

New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2019

September 2019

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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 2017.

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 (CO₂e) 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 CO₂e basis. The GWPs for CH₄ and N₂O are 21 and 310 respectively, for a 100-year time horizon. These are from the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (IPCC, 1995). This is consistent with NZ's GHG Inventory reporting requirements but is different to PAS 2050:2008 that uses the GWP's from the IPCC's Fourth Assessment Report for CH₄ and N₂O, which are 25 and 298 respectively (IPCC, 2007). Throughout this report non-CO₂ emissions are converted to CO₂e using the IPCC Second Report (IPCC, 1995). However, Tables 2 and 3 also includes the results based on using the IPCC's Fourth Assessment Report. 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 2017 and Annual Emissions 2017), with changes to electricity and diesel emissions.

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 (2017)	kWh	3.6	2.69	9.6

† 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 – 2017) 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 ¹ – 1995 (gCO ₂ e/kWh)	GHG ² – 2007 (gCO ₂ e/kWh)	GHG ³ – 2014 (gCO ₂ e/kWh)	GHG ¹ – 1995 (gCO ₂ e/kWh)	GHG ² – 2007 (gCO ₂ e/kWh)	GHG ³ – 2014 (gCO ₂ e/kWh)
			Life Cycle Emissions			Combustion Emissions		
GHG Protocol Scope			2 + 3	2 + 3	2 + 3	2	2	2
Average Electricity (2017)	kWh	2.69	120.1	121.2	122.1	111.0	111.7	112.2
Average Electricity (2016)	kWh	2.66	107.3	108.4	109.2	99.4	100.1	100.7
Average Electricity (2015)	kWh	2.80	138.4	139.6	140.5	127.3	128.0	128.5
Average Electricity (2014)	kWh	2.70	138.6	139.8	140.6	129.0	129.7	130.2
Average Electricity (2013)	kWh	2.65	163.8	165.1	166.0	152.5	153.1	153.6
Average Electricity (2012)	kWh	2.61	197.9	199.3	200.3	182.8	183.4	183.8
Average Electricity (2011)	kWh	2.52	162.9	164.3	165.3	146.2	146.8	147.2
Average Electricity (2010)	kWh	2.49	174.5	175.9	177.0	156.4	157.0	157.3
Average Electricity (2009)	kWh	2.35	196.5	198.2	199.4	179.1	179.7	180.1
Average Electricity (2008)	kWh	2.40	254.7	256.5	257.7	232.2	232.6	232.8
Average Electricity (2007)	kWh	2.26	213.0	214.3	215.3	191.9	192.2	192.4
Average Electricity (2006)	kWh	2.29	256.6	258.3	259.5	234.6	235.0	235.1
Average Electricity (2005)	kWh	1.86	254.5	255.7	256.5	243.2	243.5	243.7
Average Electricity (1991)	kWh	2.21	153.7	154.7	155.5	143.6	143.9	144.2

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 Uses the IPCC Fifth Assessment Report (2014) GWP's CH₄ = 28, N₂O = 265

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):

$$73.1 \text{ CO}_2 + (0.9/1000)*21 \text{ for CH}_4 + (0.3/1000)*310 \text{ for N}_2\text{O}$$

$$= 73.2 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}.$$

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):

$$65.2 \text{ CO}_2 + (1.9/1000)*21 \text{ for CH}_4 + (1.9/1000)*310 \text{ for N}_2\text{O}$$

$$= 65.9 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}.$$

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 $763 + (391 * 57\%) = 988 \text{ ktCO}_2 \text{ p.a.}$ 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 $988/165.1 = 5.98 \text{ gCO}_2/\text{MJ}$.

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 $53.2 + 5.98 = 59.1 \text{ gCO}_2/\text{MJ}_{\text{consumer}}$. In primary energy terms the result is $52.3 \text{ gCO}_2/\text{MJ}_{\text{primary}}$.

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

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

In addition to the CO_2 emissions described above for flaring/venting and distribution/transmission, methane emissions are $10,55 \text{ tCH}_4$ (MED, 2010a) or $222 \text{ ktCO}_2\text{e}$. Extraction and processing account for a further 9.6 tCH_4 (MED, 2010a) or $0.201 \text{ ktCO}_2\text{e}$; and nitrous oxide emissions are $0.75 \text{ tN}_2\text{O}$ (MED, 2010a) or $0.233 \text{ ktCO}_2\text{e}$. As above, 57% of these emissions are attributable to gas. Thus $(222 + 0.201 + 0.233) * 57\% = 127.6 \text{ ktCO}_2\text{e p.a.}$ of fugitive and own use GHG emissions are attributable to gas.

GHG emissions for gas from flaring/venting and distribution/transmission are $988/165.1 + 127.6/165.1 = 6.76 \text{ gCO}_2\text{e}/\text{MJ}$.

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 $53.8 + 6.76 = 60.6 \text{ gCO}_2\text{e}/\text{MJ}_{\text{consumer}}$. In primary energy terms the result is $53.6 \text{ gCO}_2\text{e}/\text{MJ}_{\text{primary}}$.

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 $59.8 \text{ gCO}_2/\text{MJ}$ (MED, 2010a).

The natural gas and LPG CO_2 fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at $5.98 \text{ gCO}_2/\text{MJ}$.

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 $59.8 + 5.98 = 65.8 \text{ gCO}_2/\text{MJ}_{\text{consumer}}$. In primary energy terms the result is $58.2 \text{ gCO}_2/\text{MJ}_{\text{primary}}$.

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

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

The natural gas and LPG GHG fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at $6.76 \text{ gCO}_2\text{e}/\text{MJ}$.

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 $60.0 + 6.76 = 66.8 \text{ gCO}_2\text{e}/\text{MJ}_{\text{consumer}}$. In primary energy terms the result is $59.1 \text{ gCO}_2\text{e}/\text{MJ}_{\text{primary}}$.

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 $89.9 + (0.02 * 80.7) + 348.9/116.5 = 94.5 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$ 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 $93.3 + (0.02 * 80.1) = 94.9 \text{ gCO}_2\text{/MJ}_{\text{consumer}}$ 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 $93.8 + (0.02 * 80.1) + 348.9/116.5 = 98.4 \text{ gCO}_2\text{e/MJ}_{\text{consumer}}$ 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 2017) and Energy Balances (MBIE 2017)

In 2017 the primary energy content of electricity was 2.69 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 2017 of 376 PJ (MBIE 2017). 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 (8.1 PJ MBIE 2017).

The additional 8.05 PJ of coal, gas and liquid fuel (diesel) energy has been calculated based on the energy coefficients of 1.02 MJ_{consumer}/MJ_{primary} for coal, 1.13 MJ_{consumer}/MJ_{primary} for gas and 1.21 MJ_{consumer}/MJ_{primary} for diesel.

Total primary energy was 376 PJ divided by observed consumption of 142.8 PJ (Ibid.) equalling 2.63 MJ_{consumer}/MJ_{primary}.

The carbon dioxide emissions in 2017 for electricity generation were 3,611.0 ktCO₂ (MBIE 2017). Fugitive CO₂ emissions from geothermal fields in 2016 were 643.3 ktCO₂ (MBIE 2017). 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 50.1 and 341.9 ktCO₂ respectively.

Thus, the final CO₂ emission factor for electricity is $4,451/142.8 = 31.17 \text{ gCO}_2/\text{MJ}_{\text{consumer}}$ or 0.112 kgCO₂/kWh.

In primary energy terms the result is 12.61 gCO₂/MJ_{primary}.

The direct GHG emission factor for electricity includes the CO₂ described above, plus direct generation emissions of 0.06 ktCH₄ (Ibid.) and 0.01 ktN₂O (Ibid.). Fugitive methane emissions from geothermal fields were 6.86 ktCH₄ (Ibid.). Total GHG emissions from electricity generation including fugitive geothermal emissions in 2016 were 4,451 ktCO_{2e}.

The upstream emissions from coal were 50.11 ktCO_{2e}. This included direct GHG emissions from diesel plus methane from coal mining and post mining activities. Additional upstream gas GHG emissions were 342 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 2017 from electricity generation, including upstream emissions were 4,843.8 ktCO_{2e}.

Thus, the final GHG emission factor for electricity is $4,843.8/142.8 = 33.9 \text{ gCO}_2\text{e}/\text{MJ}$ or 0.122 kgCO_{2e}/kWh. In primary energy terms the result is 12.6 gCO_{2e}/MJ_{primary}.

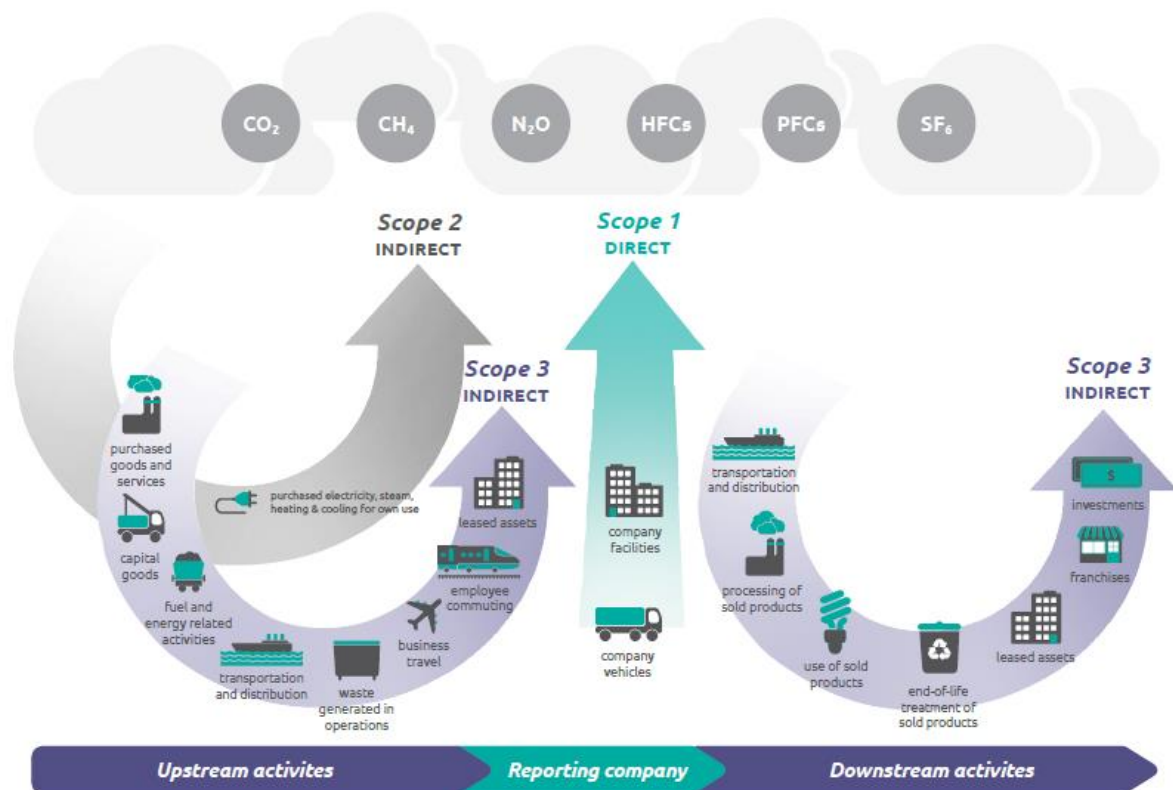
References

- Baines, J.T., and Peet, N.J. 1995. *1991 Input-Output Energy Analysis Coefficients*. Commissioned by the CBPR from Taylor Baines and Associates.
- 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.
- IPCC. 1995. Houghton JT, Meira Filho LG, Callender BA, Harris N, Kattenberg A, Maskell K (eds). *Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change*. Cambridge University Press: United Kingdom.
- IPCC. 2007. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K, Tignor MB, and Miller HL (eds). *Climate Change 2007: The physical science basis. Contribution of Working Group I to the Forth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: United Kingdom.
- MBIE, 2017. Annual Emissions. Ministry of Business, Innovation and Employment. www.mbie.govt.nz
- MBIE, 2017. Energy Balances. Ministry of Business, Innovation and Employment. www.mbie.govt.nz
- MBIE, 2016. Electricity Emissions Factors. Ministry of Business, Innovation and Employment. www.mbie.govt.nz
- MED, 2007. *Energy Greenhouse Gas Emissions 1990-2006 June 2007*, Ministry of Economic Development, Wellington. www.med.govt.nz
- MED, 2010a. *Energy Greenhouse Gas Emissions 10*, Ministry of Economic Development, Wellington. www.med.govt.nz
- MED, 2010b. *New Zealand Energy Data File 10*. Ministry of Economic Development, Wellington. www.med.govt.nz
- Sheehan, J., Camobreco, V., Duffield, J., Graboski, M., Shapouri, H. 1998. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus*. Prepared for U.S. Department of Energy's Office of Fuels Development and U.S. Department of Agriculture's Office of Energy. NREL/SR-580-24089. <http://www.nrel.gov/docs/legosti/fy98/24089.pdf>

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>