

New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2023

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Prepared by Andrew Barber and Henry Stenning



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Introduction

This paper has been prepared describing the results and methodology used for determining the primary energy, carbon dioxide and greenhouse gas (GHG) emission factors for New Zealand electricity and fuels. The analysis uses the latest information provided by the Ministry of Economic Development (MED). The emission factors for fuel are virtually unchanged between years; however, emissions from electricity generation do change depending upon the fuel mix. Electricity emission factors are reported for the years ending December 1991, and 2005 to 2021.

This edition is the latest update to the original paper, which has been revised annually for over 10 years. Annual updates to the original report primarily focus on calculated electricity emission factors. Other fuel LCA emission factors have not been updated since the original paper, though there are plans to update these in the next edition.

The analysis is based on using life cycle analysis (LCA) methodology and consequently includes all upstream, as well as in-use, emissions. With the publishing of the World Resources Institute Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard, we have decided to separate the emissions into these various scopes.

Total energy use is calculated using primary energy values. This is the sum of consumer energy, plus all the energy used, or lost, in the process of transforming energy into other forms and in bringing the energy to the final consumers. Consumer energy is defined as the amount of energy consumed by the final user, for example the kilowatt-hours recorded on the electricity meter or the actual energy value of fuel available to an engine.

Carbon dioxide equivalent (CO_{2e}) emissions are calculated based on the estimated global warming potential (GWP) of each GHG, expressed as the effect of one kilogram of CO₂ on global warming over a given time horizon. Non-CO₂ emissions are multiplied by the appropriate warming potential to convert to a CO_{2e} basis. GWP values differ based on the edition of the Intergovernmental Panel on Climate Change (IPCC) Assessment Report used.

This report has been updated to reflect annual changes to New Zealand electricity emission factors. These factors have been presented in Table 3 for the last three IPCC assessment reports. For context, the most recent New Zealand Greenhouse Gas Inventory uses GWPs from the IPCC 4th Assessment Report (IPCC, 2013). As previously mentioned, other fuel LCA emission factors have not been updated since the original paper, as the effect of changes to GWP factors for methane and nitrous oxide on these calculated values has been estimated to be small. Therefore, non-CO₂ emissions for non-electricity energy sources are converted to CO_{2e} using the IPCC 2nd Report (IPCC, 1995). However, Table 2 also includes the results based on using the IPCC's Fourth Assessment Report to align with PAS 2050:2008. In addition, emissions are reported as grams per MJ, which is equivalent to kilo tonnes per PJ.

Tables 1, 2 and 3 describe the primary energy and GHG emissions (CO₂, CH₄, N₂O) of NZ electricity and fuels. A full description of how these emission factors were determined can be found in the following sections.

The report was updated this year to include the latest MBIE energy emissions data (MBIE, Energy Balances 2023 and Annual Emissions 2023), with changes to electricity and diesel emissions. Note the most recent full set of energy and emission data is for 2021.

Table 1 Summary of electricity and fuel energy values.

Fuel Type	Unit	Consumer Energy (MJ/unit)	Fugitive Energy Coefficient	Primary Energy (MJ/unit)
Diesel	litres	38.4	1.21	46.3
Petrol (regular unleaded)	litres	35.1	1.21	42.3
Biodiesel (tallow) †	kg	40.0	0.50	20.0
Light fuel oil	litres	40.6	1.21	49.0
Marine diesel oil	litres	38.8	1.21	46.8
Bunker/Heavy fuel oil	litres	41.3	1.21	49.8
Intermediate fuel oil	litres	41.0	1.21	49.5
Heavy fuel oil - electricity	litres	41.1	1.21	49.6
Aviation gasoline	litres	33.9	1.21	40.9
Natural Gas	MJ	1.0	1.13	1.1
LPG	kg	49.5	1.13	55.9
Coal (bituminous)	kg	29.8	1.02	30.4
Coal (sub-bituminous)	kg	21.8	1.02	22.2
Coal (lignite)	kg	15.3	1.02	15.6
Average Electricity (2021)	kWh	3.6	2.82	10.2

† Barber, A., Campbell, A., Hennessy, W., 2007. *Embodied Fossil Energy and Net Greenhouse Gas Emissions from Biodiesel Made From New Zealand Tallow*. Report prepared for the Energy Efficiency Conservation Authority. CRL Energy Ltd, Wellington.

Note annual electricity energy and emission factors (1991, and 2005 – 2021) are included in Table 3.

Table 2 Summary of fuel energy and life cycle emission factors.

Fuel type	Unit	Fugitive Energy Coefficient	GHG ¹ – 1995 (gCO ₂ e/ unit)	GHG ² – 2007 (gCO ₂ e/ unit)	GHG ¹ – 1995 (gCO ₂ e/ unit) ³	GHG ² – 2007 (gCO ₂ e/ unit) ³
			Life Cycle Emissions		Combustion Emissions	
GHG Protocol Scope			1 & 3	1 & 3	1	1
Diesel	litres	1.21	3,148	3,147	2,690	2,689
Petrol (regular unleaded)	litres	1.21	2,758	2,760	2,339	2,341
Biodiesel (tallow) †	kg	0.50	1,750	1,750	-	-
Light fuel oil	litres	1.21	3,415	3,415	2,930	2,930
Marine diesel oil	litres	1.21	3,342	3,342	2,879	2,879
Bunker/Heavy fuel oil	litres	1.21	3,538	3,539	3,046	3,046
Intermediate fuel oil	litres	1.21	3,519	3,520	3,030	3,030
Heavy fuel oil (electricity)	litres	1.21	3,498	3,498	3,007	3,007
Aviation gasoline	litres	1.21	2,635	2,634	2,231	2,230
Natural Gas (Commercial)	MJ	1.13	60.6	60.7	53.8	53.8
LPG	kg	1.13	3,306	3,313	2,972	2,972
Coal (bituminous)	kg	1.02	2,745	2,761	2,607	2,607
Coal (sub-bituminous)	kg	1.02	2,056	2,068	1,955	1,955
Coal (lignite)	kg	1.02	1,503	1,512	1,433	1,433

1 Uses the IPCC Second Assessment Report (1995) GWPs CH₄ = 21, N₂O = 310

2 Uses the IPCC Fourth Assessment Report (2007) GWP's CH₄ = 25, N₂O = 298

3 MED Energy Greenhouse Gas Emissions 2010. These are combustion (Scope 1) rather than LCA based emissions and are included for comparison.

Table 3 Summary of fuel energy and life cycle emission factors.

Fuel type	Unit	Fugitive Energy Coefficient	GHG – 2007 (gCO ₂ e/kWh)	GHG – 2014 without climate-carbon feedback (gCO ₂ e/kWh)	GHG – 2014 with climate-carbon feedback (gCO ₂ e/kWh)	GHG – 2021 (gCO ₂ e/kWh)	GHG – 2007 (gCO ₂ e/kWh)	GHG – 2014 without climate-carbon feedback (gCO ₂ e/kWh)	GHG – 2014 with climate-carbon feedback (gCO ₂ e/kWh)	GHG – 2021 (gCO ₂ e/kWh)
			Life Cycle Emissions				Combustion Emissions			
GHG Protocol Scope			2 + 3	2 + 3	2 + 3	2 + 3	2	2	2	2
Average Electricity (2021)	kWh	2.82	132.5	133.2	134.4	133.2	125.5	125.9	126.6	125.9
Average Electricity (2020)	kWh	2.84	138.9	139.5	140.8	139.5	130.9	131.3	132.0	131.3
Average Electricity (2019)	kWh	2.78	127.7	128.4	129.6	128.4	119.9	120.3	121.0	120.2
Average Electricity (2018)	kWh	2.71	110.9	111.6	112.9	111.6	102.3	102.7	103.4	102.6
Average Electricity (2017)	kWh	2.71	117.0	117.7	119.1	117.6	108.0	108.4	109.3	108.4
Average Electricity (2016)	kWh	2.61	101.8	102.6	104.1	102.6	94.0	94.5	95.4	94.4
Average Electricity (2015)	kWh	2.67	129.5	130.4	132.2	130.4	118.7	119.2	120.2	119.1
Average Electricity (2014)	kWh	2.66	134.5	135.3	137.0	135.3	124.5	125.0	125.9	125.0
Average Electricity (2013)	kWh	2.70	163.0	163.9	165.8	163.9	151.2	151.6	152.6	151.6
Average Electricity (2012)	kWh	2.63	197.6	198.8	201.2	198.9	180.3	180.7	181.6	180.7
Average Electricity (2011)	kWh	2.52	164.3	165.7	168.5	165.6	144.0	144.4	145.2	144.4
Average Electricity (2010)	kWh	2.51	176.6	178.0	180.8	178.0	156.1	156.5	157.3	156.5
Average Electricity (2009)	kWh	2.42	196.7	198.1	200.7	198.0	178.2	178.6	179.4	178.6
Average Electricity (2008)	kWh	2.49	254.6	255.9	258.6	255.9	231.5	231.7	232.3	231.7
Average Electricity (2007)	kWh	2.37	217.3	218.9	222.2	218.9	191.6	191.8	192.2	191.8
Average Electricity (2006)	kWh	2.41	263.1	265.1	269.1	265.1	235.1	235.3	235.8	235.3
Average Electricity (2005)	kWh	2.43	268.9	270.5	273.8	270.5	243.4	243.7	244.1	243.7
Average Electricity (1991)	kWh	2.39	157.7	159.0	161.5	159.0	143.1	143.3	143.8	143.3

For information on Global Warming Potentials used to calculate the factors in this table, please refer to the section on Global Warming Potentials at the end of this report.

Diesel

The primary energy content of diesel is 1.207 MJ_{primary}/MJ_{consumer}. This figure is based on an analysis of the fuel mix, primary energy, carbon dioxide emissions and GHG emissions from the upstream diesel energy (Sheehan et al. 1998).

The fuel mix for NZ diesel is outlined in Table 4. It was assumed that half of the upstream electricity use occurs in NZ, during refining and domestic transport, and the other half during foreign oil

extraction. Carbon dioxide and GHG emissions from NZ electricity generation are 10.5 gCO₂/MJ_{primary} and 11.0 gCO_{2e}/MJ_{primary}. The CO₂ and GHG emissions from foreign electricity generation were based on Saudi Arabia's electricity being mostly oil-fired generation plants at a rate of 70.3 gCO₂/MJ and 71.0 gCO_{2e}/MJ (see heavy oil description below). In addition to the emissions from burning fossil fuels, advanced onshore oil extraction techniques use carbon dioxide directly at a rate of 0.62 g/MJ (Sheehan et al., 1998).

Table 4 NZ fossil diesel's primary energy fuel mix, CO₂ and GHG emissions.

Fuel Type	Energy MJ _{primary} /MJ _{consumer}	Carbon dioxide emissions		Greenhouse gases emissions	
		Fuel Type gCO ₂ / MJ _{primary}	Diesel component gCO ₂ / MJ _{consumer}	Fuel Type gCO _{2e} / MJ _{primary}	Diesel component gCO _{2e} / MJ _{consumer}
CO ₂ for oil extraction	0.017		0.62		0.62
Electricity – NZ	0.019	10.5	0.20	11.0	0.21
Electricity – Foreign	0.019	70.3	1.35	71.0	1.36
Natural gas	0.069	53.4	3.68	54.1	3.72
Heavy fuel oil	0.077	70.3	5.40	71.0	5.46
Diesel	0.004	66.8	0.28	67.9	0.29
Coal	0.001	89.2	0.06	89.7	0.06
Steam	0.002				
Sub-total	0.207		11.59		11.72
Diesel (consumer)	1.000		69.69		70.91
Total	1.207		81.28		82.63

Based on a consumer energy value of 38.4 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2, the primary energy value of NZ diesel is 46.3 MJ/L.

The direct carbon dioxide emission factor for NZ diesel is 69.69 gCO₂/MJ_{consumer} (MBIE

2016). Including upstream emissions, total CO₂ emissions are 81.28 gCO₂/MJ_{consumer} or 3.12 kgCO₂/L. In primary energy terms the result is 66.8 gCO₂/MJ_{primary}.

The direct GHG emission factor for NZ diesel is (MBIE 2016):

$$69.69 \text{ CO}_2 + (3.71/1000)*21 \text{ for CH}_4 + (3.71/1000)*310 \text{ for N}_2\text{O}$$

$$= 70.91 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for NZ diesel is $70.91 + 11.72 = 82.63 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$ or $3.17 \text{ kgCO}_2\text{e/L}$. In primary energy terms the result is $67.9 \text{ gCO}_2\text{e/MJ}_{\text{primary}}$.

Petrol

It was assumed that petrol (regular unleaded) had the same upstream fuel mix as diesel. Based on a consumer energy value of 35.1 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2, the primary energy value of NZ diesel is 42.3 MJ/L .

The direct carbon dioxide emission factor for petrol is $65.9 \text{ gCO}_2\text{/MJ}$ (MED 2010a). Including the upstream CO_2 emissions of 11.8 gCO_2 , total CO_2 emissions are $77.7 \text{ gCO}_2\text{/MJ}_{\text{consumer}}$ or $2.72 \text{ kgCO}_2\text{/L}$. In primary energy terms the result is $64.4 \text{ gCO}_2\text{/MJ}_{\text{primary}}$.

The direct GHG emission factor for petrol oil is (MED 2010a):

$$65.9 \text{ CO}_2 + (18.5/1000)*21 \text{ for CH}_4 + (1.4/1000)*310 \text{ for N}_2\text{O}$$

$$= 66.7 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for petrol is $66.7 + 11.9 = 78.7 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$ or $2.76 \text{ kgCO}_2\text{e/L}$. In primary energy terms the result is $65.2 \text{ gCO}_2\text{e/MJ}_{\text{primary}}$.

Light Fuel Oil

It was assumed that light fuel oil had the same upstream fuel mix as diesel. Based on a consumer energy value of 40.6 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2 the primary energy value of NZ diesel is 49.0 MJ/L .

The direct carbon dioxide emission factor for light fuel oil is $72.0 \text{ gCO}_2\text{/MJ}$ (MED 2010a). Including the upstream CO_2 emissions of 11.8 gCO_2 , total CO_2 emissions are $83.9 \text{ gCO}_2\text{/MJ}_{\text{consumer}}$ or $3.40 \text{ kgCO}_2\text{/L}$. In primary energy terms the result is $69.4 \text{ gCO}_2\text{/MJ}_{\text{primary}}$.

The direct GHG emission factor for light fuel oil (stationary – commercial and residential) is (MED 2010a):

$$72.0 \text{ CO}_2 + (1.3/1000)*21 \text{ for CH}_4 + (0.3/1000)*310 \text{ for N}_2\text{O}$$

$$= 72.2 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for light fuel oil is $72.2 + 11.94 = 84.1 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$ or $3.42 \text{ kgCO}_2\text{e/L}$. In primary energy terms the result is $69.7 \text{ gCO}_2\text{e/MJ}_{\text{primary}}$.

Marine Diesel Oil

Based on a consumer energy value of 38.8 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2 the primary energy value of NZ marine diesel is 46.8 MJ/L . The weight of marine diesel oil is 0.854 kg/L , making a consumer energy value of 45.42 MJ/kg , or 54.8 MJ/kg in primary energy terms.

The direct carbon dioxide emission factor for NZ marine diesel oil is $73.5 \text{ gCO}_2\text{/MJ}_{\text{consumer}}$ (MED 2007a). Including the upstream emissions, total CO_2 emissions are $85.3 \text{ gCO}_2\text{/MJ}_{\text{consumer}}$ or

3.31 kgCO₂/L. In primary energy terms the result is 70.6 gCO₂/MJ_{primary}.

The direct GHG emission factor for NZ marine diesel oil is (MED 2010a):

$$73.5 \text{ CO}_2 + (6.7/1000)*21 \text{ for CH}_4 + (1.9/1000)*310 \text{ for N}_2\text{O}$$

$$= 74.2 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for NZ marine diesel is 74.2 + 11.94 = 86.2 gCO₂e/MJ_{consumer} or 3.34 kgCO₂e/L (3.91 kgCO₂e/kg). In primary energy terms the result is 71.4 gCO₂e/MJ_{primary}.

Bunker Fuel Oil / Heavy Fuel Oil

Based on a consumer energy value for bunker fuel oil of 41.3 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2 the primary energy value of NZ bunker fuel oil is 49.81 MJ/L. The weight of bunker fuel is 0.969 kg/L making a consumer energy value of 42.56 MJ/kg, or 51.39 MJ/kg in primary energy terms.

The direct carbon dioxide emission factor for bunker fuel oil is not available, it is therefore assumed to be the same as for heavy fuel oil, which is 73.1 gCO₂/MJ_{consumer} (MED 2010a). Including the upstream emissions, total CO₂ emissions are 84.9 gCO₂/MJ_{consumer} or 3.50 kgCO₂/L. In primary energy terms the result is 70.3 gCO₂/MJ_{primary}.

The direct GHG emission factor for heavy fuel oil is (MED 2010a):

$$73.1 \text{ CO}_2 + (6.7/1000)*21 \text{ for CH}_4 + (1.9/1000)*310 \text{ for N}_2\text{O}$$

$$= 73.8 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for heavy fuel oil is 73.8 + 11.94 = 85.8 gCO₂e/MJ_{consumer} or 3.54 kgCO₂e/L (3.63 kgCO₂e/kg). In primary energy terms the result is 71.0 gCO₂e/MJ_{primary}.

Intermediate Fuel Oil (IFO 380)

Intermediate fuel oil is a mix of 98% heavy fuel oil and 2% distillate oil (marine diesel oil). Based on a consumer energy values for bunker fuel oil and marine diesel oil, the energy content is 41.0 MJ/L (42.9 MJ/kg) and the fugitive energy coefficient described in Table 2, the primary energy value is 49.5 MJ/L (51.8 MJ/kg).

The direct carbon dioxide emission factor for IFO 380 is 73.1 gCO₂/MJ_{consumer}. Including the upstream emissions, total CO₂ emissions are 84.9 gCO₂/MJ_{consumer} or 3.48 kgCO₂/L. In primary energy terms the result is 70.3 gCO₂/MJ_{primary}.

The direct GHG emission factor for IFO 380:

$$73.1 \text{ CO}_2 + (6.7/1000)*21 \text{ for CH}_4 + (1.9/1000)*310 \text{ for N}_2\text{O}$$

$$= 73.8 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for IFO 380 is 85.8 gCO₂e/MJ_{consumer} or 3.52 kgCO₂e/L (3.68 kgCO₂e/kg). In primary energy terms the result is 71.0 gCO₂e/MJ_{primary}.

Heavy Fuel Oil – Electricity Generation

It was assumed that heavy fuel oil had the same upstream fuel mix as diesel. Based on a consumer energy value of 41.1 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2, the primary energy value of heavy fuel oil is 49.6 MJ/L.

The direct carbon dioxide emission factor for heavy fuel oil is 73.1 gCO₂/MJ (MED 2010a). Including the upstream CO₂ emissions of 11.8 gCO₂, total CO₂ emissions are 84.9 gCO₂/MJ_{consumer} or 3.49 kgCO₂/L. In primary energy terms the result is 70.3 gCO₂/MJ_{primary}.

The direct GHG emission factor for heavy fuel oil is (MED 2010a):

$$\begin{aligned} &73.1 \text{ CO}_2 + (0.9/1000)*21 \text{ for CH}_4 + \\ &(0.3/1000)*310 \text{ for N}_2\text{O} \\ &= 73.2 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}. \end{aligned}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for heavy fuel oil is 73.2 + 11.94 = 85.2 gCO₂e/MJ_{consumer} or 3.50 kgCO₂e/L. In primary energy terms the result is 70.5 gCO₂e/MJ_{primary}.

Aviation Gasoline

It was assumed that aviation gasoline had the same upstream fuel mix as diesel. Based on a consumer energy value of 33.9 MJ/L (MED 2010b) and the fugitive energy coefficient described in Table 2 the primary energy value of NZ diesel is 40.9 MJ/L.

The direct carbon dioxide emission factor for aviation gasoline is 65.2 gCO₂/MJ (MED 2010a). Including the upstream CO₂ emissions of 11.80 gCO₂, total CO₂ emissions are 77.0 gCO₂/MJ_{consumer} or 2.61 kgCO₂/L. In primary energy terms the result is 63.8 gCO₂/MJ_{primary}.

The direct GHG emission factor for aviation gasoline is (MED 2010a):

$$\begin{aligned} &65.2 \text{ CO}_2 + (1.9/1000)*21 \text{ for CH}_4 + \\ &(1.9/1000)*310 \text{ for N}_2\text{O} \\ &= 65.9 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}. \end{aligned}$$

Including the GHG emissions from upstream primary energy, the total GHG emission factor for petrol is 65.9 + 11.94 = 77.8 gCO₂e/MJ_{consumer} or 2.63 kgCO₂e/L. In primary energy terms the result is 64.4 gCO₂e/MJ_{primary}.

Natural Gas

The fugitive energy use factor for gas is 1.13 (Bains and Peet, 1995). This is much higher than the figure reported by Sheehan et al., (1998) of 1.029. It is not clear why there is such a large difference.

The carbon dioxide emission factor for natural gas is 53.2 gCO₂/MJ (MED, 2010a).

Flaring/venting and distribution/transmission account for 763 ktCO₂ (MED, 2010a). Extraction and processing account for 391 ktCO₂ (MED, 2010a) but must be apportioned to gas and oil in the ratio of their indigenous

production for the 2009 calendar year, which was 57% and 43% respectively (MED, 2010b). Thus $763 + (391 * 57\%) = 988$ ktCO₂ p.a. of fugitive and own use emissions attributable to gas. Gas demand is 165.1 PJ (MED, 2010b). Carbon dioxide emissions for gas from flaring/venting and distribution/transmission are $988/165.1 = 5.98$ gCO₂/MJ.

The final carbon dioxide emission factor for gas is the sum of emissions for combustion of the gas and the 'fugitive' and 'own use' emissions; which is $53.2 + 5.98 = 59.1$ gCO₂/MJ_{consumer}. In primary energy terms the result is 52.3 gCO₂/MJ_{primary}.

The direct GHG emission factor for natural gas in commercial boilers (MED 2010a) is:

$$53.2 \text{ CO}_2 + (1.1/1000)*21 \text{ for CH}_4 + (2.1/1000)*310 \text{ for N}_2\text{O} \\ = 53.8 \text{ gCO}_2\text{e/MJ.}$$

In addition to the CO₂ emissions described above for flaring/venting and distribution/transmission, methane emissions are 10,55 tCH₄ (MED, 2010a) or 222 ktCO₂e. Extraction and processing account for a further 9.6 tCH₄ (MED, 2010a) or 0.201 ktCO₂e; and nitrous oxide emissions are 0.75 tN₂O (MED, 2010a) or 0.233 ktCO₂e. As above, 57% of these emissions are attributable to gas. Thus $(222 + 0.201 + 0.233) * 57\% = 127.6$ ktCO₂e p.a. of fugitive and own use GHG emissions are attributable to gas.

GHG emissions for gas from flaring/venting and distribution/transmission are $988/165.1 + 127.6/165.1 = 6.76$ gCO₂e/MJ.

The final GHG emission factor for gas is the sum of emissions for combustion of the gas, and the 'fugitive' and 'own use' emissions; which is $53.8 + 6.76 = 60.6$ gCO₂e/MJ_{consumer}. In primary energy terms the result is 53.6 gCO₂e/MJ_{primary}.

LPG

The fugitive energy use factor for gas is 1.13 (Bains and Peet, 1995).

The energy value of LPG is 49.5 MJ/kg or 26.4 MJ/L (MED, 2010b).

The carbon dioxide emission factor for LPG is 59.8 gCO₂/MJ (MED, 2010a).

The natural gas and LPG CO₂ fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at 5.98 gCO₂/MJ.

The final carbon dioxide emission factor for gas is the sum of emissions for combustion of the gas and the 'fugitive' and 'own use' emissions; which is $59.8 + 5.98 = 65.8$ gCO₂/MJ_{consumer}. In primary energy terms the result is 58.2 gCO₂/MJ_{primary}.

The direct GHG emission factor for LPG in commercial boilers (MED 2010a) is:

$$59.8 \text{ CO}_2 + (1/1000)*21 \text{ for CH}_4 + (0.6/1000)*310 \text{ for N}_2\text{O} \\ = 60.0 \text{ gCO}_2\text{e/MJ}$$

The natural gas and LPG GHG fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at 6.76 gCO₂e/MJ.

The final GHG emission factor for gas is the sum of emissions for combustion of the gas, and the 'fugitive' and 'own use' emissions; which is $60.0 + 6.76 = 66.8$ gCO₂e/MJ_{consumer}. In primary energy terms the result is 59.1 gCO₂e/MJ_{primary}.

Coal – bituminous

An early reported fugitive energy use factor for coal was 1.04 (Bains and Peet, 1995). Subsequent reports have suggested that this figure represents an over-estimation and an emission factor of 1.02 has been used in this report (Sheehan et al., 1998, Barber et al., 2007).

Based on a consumer energy value of 29.8 MJ/kg (MED, 2010b) and the fugitive energy coefficient of 1.02, the primary energy value of bituminous NZ coal is 30.4 MJ/kg.

The carbon dioxide emission factor for bituminous coal is 87.0 gCO₂/MJ (MED, 2010a). The total carbon dioxide emission factor for coal is assumed to include the indirect CO₂ emissions from the extra 2% upstream primary energy (using the diesel emission factor).

Thus, the final CO₂ emission factor for bituminous coal is $87.0 + (0.02 * 80.7) = 88.6$ gCO₂/MJ_{consumer} or 2.6 kgCO₂/kg coal. In primary energy terms the result is 86.9 gCO₂/MJ_{primary}.

The direct GHG emission factor for the average bituminous coal in industrial boilers (MED, 2010a) is:

$$\begin{aligned} & 87.0 \text{ CO}_2 + (0.7/1000)*21 \text{ for CH}_4 + \\ & (1.5/1000)*310 \text{ for N}_2\text{O} \\ & = 87.5 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}. \end{aligned}$$

The total GHG emission factor for the average bituminous coal in industrial boilers is assumed to include the indirect GHG emissions from the extra 2% upstream primary energy (using the diesel emission factor) plus fugitive coal mining methane emissions.

Methane emissions from coal mining and post-mining activities were 16,616 tCH₄, or 348.9 ktCO₂e (MED, 2010a). Indigenous coal production was 116.5 PJ (MED, 2010b).

The final GHG emission factor for bituminous coal is $87.5 + (0.02 * 80.7) + 348.9/116.5 = 92.1$ gCO₂e/MJ_{consumer} or 2.7 kgCO₂/kg coal. In primary energy terms the result is 90.3 gCO₂e/MJ_{primary}.

Coal – sub-bituminous

An early reported fugitive energy use factor for coal was 1.04 (Bains and Peet, 1995). Subsequent reports have suggested that this figure represents an over-estimation and an emission factor of 1.02 has been used in this report (Sheehan et al., 1998, Barber et al., 2007).

Based on a consumer energy value of 21.8 MJ/kg (MED, 2010b) and the fugitive energy coefficient of 1.02, the primary energy value of sub-bituminous NZ coal is 22.2 MJ/kg.

The carbon dioxide emission factor for sub-bituminous coal is 89.4 gCO₂/MJ (MED, 2010a). The total carbon dioxide emission factor for coal is assumed to include the indirect CO₂ emissions from the extra 2% upstream primary energy (using the diesel emission factor).

Thus, the final CO₂ emission factor for sub-bituminous coal is $89.4 + (0.02 * 80.7) = 91.0$ gCO₂/MJ_{consumer} or 2.0 kgCO₂/kg coal. In primary energy terms the result is 89.2 gCO₂/MJ_{primary}.

The direct GHG emission factor for the average sub-bituminous coal in industrial boilers (MED, 2010a) is:

$$\begin{aligned} & 89.4 \text{ CO}_2 + (0.7/1000)*21 \text{ for CH}_4 + \\ & (1.5/1000)*310 \text{ for N}_2\text{O} \\ & = 89.9 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}. \end{aligned}$$

The total GHG emission factor for the average sub-bituminous coal in industrial boilers is assumed to include the indirect GHG emissions from the extra 2% upstream primary energy (using the diesel emission factor) plus fugitive coal mining methane emissions.

Methane emissions from coal mining and post-mining activities were 16,616 tCH₄, or 348.9 ktCO₂e (MED, 2010a). Indigenous coal production was 116.5 PJ (MED, 2010b).

The final GHG emission factor for sub-bituminous coal is $89.9 + (0.02 * 80.7) + 348.9/116.5 = 94.5$ gCO₂e/MJ_{consumer} or 2.1 kgCO₂/kg coal. In primary energy terms the result is 92.6 gCO₂e/MJ_{primary}.

Coal – lignite

An early reported fugitive energy use factor for coal was 1.04 (Bains and Peet, 1995). Subsequent reports have suggested that this figure represents an over-estimation and an emission factor of 1.02 has been used in this report (Sheehan et al., 1998, Barber et al., 2007).

Based on a consumer energy value of 15.3 MJ/kg (MED, 2010b) and the fugitive energy coefficient of 1.02, the primary energy value of lignite NZ coal is 15.6 MJ/kg.

The carbon dioxide emission factor for lignite coal is 93.3 gCO₂/MJ (MED, 2010a). The total carbon dioxide emission factor for coal is assumed to include the indirect CO₂ emissions from the extra 2% upstream primary energy (using the diesel emission factor).

Thus, the final CO₂ emission factor for lignite coal is $93.3 + (0.02 * 80.1) = 94.9$ gCO₂/MJ_{consumer} or 1.5 kgCO₂/kg coal. In primary energy terms the result is 93.0 gCO₂/MJ_{primary}.

The direct GHG emission factor for the average lignite coal in industrial boilers (MED, 2010a) is:

$$93.3 \text{ CO}_2 + (0.7/1000)*21 \text{ for CH}_4 + (1.5/1000)*310 \text{ for N}_2\text{O}$$

$$= 93.8 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$$

The total GHG emission factor for the average lignite coal in industrial boilers is assumed to include the indirect GHG emissions from the extra 2% upstream primary energy (using the diesel emission factor) plus fugitive coal mining methane emissions.

Methane emissions from coal mining and post-mining activities were 16,616 tCH₄, or 348.9 ktCO₂e (MED, 2010a). Indigenous coal production was 116.5 PJ (MED, 2010b).

The final GHG emission factor for coal is $93.8 + (0.02 * 80.1) + 348.9/116.5 = 98.4$ gCO₂e/MJ_{consumer} or 1.5 kgCO₂/kg coal. In primary energy terms the result is 96.5 gCO₂e/MJ_{primary}.

Electricity

Electricity primary energy use and emission factors presented in Table 1 and 3 use the methodology as described in detail here, using the figures presented in the publications Annual Emissions (MBIE, 2023) and Energy Balances (MBIE, 2023). The methodology below uses Global Warming Potentials (GWPs) from the IPCC 6th Assessment Report (see section on Global Warming Potentials).

In 2021 the primary energy content of electricity was 2.82 kWh per 1 kWh of energy supplied to the consumer. This is based on the primary energy supply figure for electricity generation (including cogeneration) in 2021 of 395 PJ (MBIE, 2023). In addition to the primary energy supply figure described in the MBIE Energy Balances data, additional energy is added to consider coal mining and distribution plus gas extraction, treatment, and distribution as well as liquid fuel use (6.3 PJ MBIE, 2023).

The additional 6.3 PJ of coal, gas and liquid fuel (diesel) energy has been calculated based on the energy coefficients of $1.02 \text{ MJ}_{\text{consumer}}/\text{MJ}_{\text{primary}}$ for coal, $1.13 \text{ MJ}_{\text{consumer}}/\text{MJ}_{\text{primary}}$ for gas and $1.21 \text{ MJ}_{\text{consumer}}/\text{MJ}_{\text{primary}}$ for diesel.

Total primary energy was 402 PJ divided by observed consumption of 142.3 PJ (Ibid.) equalling $2.82 \text{ MJ}_{\text{consumer}}/\text{MJ}_{\text{primary}}$.

The carbon dioxide emissions in 2021 for electricity generation were 4,403.8 ktCO₂ (MBIE, 2023). Fugitive CO₂ emissions from geothermal fields in 2021 were 431.6 ktCO₂ (Ibid.). The total carbon dioxide emission factor for electricity is assumed to include the indirect CO₂ emissions from the extra 2% upstream primary energy (using the diesel emission factor of 81.28 gCO₂/MJ) of coal and the 'fugitive' and 'own use' emissions of gas at 4.00 gCO₂/MJ. This added 54.5 and 130.9 ktCO₂ respectively.

The direct GHG emission factor for electricity includes the CO₂ described above, plus direct generation emissions of 0.06 ktCH₄ (Ibid.) and 0.04 ktN₂O (Ibid.). Fugitive methane emissions from geothermal fields were 4.58 ktCH₄ (Ibid.). Total GHG emissions from electricity generation including fugitive geothermal emissions in 2021 were 4,976 ktCO_{2e}.

The upstream emissions from coal were 88.4 ktCO_{2e}. This included direct GHG emissions from diesel plus methane from coal mining and post mining activities. Additional upstream gas GHG emissions were 200.2 ktCO_{2e}. This is based on the gas GHG emission factor for flaring/venting and distribution/transmission of 4.00 gCO₂/MJ (see Gas description above), as well as the Liquid fuel emission factor of 81.28 gCO₂/MJ. The total GHG emissions in 2021 from electricity generation, including upstream emissions were 5,265 ktCO_{2e}.

Thus, the final GHG emission factor for electricity is $5,265/142.3 = 37.0 \text{ gCO}_{2e}/\text{MJ}$ or $0.133 \text{ kgCO}_{2e}/\text{kWh}$. In primary energy terms the result is $13.1 \text{ gCO}_{2e}/\text{MJ}_{\text{primary}}$.

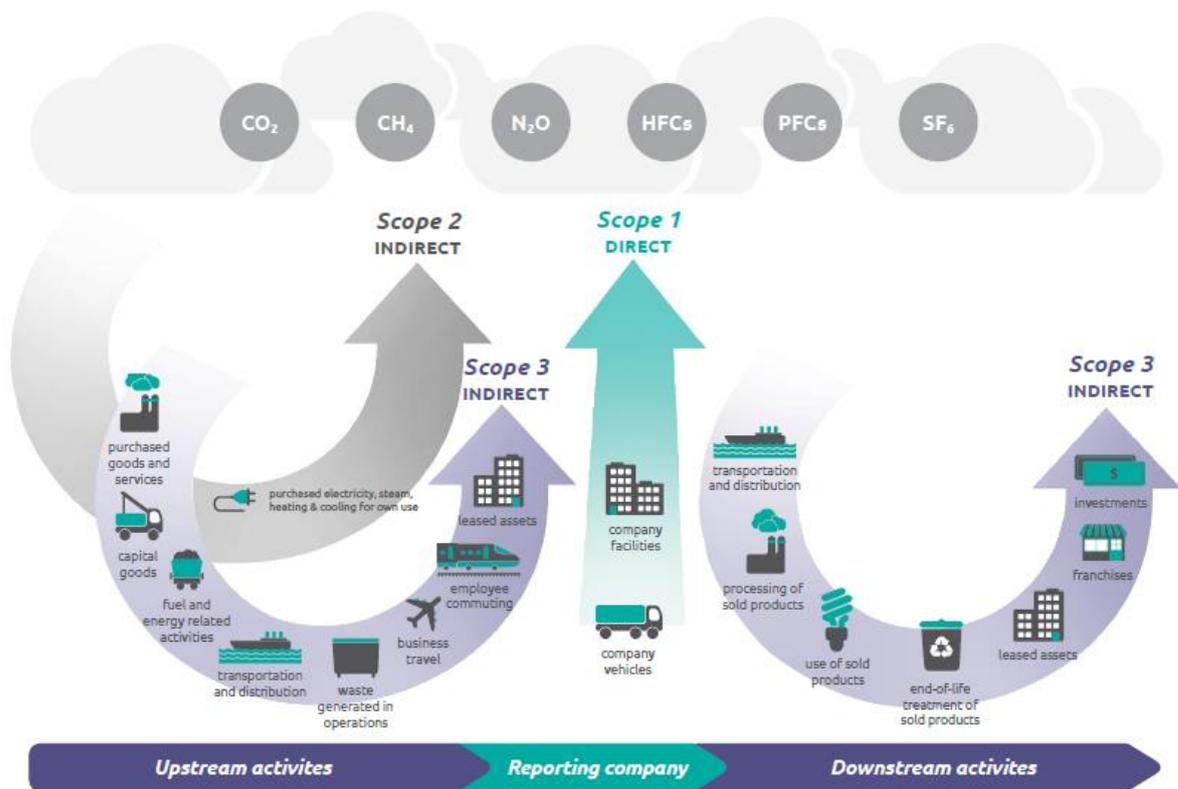
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Greenhouse Gas Protocol

Corporate Value Chain (Scope 3) Accounting and Reporting Standards

Overview of GHG Protocol scopes and emissions across the value chain



Corporate-level GHG Protocol reporting options

Reporting Option	Scope 1	Scope 2	Scope 3
Report in conformance with the <i>GHG Protocol Corporate Standard</i>	Required	Required	Optional: Companies may report any scope 3 emissions the company chooses
Report in conformance with the <i>GHG Protocol Corporate Standard</i> and the <i>GHG Protocol Scope 3 Standard</i>	Required	Required	Required: Companies shall report scope 3 emissions following the requirements of the <i>Scope 3 Standard</i>

Source: <http://www.ghgprotocol.org/standards/scope-3-standard>

Global Warming Potentials

The explanation below is from the United States Environmental Protection Agency (EPA).

Greenhouse gases (GHGs) warm the earth by absorbing energy and slowing the rate at which the energy escapes to space; they act like a blanket insulating the earth. Different GHGs can have different effects on the earth's warming. Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime").

The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of 1 tonne of carbon dioxide (CO₂). The larger the GWP, the more that a given gas warms the earth compared to CO₂ over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

CO₂, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO₂ remains in the climate system for a very long time: CO₂ emissions cause increases in atmospheric concentrations of CO₂ that will last thousands of years.

Methane (CH₄) is estimated to have a GWP of 27.2 or 29.8 over 100 years, depending upon the origin. CH₄ emitted today lasts about a decade on average, which is much less time than CO₂. But CH₄ also absorbs much more energy than CO₂. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH₄ GWP also accounts for some indirect effects, such as the fact that CH₄ is a precursor to ozone, and ozone is itself a GHG.

Nitrous Oxide (N₂O) has a GWP 273 times that of CO₂ for a 100-year timescale. N₂O emitted today remains in the atmosphere for more than 100 years, on average.

Table 5 Global Warming Potentials from the 2nd to the 6th IPCC Assessment Reports.

Greenhouse gas	1996 IPCC GWP 2 nd Assessment Report	2007 IPCC GWP 4 th Assessment Report	2014 IPCC GWP 5 th Assessment Report		2021 IPCC GWP 6 th Assessment Report
	<i>Without climate-carbon feedback</i>			<i>With climate-carbon feedback¹</i>	
Carbon dioxide (CO ₂)	1	1	1	1	1
Methane (CH ₄) fossil origin	21	25	28	34	29.8
Methane (CH ₄) Non fossil origin					27.2
Nitrous oxide (N ₂ O)	310	298	265	298	273

¹ Climate-carbon feedback is the effect of a changing climate on the carbon cycle, and is accounted for in more recent assessment reports.

