1748	260.9
R-407E (HFC)	1424.75	1672	247.3
R-407F (HFC)	1825	1965	140.0
R-408A (HCFC)	3257.1	3000	-257.1
R-409A (HCFC)	1484.75	1600	115.3
R-410A (HFC)	1923.5	2256	332.5
R-410B (HFC)	2048.15	2404	355.9

Name	FEM 22 GWP	FEM 23 GWP	Difference
R-411A (HCFO)	1555.18	14	-1541.2
R-412A (HCFC)	0	2286	2286.0
R-413A (HFC)	1945	2183	238.0
R-417A (HFC)	1542.22	2508	965.8
R-418A (HCFC)	4	1741	1737.0
R-420A (HCFC)	0	1548	1548.0
R-421A (HFC)	0	2812	2812.0
R-421B (HFC)	0	3409	3409.0
R-422A (HFC)	2847.17	3359	511.8
R-422B (HFC)	0	2700	2700.0
R-422D (HFC)	2473.17	2917	443.8
R-425A (HFC)	1430.745	1638	207.3
R-427A (HFC)	2138	2397	259.0
R-430A (HFC)	0	125	125.0
R-434A (HFC)	3075.44	3654	578.6
R-438A (HFC)	2265	2425	160.0
R-440A (HFC)	0	185	185.0
R-500 (HCFC)	8422.636	8100	-322.6
R-507[A] (HFC)	3985	3300	-685.0
R-508B (HFC)	11698	10350	-1348.0

Notes

Due to the large number of refrigerants the table of refrigerant emission factor changes is limited to refrigerants historically used in FEM that have changed by a significant amount.

Grid Emission Factors

In both FEM 3.0 and FEM 4.0 grid emission factors are licensed and cannot be shared.

FEM 2023 uses the same grid emission factors as FEM 2022 so purchased electricity will not be a source of variation in GHG calculations. # New and Modified Energy Sources

For specific details on energy sources used in FEM 2023 please see the FEM 2023 Energy and Carbon documentation.

New

- Biogas
  - Reference: `biogas`
  - Impact: extremely similar properties to `natgasng` which it would have been reported as previously. Likely to have a minimal effect.
- Biomass
  - Reference: `biomasscert` and `biomassgen`
  - Impact: Middle ground between the previously available `biomasswood` and `biomassother` which it would previously have been one of. The effective emissions of wood increase but the energy density increases partially offsetting so the impact should be small.
- Coal Water Slurry
  - Reference: `coalwaterslurry`
  - Impact: Emission factor modeled as the same as coal absent clear authoritative source.If reported previously would have been as coal converted to mass units so the impact should be small. Scope of use is unclear.
- District Heating
  - Reference: `districtheating`
  - Impact: Energy density must be self reported by facility as delta between intake and output temperatures. Emission factor may be specified by facility. Default emission factor modeled assuming heat generation using fuel oil. If previously reported would have been as the primary energy source and so should have a minimal impact.
- Ethanol
  - Reference: `ethenol`
  - Impact: Vehicle only, would previously have been reported as petrol or unreported. May have a small impact because of decreased energy density of ethanol relative to petrol.
- Hydrogen
  - Reference: `hydrogennr` and `hydrogenr`

  - Impact: Vehicle only, would previously have been unreported. Minimal impact is expected.

Modified

- Chilled Water
  - Reference: `chilledwater`
  - Impact: Emission factor may be specified by the facility. Default emission factor changed from US EPA source based on the US grid to assumption of fuel oil. Unpredictable impact depending on scale of reporting of specific emission factors.
- Purchased Steam
  - Reference: `steampurch`
  - Impact: Emission factor may be specified by the facility. Default emission factor changed from US EPA source based on the US grid to assumption of fuel oil. Unpredictable impact depending on scale of reporting of specific emission factors.
- Purchased Renewable
  - Reference: `purchrenew`
  - Impact: Emission factor may be specified by the facility. Typical emission factor likely to remain near default of 0 for minimal impact.