# NZ Fuel and Electricity Life Cycle Emission Factors
# Total Primary Energy Use, Carbon Dioxide and GHG Emissions

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This paper has been prepared describing the results and methodology used for determining the primary energy, carbon dioxide and greenhouse gas 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, 2005, 2006, 2007 and 2008.

The analysis is based on using life cycle analysis (LCA) methodology so consequently includes all upstream as well as in-use emissions. The results have also been compared to the MED published in-use emissions.

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 emissions are calculated based on the estimated global warming potential (GWP) of each greenhouse gas, expressed as the effect of one kilogram of $CO_2$ on global warming over a given time horizon. Non-$CO_2$ emissions are multiplied by the appropriate warming potential to convert to a $CO_2$ equivalent basis. The GWPs for $CH_4$ and $N_2O$ applied are 21 and 310, respectively, which are for a 100-year time horizon. These are from the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (1995) (MED, 2007a). 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 which is 25 and 298 for $CH_4$ and $N_2O$ respectively.

Tables 1 and 2 describe the primary energy, carbon dioxide emissions and greenhouse gas emissions ($CO_2$, $CH_4$, $N_2O$) of NZ electricity and fuels. A full description of how these emission factors were determined can be found in the following sections.

**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 | 37.9 | 1.19 | 45.2 |
| Petrol (regular unleaded) | litres | 34.9 | 1.19 | 41.6 |
| Biodiesel (tallow) † | kg | 40.0 | 0.50 | 20.0 |
| Marine Diesel Oil | litres | 38.2 | 1.19 | 45.6 |
| Heavy fuel oil | litres | 40.7 | 1.19 | 48.6 |
| Aviation gasoline | litres | 33.9 | 1.19 | 40.4 |
| Natural Gas | MJ | 1.0 | 1.13 | 1.13 |
| LPG | kg | 49.5 | 1.13 | 55.9 |
| Coal (sub-bituminous) | kg | 22.4 | 1.02 | 22.9 |
| Coal (lignite) | kg | 16.0 | 1.02 | 16.3 |
| Avg Electricity (2008) | kWh | 3.6 | 2.36 | 8.50 |
| Avg Electricity (2007) | kWh | 3.6 | 2.20 | 7.91 |
| Avg Electricity (2006) | kWh | 3.6 | 2.28 | 8.22 |
| Avg Electricity (2005) | kWh | 3.6 | 2.33 | 8.38 |
| Avg Electricity (1991) | kWh | 3.6 | 2.30 | 8.27 |

† 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.

**Table 2 Summary of fuel energy and emission factors**

| Fuel type | Unit | Fugitive Energy Coefficient | Carbon Dioxide ($gCO_2$/ $MJ_{primary}$) | Carbon Dioxide ($gCO_2$/ unit) | GHG ($gCO_2eq$/ $MJ_{primary}$) | GHG ($gCO_2eq$/ unit) | MED‡ GHG ($gCO_2eq$/ unit) |
|---|---|---|---|---|---|---|---|
| Diesel | litres | 1.19 | 67.64 | 3,057 | 68.80 | 3,108 | 2,678 |
| Petrol (regular unleaded) | litres | 1.19 | 64.87 | 2,701 | 65.70 | 2,735 | 2,339 |
| Biodiesel (tallow) † | kg | 0.50 | - | - | 87.6 | 1,750 | - |
| Marine Diesel Oil | litres | 1.19 | 70.99 | 3,239 | 71.73 | 3,270 | 2,837 |
| Heavy fuel oil (electricity generation) | litres | 1.19 | 70.99 | 3,449 | 71.21 | 3,460 | 2,997 |
| Aviation gasoline | litres | 1.19 | 63.86 | 2,581 | 64.53 | 2,608 | 2,223 |
| Natural Gas | MJ | 1.13 | 51.64 | 58.35 | 53.95 | 60.96 | 52.35 |
| LPG | kg | 1.13 | 58.27 | 3,260 | 60.00 | 3,357 | 3,000 |
| Coal (sub-bituminous) | kg | 1.02 | 90.99 | 2,079 | 93.97 | 2,147 | 2,044 |
| Coal (lignite) | kg | 1.02 | 94.92 | 1,545 | 97.89 | 1,594 | 1,520 |
| Avg Electricity (2008) | kWh | 2.36 | 26.72 | 227.1 | 27.94 | 237.5 | 214.8 |
| Avg Electricity (2007) | kWh | 2.20 | 24.39 | 193.0 | 25.52 | 201.9 | 179.5 |
| Avg Electricity (2006) | kWh | 2.28 | 28.47 | 234.1 | 29.78 | 245.0 | 221.5 |
| Avg Electricity (2005) | kWh | 2.33 | 29.52 | 247.5 | 30.20 | 253.2 | 228.2 |
| Avg Electricity (1991) | kWh | 2.30 | 19.56 | 161.7 | 20.45 | 169.1 | 151.8 |

‡ Energy Greenhouse Gas Emissions 1990-2008 June 2009. These are combustion rather than LCA based emissions. They are included for comparison.

**Diesel**

The primary energy content of diesel is 1.193 MJ/MJ. This is based on the following analysis. Using the fuel mix described by Sheehan et al. (1998) an analysis was conducted to determine the primary energy, carbon dioxide emissions and greenhouse gas emissions from the upstream diesel energy.

Table 3 shows the fuel mix for NZ diesel. It was assumed that half of the 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 29.1 $gCO_2/MJ_{primary}$ and 30.4 $gCO_2eq/MJ_{primary}$. The $CO_2$ and GHG emissions from foreign electricity generation were based on Saudi Arabia's electricity being mostly oil fired generation plants at a rate of 71.0 $gCO_2/MJ$ and 71.5 $gCO_2eq/MJ$ (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 3 NZ Fossil Diesel's Primary Energy Fuel Mix, $CO_2$ and Greenhouse Gas 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 $gCO_2eq/MJ_{primary}$ | Diesel component $gCO_2eq/MJ_{consumer}$ |
| $CO_2$ for oil extraction | 0.016 | | 0.62 | | 0.62 |
| Electricity – NZ | 0.018 | 29.1 | 0.53 | 30.4 | 0.55 |
| Electricity – Foreign | 0.018 | 71.0 | 1.28 | 71.2 | 1.28 |
| Natural gas | 0.065 | 51.6 | 3.34 | 53.4 | 3.45 |
| Heavy fuel oil | 0.072 | 71.0 | 5.13 | 71.2 | 5.14 |
| Diesel | 0.004 | 67.6 | 0.27 | 68.8 | 0.27 |
| Coal | 0.001 | 91.0 | 0.06 | 94.0 | 0.06 |
| **Sub-total** | **0.193** | | **11.21** | | **11.37** |
| | | | | | |
| Diesel (consumer) | 1.000 | | 69.5 | | 70.73 |
| **Total** | **1.193** | | **80.71** | | **82.10** |

Based on a consumer energy value of 37.86 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ diesel is 45.18 MJ/L.

The direct carbon dioxide emission factor for NZ diesel is 69.5 $ktCO_2/PJ$ or $gCO_2/MJ$consumer (MED 2007a). Including the upstream emissions total $CO_2$ emissions are 80.71 $gCO_2/MJ$consumer or 3.057 $kgCO_2/L$. In primary energy terms the result is 67.64 $gCO_2/MJ$primary.

The direct GHG emission factor for NZ diesel is (MED 2007a):

$69.5\ CO_2 + (3.8/1000)*21$ for $CH_4 + (3.7/1000)*310$ for $N_2O$
$= 70.73$ kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for NZ diesel is 70.73 + 11.37 = 82.10 g$CO_2$eq/MJconsumer or 3.108 kg$CO_2$eq/L. In primary energy terms the result is 68.80 g$CO_2$eq/MJprimary.

**Petrol**

It was assumed that petrol (regular unleaded) had the same upstream fuel mix as diesel. Based on a consumer energy value of 34.89 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ diesel is 41.63 MJ/L.

The direct carbon dioxide emission factor for petrol is 66.2 kt$CO_2$/PJ (MED 2007a). Including the upstream $CO_2$ emissions of 11.21 g$CO_2$ total $CO_2$ emissions are 77.41 g$CO_2$/MJconsumer or 2.701 kg$CO_2$/L. In primary energy terms the result is 64.87 g$CO_2$/MJprimary.

The direct GHG emission factor for petrol oil is (MED 2007a):
$66.2\ CO_2 + (18.5/1000)*21$ for $CH_4 + (1.4/1000)*310$ for $N_2O$
$= 67.03$ kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for petrol is 67.03 + 11.37 = 78.40 g$CO_2$eq/MJconsumer or 2.735 kg$CO_2$eq/L. In primary energy terms the result is 65.70 g$CO_2$eq/MJprimary.

**Marine Diesel Oil**

Based on a consumer energy value of 38.22 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ marine diesel is 45.61 MJ/L. The weight of marine diesel oil is 0.835 kg/L making it 45.79 MJ/kg and 54.64 MJ/kg in primary energy terms.

The direct carbon dioxide emission factor for NZ marine diesel oil is 73.50 kt$CO_2$/PJ or g$CO_2$/MJconsumer (MED 2007a). Including the upstream emissions total $CO_2$ emissions are 84.71 g$CO_2$/MJconsumer or 3.2387 kg$CO_2$/L. In primary energy terms the result is 70.99 g$CO_2$/MJprimary.

The direct GHG emission factor for NZ marine diesel oil is (MED 2007a):
$73.50\ CO_2 + (6.65/1000)*21$ for $CH_4 + (1.9/1000)*310$ for $N_2O$
$= 74.23$ kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for NZ marine diesel is 74.23 + 11.37 = 85.60 g$CO_2$eq/MJconsumer or 3.27 kg$CO_2$eq/L (3.92 kg$CO_2$eq/kg). In primary energy terms the result is 71.73 g$CO_2$eq/MJprimary.

**Bunker Fuel Oil / Heavy Fuel Oil**

Based on a consumer energy value for bunker fuel oil of 41.01 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ bunker fuel oil is 48.94 MJ/L. The weight of bunker fuel is 0.955 kg/L making it 42.93 MJ/kg and 51.23 MJ/kg in primary energy terms.

Over 90% of the upstream energy use is associated with crude oil extraction, with just 10% used in refining and transportation. Consequently we have assumed that given the uncertainty the upstream emissions are the same for heavy less refined fuel oil as they are for the more refined diesel.

The direct carbon dioxide emission factor for heavy fuel oil (bunker fuel oil emission factors are not available) is 73.50 kt$CO_2$/PJ or g$CO_2$/MJconsumer (MED 2007a). Including the upstream emissions total $CO_2$ emissions are 84.71 g$CO_2$/MJconsumer or 3.474 kg$CO_2$/L. In primary energy terms the result is 70.98 g$CO_2$/MJprimary.

The direct GHG emission factor for heavy fuel oil is (MED 2007a):

73.50 $CO_2$ + (6.65/1000)*21 for $CH_4$ + (1.9/1000) *310 for $N_2O$
= 74.23 kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for heavy fuel oil is 74.23 + 11.37 = 85.60 g$CO_2$eq/MJconsumer or 3.510 kg$CO_2$eq/L (3.68 kg$CO_2$eq/kg). In primary energy terms the result is 71.73 g$CO_2$eq/MJprimary.

**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 marine diesel oil and bunker fuel oil the energy content is 40.95 MJ/L (42.99 MJ/kg) and the fugitive energy coefficient described in Table 3 the primary energy value is 48.87 MJ/L (51.30 MJ/kg).

Including the GHG emissions from upstream primary energy, the total GHG emission factor for IFO 380 is 85.60 g$CO_2$eq/MJconsumer or 3.51 kg$CO_2$eq/L (3.68 kg$CO_2$eq/kg). In primary energy terms the result is 71.73 g$CO_2$eq/MJprimary.

**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 40.72 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ diesel is 48.59 MJ/L.

The direct carbon dioxide emission factor for heavy fuel oil is 73.5 kt$CO_2$/PJ (MED 2007a). Including the upstream $CO_2$ emissions of 11.21 g$CO_2$ total $CO_2$ emissions are 84.71 g$CO_2$/MJconsumer or 3.449 kg$CO_2$/L. In primary energy terms the result is 70.99 g$CO_2$/MJprimary.

The direct GHG emission factor for heavy fuel oil is (MED 2007a):

73.5 $CO_2$ + (0.9/1000)*21 for $CH_4$ + (0.3/1000) *310 for $N_2O$
= 73.61 kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for heavy fuel oil is 73.61 + 11.37 = 84.98 g$CO_2$eq/MJconsumer or 3.460 kg$CO_2$eq/L. In primary energy terms the result is 71.21 g$CO_2$eq/MJprimary.

### Aviation Gasoline

It was assumed that aviation gasoline had the same upstream fuel mix as diesel. Based on a consumer energy value of 33.87 MJ/L (MED 2007b) and the fugitive energy coefficient described in Table 3 the primary energy value of NZ diesel is 40.42 MJ/L.

The direct carbon dioxide emission factor for aviation gasoline is 65.0 kt$CO_2$/PJ (MED 2007a). Including the upstream $CO_2$ emissions of 11.21 g$CO_2$ total $CO_2$ emissions are 76.21 g$CO_2$/MJconsumer or 2.581 kg$CO_2$/L. In primary energy terms the result is 63.86 g$CO_2$/MJprimary.

The direct GHG emission factor for aviation gasoline is (MED 2007a):

65.0 $CO_2$ + (1.9/1000)*21 for $CH_4$ + (1.9/1000) *310 for $N_2O$
= 65.63 kt$CO_2$eq/PJ or g$CO_2$eq/MJconsumer.

Including the GHG emissions from upstream primary energy, the total GHG emission factor for petrol is 65.63 + 11.37 = 77.00 g$CO_2$eq/MJconsumer or 2.608 kg$CO_2$eq/L. In primary energy terms the result is 64.53 g$CO_2$eq/MJprimary.

### 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 52.3 kt$CO_2$/PJ or g$CO_2$/MJ (MED, 2007a).

Flaring/venting and distribution/transmission account for 656.0 kt$CO_2$ (Ibid.). Extraction and processing account for 349 kt$CO_2$ (Ibid.) but must be apportioned to gas and oil in the ratio of 77% gas (152.5/199.3, MED, 2007b) 23% oil. Thus 656 + (349 * 77%) = 923.0 kt$CO_2$ p.a. of fugitive and own use emissions attributable to gas. Gas demand is 152.5 (Ibid). Carbon dioxide emissions for gas from flaring/venting and distribution/transmission are 923.0/152.5 = 6.05 kt$CO_2$/PJ or g$CO_2$/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 52.3 + 6.1 = 58.4 kt$CO_2$/PJ or g$CO_2$/MJconsumer. In primary energy terms the result is 51.6 kt$CO_2$/PJprimary.

The direct GHG emission factor for natural gas in commercial boilers (MED 2007a) is:

52.3 $CO_2$ + 0.00108*21 for $CH_4$ + 0.00207*310 for $N_2O$ = 52.96 $ktCO_2eq/PJ$ or $gCO_2eq/MJ$

In addition to the $CO_2$ emissions described above for flaring/venting and distribution/transmission, methane emissions are 14,166 $tCH_4$ (MED, 2007a) or 297.5 $ktCO_2eq$. Extraction and processing account for a further 8.00 $tCH_4$ (Ibid.) or 0.168 $ktCO_2eq$; and nitrous oxide emissions are 0.57 $tN_2O$ (Ibid.) or 0.177 $ktCO_2eq$. As above 77% of these emissions are attributable to gas. Thus 297.5 + (0.168 + 0.177) * 77% = 297.8 $ktCO_2eq$ p.a. of fugitive and own use GHG emissions are attributable to gas.

GHG emissions for gas from flaring/venting and distribution/transmission are 923.0/152.5 + 297.8/152.5 = 8.00 $ktCO_2eq/PJ$ or $gCO_2eq/MJ$.

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 52.96 + 8.00 = 60.96 $ktCO_2eq/PJ$ or $gCO_2eq/MJ$consumer. In primary energy terms the result is 53.95 $ktCO_2eq/PJ$primary.

**LPG**

The energy value of LPG is 49.51 MJ/kg or 26.54 MJ/litre (MED, 2008b).

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

The carbon dioxide emission factor for LPG is 59.8 $ktCO_2/PJ$ or $gCO_2/MJ$ (MED, 2008a).

The natural gas and LPG $CO_2$ fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at 6.05 $ktCO_2/PJ$ or $gCO_2/MJ$.

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 + 6.1 = 65.9 $ktCO_2/PJ$ or $gCO_2/MJ$consumer. In primary energy terms the result is 58.3 $ktCO_2/PJ$primary.

The direct GHG emission factor for LPG in commercial boilers (MED 2008a) is:

59.8 $CO_2$ + 0.001*21 for $CH_4$ + 0.0006*310 for $N_2O$ = 60.0 $ktCO_2eq/PJ$ or $gCO_2eq/MJ$

The natural gas and LPG GHG fugitive emission factor for flaring/venting and distribution/transmission were assumed to be the same at 8.0 $ktCO_2/PJ$ or $gCO_2/MJ$.

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 59.8 + 8.00 = 67.8 $ktCO_2eq/PJ$ or $gCO_2eq/MJ$consumer. In primary energy terms the result is 60.0 $ktCO_2eq/PJ$primary.

**Coal – sub-bituminous**

Bains and Peet (1995) reported a fugitive energy use factor for coal is 1.04. This is higher than the figure reported by Sheehan et al., (1998) of 1.014 which is consistent with Barber et al. (2007) who also felt that the fugitive emission factor was an overestimate. An emission factor of 1.02 was used in this report.

Based on a consumer energy value of 22.40 MJ/kg (MED, 2007b) and the fugitive energy coefficient of 1.02 the primary energy value of sub-bituminous NZ coal is 22.85 MJ/kg.

The carbon dioxide emission factor for sub-bituminous coal is 91.2 $ktCO_2/PJ$ or $gCO_2/MJ$ (MED, 2007a). The total carbon dioxide emission factor for coal is assumed to include the indirect $CO_2$ emissions from the extra 2% upstream primary energy (using the diesel emission factor).

Thus the final $CO_2$ emission factor for sub-bituminous coal is 91.2 + 0.02 * 80.71 = 92.81 $ktCO_2/PJ$ ($gCO_2/MJ$consumer) or 2.079 $kgCO_2/kg$ coal. In primary energy terms the result is 90.99 $ktCO_2/PJ$primary.

The direct GHG emission factor for the average sub-bituminous coal in industrial boilers (MED, 2007a) is:

91.2 $CO_2$ + 0.000665*21 for $CH_4$ + 0.000152*310 for $N_2O$ = 91.26 $ktCO_2eq/PJ$ or gCO2eq/MJconsumer.

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 21,438 $tCH_4$ (MED, 2007a) or 450.2 $ktCO_2eq$. Indigenous coal production was 153.0 PJ (MED, 2007b).

The final GHG emission factor for coal is 91.26 + 0.02 * 82.10 + 450/153 = 95.84 $gCO_2eq/MJ$consumer or 2.147 $kgCO_2/kg$ coal. In primary energy terms the result is 93.97 $ktCO_2eq/PJ$primary.

**Coal – lignite**

Bains and Peet (1995) reported a fugitive energy use factor for coal is 1.04. This is higher than the figure reported by Sheehan et al., (1998) of 1.014 which is consistent with Barber et al. (2007) who also felt that the fugitive emission factor was an overestimate. An emission factor of 1.02 was used in this report.

Based on a consumer energy value of 15.96 MJ/kg (MED, 2007b) and the fugitive energy coefficient of 1.02 the primary energy value of sub-bituminous NZ coal is 16.28 MJ/kg.

The carbon dioxide emission factor for lignite coal is 95.2 $ktCO_2/PJ$ or $gCO_2/MJ$ (MED, 2007a). The total carbon dioxide emission factor for coal is assumed to include the indirect $CO_2$ emissions from the extra 2% upstream primary energy (using the diesel emission factor).

Thus the final $CO_2$ emission factor for lignite coal is 95.2 + 0.02 * 80.71 = 96.81 $ktCO_2/PJ$ ($gCO_2$/MJconsumer) or 1.545 $kgCO_2$/kg coal. In primary energy terms the result is 94.9 $ktCO_2$/PJprimary.

The direct GHG emission factor for the average lignite coal in industrial boilers (MED, 2007a) is:

95.2 $CO_2$ + 0.000665*21 for $CH_4$ + 0.000152*310 for $N_2O$ = 95.26 $ktCO_2eq/PJ$ or gCO2eq/MJconsumer.

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 21,438 $tCH_4$ (MED, 2007a) or 450.2 $ktCO_2eq$. Indigenous coal production was 153.0 PJ (MED, 2007b).

The final GHG emission factor for coal is 95.26 + 0.02 * 82.10 + 450/153 = 99.84 $gCO_2eq$/MJconsumer or 1.594 $kgCO_2$/kg coal. In primary energy terms the result is 97.89 $ktCO_2eq$/PJprimary.

**Electricity 2008**
The electricity primary energy use and emission factors presented in Table 1 and 2 use the same methodology as described below for Electricity 2007, but uses the figures presented in the publications Energy Greenhouse Gas Emissions 09 (2008 Calendar Year Edition) and New Zealand Energy Data File June 09 (www.med.govt.nz).

**Electricity 2007**

The primary energy content of electricity in 2007 was 2.20 kWh of primary energy to supply 1 kWh to the consumer. This is based on the primary energy supply figure for electricity generation (including cogeneration) in 2007 of 297.5 PJ (MED, 2008b). In addition to the primary energy supply figure energy described by the MED Energy Data File, additional energy is added to take into account coal mining and distribution plus gas extraction, treatment and distribution (12.7 PJ).

The additional 13 PJ of coal and gas energy has been calculated based on the energy coefficients of 1.02 MJ/MJ for coal and 1.13 MJ/MJ for gas.

Total primary energy was 308.8 PJ divided by observed consumption of 140.5 PJ (Ibid.) equalling 2.20 $MJ_{consumer}/MJ_{primary}$

The carbon dioxide emissions in 2007 for electricity generation was 6,618 $ktCO_2$ (MED, 2008a). Fugitive $CO_2$ emissions from geothermal fields in 2007 were 301 $ktCO_2$ (MED, 2008a). The total carbon dioxide emission factor for electricity is assumed to include the indirect $CO_2$ emissions from the extra 2% upstream primary energy (using the diesel emission factor of 80.7 $gCO_2/MJ$) of coal and the 'fugitive' and 'own use' emissions of gas at 6.1 $ktCO_2/PJ$. This added 43.5 and 567.1 $ktCO_2$ respectively.

Thus the final $CO_2$ emission factor for electricity is 7,530/140 = 53.6 $ktCO_2/PJ$ ($gCO_2$/MJconsumer) or 0.193 $kgCO_2/kWh$. In primary energy terms the result is 24.4 $ktCO_2$/PJprimary.

The direct GHG emission factor for electricity includes the $CO_2$ described above plus direct generation emissions of 0.24 $ktCH_4$ (Ibid.) and 0.05 $ktN_2O$ (Ibid.). Fugitive methane emissions from geothermal fields were 3.07 $ktCH_4$ (Ibid.). Total GHG emissions from electricity generation including fugitive geothermal emissions in 2007 were 7,878 $ktCO_2eq$.

The upstream emissions from coal were 123 $ktCO_2eq$. This included direct GHG emissions from diesel plus methane from coal mining and post mining activities. Additional upstream gas GHG emissions were 750 $ktCO_2eq$. This is based on the gas GHG emission factor for flaring/venting and distribution/transmission of 8.0 $ktCO_2/PJ$ (see Gas description above). The total GHG emissions in 2007 from electricity generation, including upstream emissions, was 7,878 $ktCO_2eq$.

Thus the final GHG emission factor for electricity is 7,878/140 = 56.1 kt$CO_2$eq/PJ (g$CO_2$eq/MJconsumer) or 0.202 kg$CO_2$eq/kWh. In primary energy terms the result is 25.5 kt$CO_2$eq/PJprimary.

**Electricity 2006**

The primary energy content of electricity in 2006 was 2.28 kWh of primary energy to supply 1 kWh to the consumer. This is based on the primary energy supply figure for electricity generation (including cogeneration) in 2006 of 305.0 PJ (MED, 2008b). In addition to the primary energy supply figure energy described by the MED Energy Data File (305 PJ), additional energy is added to take into account coal mining and distribution plus gas extraction, treatment and distribution (11.8 PJ).

The additional 12 PJ of coal and gas energy has been calculated based on the energy coefficients of 1.02 MJ/MJ for coal and 1.13 MJ/MJ for gas.

Total primary energy was 315.5 PJ divided by observed consumption of 138.1 PJ (Ibid.) equalling 2.28 $MJ_{consumer}/MJ_{primary}$

The carbon dioxide emissions in 2006 for electricity generation was 8,057 kt$CO_2$ (MED, 2008a). Fugitive $CO_2$ emissions from geothermal fields in 2006 were 341 kt$CO_2$ (MED, 2008a). The total carbon dioxide emission factor for electricity is assumed to include the indirect $CO_2$ emissions from the extra 2% upstream primary energy (using the diesel emission factor of 80.7 g$CO_2$/MJ) of coal and the 'fugitive' and 'own use' emissions of gas at 6.1 kt$CO_2$/PJ. This added 84.8 and 500.8 kt$CO_2$ respectively.

Thus the final $CO_2$ emission factor for electricity is 8,983/138 = 65.0 kt$CO_2$/PJ (g$CO_2$/MJconsumer) or 0.234 kg$CO_2$/kWh. In primary energy terms the result is 28.5 kt$CO_2$/PJprimary.

The direct GHG emission factor for electricity includes the $CO_2$ described above plus direct generation emissions of 0.22 kt$CH_4$ (Ibid.) and 0.09 kt$N_2O$ (Ibid.). Fugitive methane emissions from geothermal fields were 3.22 kt$CH_4$ (Ibid.). Total GHG emissions from electricity generation including fugitive geothermal emissions in 2006 were 8,497 kt$CO_2$eq.

The upstream emissions from coal were 241 kt$CO_2$eq. This included direct GHG emissions from diesel plus methane from coal mining and post mining activities. Additional upstream gas GHG emissions were 662 kt$CO_2$eq. This is based on the gas GHG emission factor for flaring/venting and distribution/transmission of 8.0 kt$CO_2$/PJ. The total GHG emissions in 2006 from electricity generation, including upstream emissions, was 9,400 kt$CO_2$eq.

Thus the final GHG emission factor for electricity is 9,400/138 = 68.1 kt$CO_2$eq/PJ (g$CO_2$eq/MJconsumer) or 0.245 kg$CO_2$eq/kWh. In primary energy terms the result is 29.8 kt$CO_2$eq/PJprimary.

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