New Zealand's electricity generation dataset: A Life Cycle Inventory for carbon footprints

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Landcare Research
Manaaki Whenua

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Executive Summary

This dataset is part of a wider project funded by the Ministry of Agriculture and Forestry and Zespri International Ltd to compile datasets that can be used by industries in New Zealand for carbon footprint studies. The project was led by the Massey University New Zealand Life Cycle Management Centre in collaboration with AgResearch, Landcare Research, Plant and Food Research, and Scion. A secondary goal of the project was to develop capability in these organisations to compile datasets consistent with the International Reference Life Cycle Data System.

This report covers the New Zealand electricity dataset and is intended to provide a credible source of electricity data for carbon footprinting studies that require life cycle data. This dataset is also intended to be a first step for further development of datasets for New Zealand specific greenhouse gas emission of electricity generation using the International Reference Life Cycle Data System.

The dataset was completed using existing inventories for European electricity generation processes and, where possible, the processes were adapted to include New Zealand specific data. For example, specific data available in the literature have been used to calculate the greenhouse gas emissions (GHG) for fossil-fuel-fired electricity generation. The direct emissions from geothermal plant are also based on New Zealand specific data. However, many processes use European data as a proxy (or placeholder for further investigation) for GHG emissions. This report describes all the processes that have been adapted for use in the New Zealand electricity dataset.

Emissions of GHG, both direct (e.g., the combustion of the fossil fuel) and indirect (e.g., from the production of cement necessary to construct a power plant) are included in this dataset. In addition to the life cycle inventory, a carbon footprint of 0.36 kg CO_2eq/kWh of electricity delivered to the consumer was calculated using characterisation factors from Intergovernmental Panel for Climate Change (IPCC 2007).

Technical summary

The goal of the New Zealand ICLD dataset project was to investigate the best methods for compiling life cycle inventory datasets that are compliant with the International Reference Life Cycle Data System. The dataset presented here is for the mix of different electricity generation sources (usually referred to simply as the electricity mix) in New Zealand for 2008. The dataset meets the International Reference Life Cycle Data System (ILCD) "entry level" requirements for data quality.

As the timeframe and funding provided for this project made developing a full life cycle inventory beyond the scope of work completed, this dataset is based on average data in the literature and includes only GHG emissions data. The inventory has been adapted from European processes taken from the ecoinvent v 2.0[1] life cycle database, which includes cradle-to-gate data (e.g., wind-powered electricity includes emissions related to the production of steel for the construction of the tower). All the New Zealand specific emissions or other necessary data (background information such as infrastructure) were drawn from the literature and publically available reports. Using characterisation factors from IPCC (2007), a final carbon footprint of 0.36 kg CO_2eq/kWh of electricity delivered to the consumer was calculated. Delivered electricity includes GHG emissions associated with transmission and distribution of electricity as well as with its generation.

The adaptation was made by altering the intended aspects (e.g., CO_2 emission of coal fired electricity generation plant) using a software package SimaPro 7.1. A New Zealand electricity mix process was created and run in SimaPro in order to generate a system process inventory list. The system was then exported into EcoSpold format and edited in Open LCA software. To meet ILCD criteria, all required information was added using ILCD editor software and in a final step exported into ILCD format.

The adaptation of the ecoinvent data and all the top-level processes included in this dataset is documented and discussed in this report.

[1] http://www.ecoinvent.ch/

1 Introduction

Product-related environmental information is a part of the decision-making processes of many businesses and consumers. Among the tools available to evaluate and quantify environmental performance is Life Cycle Assessment (LCA).

LCA, however, has a number of limitations, not least difficulty in making legitimate comparisons. The main constraints to comparative assertions are heterogeneity in system boundaries, the data used, and reporting protocol. Therefore, to address this, the European Union (EU) initiated the European Life Cycle Database (ELCD), hereafter referred to as the International Reference Life Cycle Data System (ILCD) – because it is envisaged that the ELCD will in time form the basis of the ILCD.

The New Zealand electricity mix draws on several electricity generation methods using various mineral, topographical, and meteorological resources. This report presents a summary of the first attempt to compile an ILCD dataset relevant to electricity production and delivery in New Zealand.

With the increased number of carbon footprint[2] projects across the primary sector internationally, it becomes increasingly important to improve the data used for these studies, investigate New Zealand specific data, and understand their limitations from a LCA perspective.

This project involved the creation of a dataset to represent New Zealand's electricity mix. The dataset is restricted to greenhouse-gas-related emissions. The dataset was developed from existing European datasets and adapted for New Zealand site-specific emissions where applicable, including hydropower, coal, gas, oil, wind, wood, biogas, and geothermal emissions. Data for the inventory were collected between April and June 2011. In total, 70 hours were needed in the project for data compilation, data format conversions, report writing, and meetings.

[2] "Carbon footprint" is in this study taken to mean the sum of the carbon dioxide equivalent of the greenhouse gases, including carbon dioxide, methane, nitrous oxide, chlorofluorocarbon CFCs, propane, butane, etc., as listed by the IPCC (2007).

2 Goal of the study

2.1 Goal and Intended applications

The goal of this study is to produce a dataset that details the greenhouse gas emissions from one-kilowatt hour of electricity delivered to the consumer in New Zealand in 2008. Accordingly, the reference flow for the data reported in the inventory section will be to one-kilowatt hour. In addition, the information collected in this study will contribute to a larger report on the use of the ILCD database format in New Zealand that will be compiled by Associate Professor Sarah McLaren, Director, New Life Cycle Management Centre, at Massey University.

This study is not intended to be used to support comparative assertions for public disclosure. It should be noted that use of the dataset should include appropriate consideration of its assumptions and limitations during use.

2.2 Method and Limitations

The dataset developed here is to support carbon footprinting studies; therefore its use is limited to greenhouse gas calculations and it is not intended to be applicable to any of the other environmental impact categories used in LCA.

This is an adapted dataset, i.e. a dataset available for the European electricity generation processes was used as a basis both for background (e.g., emissions related to infrastructure for electricity generation) and foreground (e.g., emissions from the burning of the fossil fuels at the electricity generation plant) emissions. The European dataset was then adapted for available New Zealand site-specific greenhouse gas emissions for each process. For the European processes, ecoinvent database[3] v 2.0 was used; the data used in background process of this dataset are presented in a cumulative results list[4].

2.3 Reasons for the study

No previous ILCD datasets are available for the New Zealand electricity mix. The reason for the study is to develop a dataset to be used in future carbon footprinting studies as an aid to internal business decision making. The dataset can also be used in future LCA studies. The use of the dataset in any LCAs designed to be communicated publically should be treated with caution. The dataset should first be assessed to ensure it is appropriate for the purpose of the study, and the appropriate assumptions and limitations should then be adequately documented during publication.

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[4] The output of this study is a cumulative list of inputs and outputs, e.g., total emissions of CO_2, CH_4, etc. This is called a system approach or ‘black box’ process, as the emissions of each of the processes composing the dataset are not disclosed.

2.4 Target audience

The target audience of the study will be other LCA researchers in New Zealand and abroad, and people associated with the kiwifruit supply chain. The users of this dataset are expected to have knowledge of LCA principles or life cycle based carbon footprinting techniques.

2.5 Comparisons

This dataset may be used to support assertions as long as the limitations of the dataset and the data on which it was based are taken into account and the dataset is fit for purpose for the intended comparison.

2.6 Commissioners

The main funder of this dataset is MAF, with co-funding from Zespri International Ltd. Landcare Research has also co-funded this project by funding additional hours for staff necessary for the completion of this project.

3 Scope of the study

3.1 Functional unit and reference flows

The functional unit of this dataset is '1 kWh of average electricity delivered to the consumer', i.e. electricity that is ready to use at the socket. The electricity mix corresponds to the mix of electricity generation methods used in 2008. The system investigated is the electricity generation mix including infrastructure and transmission, and distribution losses.

3.2 System boundaries

The dataset has been compiled as an attributional LCA.

Processes and life cycle stages:

The model is built on separate unit processes, such as different electricity types, distribution, and transmission (including infrastructure) as per the background models (based on ecoinvent data) supporting these dataset. The dataset detailed in Appendix 2 (Table 4) contains the cumulative results.

Included flows and life cycle impact assessment method:

To fulfil the scope of the study only flows that relate to global warming, i.e. GHG emissions were taken into account. These flows were derived from, and assembled into, a carbon footprint, using the IPCC (2007) characterisation factors. Given the IPCC list provides global warming potential (GWP) for additional flows, non-methane volatile organic compounds and carbon monoxide, these were also included in the dataset.

Data quality requirements:

The data requirements meet "entry level" requirements for an ILCD dataset. For the entry level there is no data quality level requirement; however, the technological, geographical, and time-related representativeness of data are to be documented.

4 Inventory analysis

The data used in the inventory were based both on national statistics published by the New Zealand government and on other literature; no primary data measurement was carried out for this inventory. The key references for this dataset are: the ecoinvent database v 2.0; the Energy Data File 2009 (MED 2009); the New Zealand's Greenhouse Gas Inventory 1990–2009 (MfE 2011); and the New Zealand Energy Information Handbook (CAENZ 2008).

4.1 Description of unit process and calculations

The data set presented here represents the New Zealand electricity mix, and distribution and transmission (collectively termed delivery) of electricity.

4.1.1 New Zealand electricity mix

The composition of the electricity mix is presented in Figure 1. The data are based on the Energy Data File, using 2008 as a reference year (MED 2009) and include New Zealand's major electricity producers. In 2008 a total of 42 246 GWh of electricity was produced (MED 2009). Data for 2008 were chosen because the data were required to be comparable to a previous carbon footprint study carried out by Zespri Kiwifruit New Zealand (Mithraratne et al. 2010).

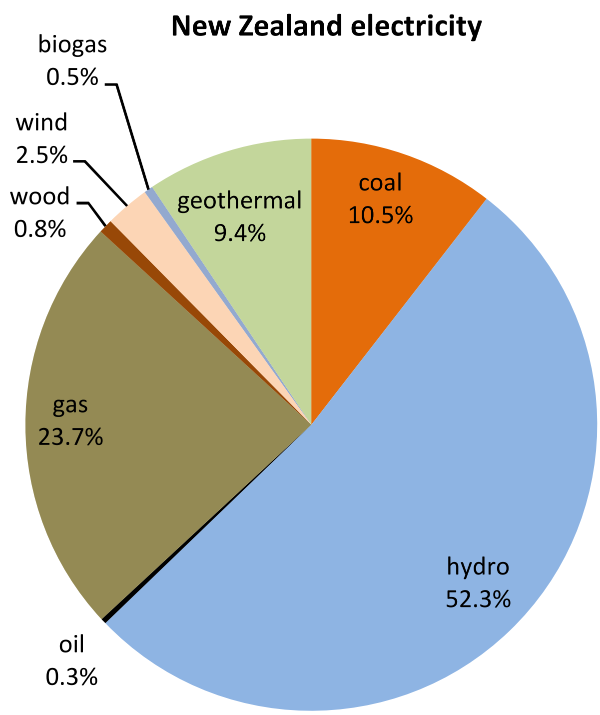

Figure 1 Electricity mix composition in 2008 (derived from MED 2009).

4.1.2 Coal, gas and oil-derived electricity

The Energy Data File (MED 2009) provides the electrical efficiency factors in their report; it states that estimates are made where actual data are unavailable at the time of publishing. Coal, gas, and oil power plants were considered to be 30% efficient (MED 2009, p. 16). As a result, 12 MJ is estimated to be necessary to generate 1 kWh of electricity for these three sources of electricity. Average annual efficiencies of gas power plants and coal only (excluding cogeneration) is greater than 30%. By using the 30% default efficiencies the inventory is therefore likely to represent a conservative scenario as the efficiencies are expected to be higher than the defaults in most situations.

New Zealand specific data for direct emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the combustion of fossil fuels used have been accounted for according to the latest version of the New Zealand Greenhouse Gas Inventory available at the time of research, i.e. 1990–2009 (MfE 2011).

Table 1 Greenhouse gas emissions of fossil combustion in New Zealand (MfE 2011)

	Carbon dioxide	***Methane***	***Nitrous oxide***
	t CO_2/TJ	t CH_4/PJ	t N_2O/PJ
Gas	53.18	5.4	0.09
Fuel oil	74.23	0.86	0.38
Coal*	92.99	0.67	1.52

*coal emissions of carbon dioxide are based on the average combustion in the public electricity and heat production emission factor

The input of coal, gas and oil per MJ produced and the caloric values, were based on the original inputs from the European processes in ecoinvent. Specific alterations to the electricity used in the background processes of hard coal, oil, and gas are detailed in the following sections. A diagram illustrating the processes is presented in Appendix 1.

Hard coal

The only background process for hard coal that was adapted was the electricity input into hard coal storage, which was altered to New Zealand's medium voltage electricity. All other background processes, such as the type of mining (open cast or underground), fugitive emissions (emissions of gases or vapours from pressurized equipment due to leaks and various other unintended or irregular releases of gases) of mining, origin and transport of imported coal, and infrastructure, were kept as standard European, as more appropriate adaptation was not possible within the scope of this study.

Oil

Similarly to hard coal, the electricity used both at storage and refinery was adapted to New Zealand by altering the electricity source to New Zealand's low and medium voltage electricity respectively. All other background processes, such as crude oil production (onshore or offshore), transportation, and infrastructure, were kept as standard European.

Gas

Electricity inputs were used as sources for the distribution of gas and, apart from greenhouse gas emissions reported in the New Zealand Greenhouse Gas Inventory (MfE 2011), all other emissions such as waste heat, infrastructure, and distribution use European values. The adaptation does not go as far as accounting for the appropriate share of onshore and offshore extraction.

4.1.3 Geothermal electricity

Fugitive emissions for geothermal plants were calculated based on the fugitive emissions values from the New Zealand Greenhouse Gas Inventory (MfE 2011) and emissions in CO_2eq per unit of electricity from Contact Energy (2010). The Inventory reported fugitive geothermal emission of 610 GgCO_2eq from carbon dioxide and 113 GgCO_2eq from methane (MfE 2011; pp. 337–338), which means 18.5% of the CO_2 eq is caused by methane. This proportion (18.5%) was applied to the total 161 tCO_2eq/GWh provided in the Contact Energy report (2010) and a global warming potential of 21 used by Contact Energy, was used to calculate the elementary flows (flows of pollutants and resources between the technosphere and nature), resulting in 1.42 g CH_4/kWh and 131 g CO_2/kWh of geothermal energy.

Infrastructure

To maintain consistency with the other generation methods included in this dataset the infrastructure of the geothermal plant was included. Given there were no New Zealand or standard European data available for a background process (in ecoinvent v.2.0), literature data were used to represent the infrastructure (Sullivan et al. 2010). The infrastructure is based on a 50 MW capacity plant and includes concrete, cement, diesel, aluminium, and reinforcing steel. Details on quantities are presented in Appendix 1 (Table 3).

Geothermal plants per kWh

It was necessary to estimate how many geothermal plants are necessary to generate 1 kWh. Geothermal plants built in the USA are estimated to last 30 years, and it is reasonable to assume New Zealand geothermal plants will have similar lifespans (New Zealand Geothermal Association 2010).

It was necessary to estimate both the ratio of electricity generated and the installed capacity of geothermal plant. Using a figure of 4.5 TWh generated by geothermal plants in a year and 600 MW of installed geothermal electricity capacity results in 7.5×10^{10} kWh per MW installed. Assuming that in this dataset one plant is 50 MW and has a 30-year operating period, this would result in 1.125×10^{10} kWh/plant.[5] Taking the calculated amount of electricity generated by a geothermal plant in its lifetime, it is possible to calculate the amount of geothermal plants required per kWh. As 1.125×10^{10} is generated per plant in its lifetime, then 8.89×10^{-11} plants are required per kWh of geothermal electricity.[6]

An alternative method for the calculation for infrastructure was suggested for consideration by the Ministry of Economic Development (MED) during feedback on the dataset. Considering a 50-MW plant could generate 24 hours per day, 365 days per year, a total of 438 000 MWh would be generated. In this method it is assumed the plants on average are run at their maximum 90% of time, resulting in 394 200 MWh or 394 200 000 kWh. A lifetime of 30 years at this rate would result in 1.1826×10^{-10} kWh of geothermal electricity per plant or 8.46×10^{-11} plants per kWh.

For this project the first method described in this section has been chosen to be consistent with other approaches used, therefore the value of 8.89×10^{-11} plants per kWh is used. The implications of this choice were evaluated in a scenario assessment. It has been found that this would result in differences in the inventory results, but have negligible effect on the impact assessment results (using a 100-year time horizon per IPCC (2007).

4.1.4 Hydropower, wind, wood and biogas electricity

The New Zealand Energy Information Handbook (CAENZ 2008, p. 77) states that the “New Zealand hydro system is predominantly “run-of-river i.e. water must be used to generate electricity as it flows down the river”. Although the handbook describes the storage capacity of New Zealand’s hydro reservoirs, it is unclear about relative share of electricity generated annually by run of river and hydro-reservoir schemes. Therefore, due to lack of specific information in the literature all hydroelectricity was modelled as run-of-river and the data were from ecoinvent.

For wind and wood sources of energy no adaptation was possible within the scope of this study. For these electricity generation methods, data from ecoinvent were used.

In 2008, 0.5% of electricity was generated by biogas, created from digesting waste at wastewater treatment plants and landfills (MED 2009). Due to the lack of precise information, the limited time frame of the study, and because biogas electricity plays a very small role in the overall grid footprint, the biogas electricity was modelled by a dummy process. In other words, in this project no environmental burdens could be allocated to biogas electricity.

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[5] $Geothemal\ electricity\ \ per\ plant\ \ = \frac{4.5\times10^{9} kWh\ \ per\ year\times}{600\ MW\ installed\ in\ the\ year} \times a\ 50\ MW\ plant \times 30\ year\ \ = 1.125 \times 10^{10}\ kWh\ of\ Geothermal\ electricity\ per\ plant$

[6] $Geothermal\ plant\ per\ kWh = \frac{1}{1.125} = 8.89 \times 10^{-10}$

4.1.5 Transmission and distribution

From the point at which electricity is generated at the power plant to its delivery point, two aspects were investigated and adapted specifically to the New Zealand situation: the emissions of sulphur hexafluoride (SF_6) for transmission systems, and the transmission and distribution losses. All other background processes, such as steel, copper for poles, and towers, were based on average European data.

Sulphur Hexafluoride (SF_6)

Using 2008–2009 data from 'Our carbon footprint findings' (Transpower 2011), it was estimated that 309 kg of SF_6 are emitted per year by Transpower.[7] A total of 10 139 t CO_2eq was provided, of which 73% are caused by emissions of SF_6. The company disclosed it was using a GWP of 23 900 for SF_6. The amount of SF_6 was divided by the total km of transmission lines, reported as 11 806 km (Transpower 2011). As the emissions published were per year it was important to calculate the emissions per km of network. To calculate the emissions over the lifetime of the distribution network a 30-year lifetime was assumed. An emission of 0.785 kg SF_6/km was calculated, as described below:

$$\frac{10139\ tCO_2eq \times 73\%\ caused\ by\ SF_6}{23900\ GWP\ of\ SF_6} = 0.309\ t\ SF_6\ per\ year$$

$$\frac{309\ kg\ SF_6 \times 30 years}{11806\ km} = 0.785\ kg\ SF_6/km$$

Note that although more recent values are available on the web site (Transpower 2011), the data for the year 2008–2009 are judged to be more appropriate, given the reference year of this ILCD dataset is 2008.

These SF_6 emissions represent the emissions of the transmission network in New Zealand; other emissions that occur in the distribution network were based on European data.

Losses

Calculation of transmission and distribution losses was based on values provided in MED (2009) and losses were calculated per kWh. Figure 2 is a schematic illustration of the data provided in MED (2009) and the data calculated in the dataset.

[7] Transpower is responsible for all transmission lines in New Zealand.

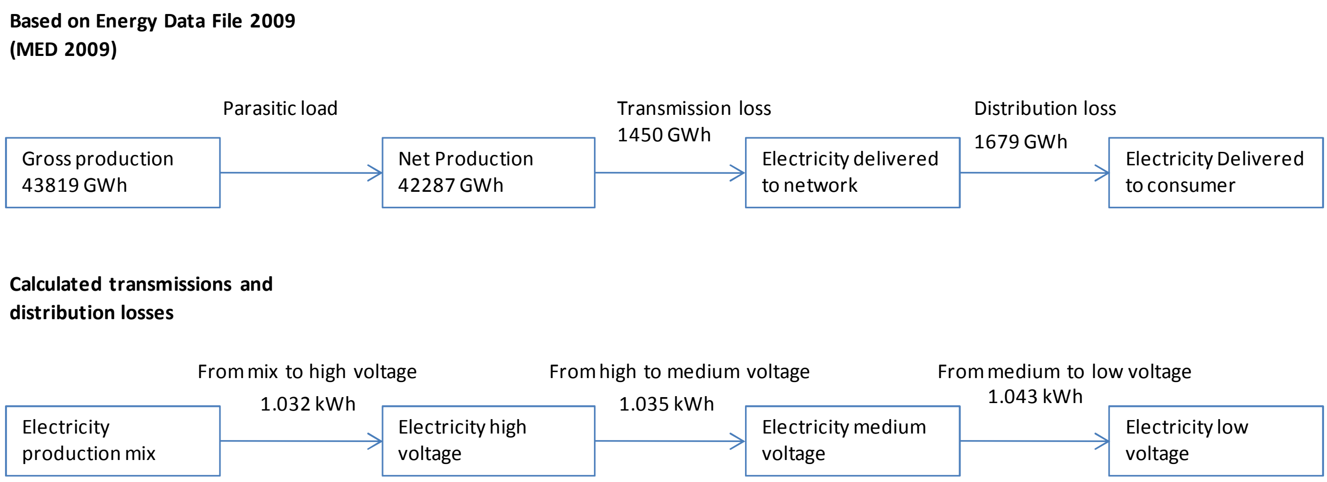

Figure 2 Values for transmission and distribution losses, and original information from MED (2009).

4.2 Data quality assessment

This dataset has two principal limitations: the emissions only account for greenhouse gases, and the majority of the data is adapted from European datasets.

Temporal correlation

Data for electricity generation are based on national statistics and cover the 42 246 GWh of electricity generated in 2008 by the five main New Zealand generating companies plus a number of small, independent generators and on-site cogenerators. These data should therefore be a fair representation of the national average electricity delivered to the New Zealand grid in that year.

With regard to the reference year it is important to note that there are variations in the mix of generation sources depending on the year. For future studies using this dataset, an assessment should be made to ensure there has not been a major shift in New Zealand's electricity grid composition. It should also be noted that in 2008 there was a higher contribution of gas-derived electricity in the electricity mix due to low rainfall reducing the usually higher contribution from hydropower.

Technological and geographical correlation

This dataset is not designed to represent small or individual electricity generation sites. The dataset represents electricity delivered to the grid by the producers of electricity in New Zealand as described in the section above.

For all electricity types, except geothermal electricity (for which infrastructure was estimated based on a USA power plant), all infrastructure was included as a background process extracted from the ecoinvent database. The infrastructure model for the geothermal plant is limited to data available in the literature and is likely to be incomplete. However, the dataset includes those materials that have significant impacts on GHG emissions, e.g., concrete, cement, steel, and aluminium. The geothermal plant fugitive emissions were obtained from sustainability reports of an electricity generation company in New Zealand, and are understood to be sufficient and representative of all New Zealand's geothermal emissions.

The type of hydropower and the amount of reservoir emissions of greenhouse gases have been limited to the available information from the literature. Several reports maintain that hydropower is greenhouse-gas free (e.g., EECA 2011); yet Hydro-Québec (2011) states that a hydropower reservoir lake is expected to release greenhouse gases from the decomposition of biomass. Currently there are no GHG emission measurements for New Zealand hydroelectric pondage and this is potentially a major shortcoming. Furthermore, no specific information was available on the share of reservoirs and run-of-river plants. In future work to update this dataset two inclusions are recommended:

- The appropriate share of run-of-river and reservoir-derived hydroelectricity in the reference year
- The quantification of the New Zealand specific value of hydropower reservoir emissions of greenhouse gases, e.g., from GHG emissions from biomass decomposition, etc.

New Zealand specific emissions of SF_6 were available for the transmissions lines; other emissions of SF_6 were kept as the emissions from European process. As over 90% of the SF_6 stocks in New Zealand are held by one company (which is responsible for the transmission lines), the most important source of SF_6 emissions is covered by New Zealand specific data. However, as the estimation of the lifetime of the transmission lane is based on assumption this could be a source of error.

Default efficiency values are used where calculation of new values was beyond the scope of the study. This dataset takes into account default values for efficiencies of 30% for coal, gas, and oil-derived electricity. As these default values represent what is likely to be out-dated technology, the users of this dataset must be aware that emissions are expected to be lower than the emissions presented here.

4.3 Treatment of missing data

Missing New Zealand data were estimated from average European data or a European country[8] was used for background and missing data (e.g., Switzerland, Germany). For geothermal infrastructure a US geothermal power plant was used to represent the amount of input material required to construct the plant in New Zealand.

[8] The adapted process and the process for which the adaptation was carried out are presented in Appendix 1.

5 Results

5.1 Inventory and impact assessment results

The inventory dataset of inputs and outputs relating to the production and delivery of one kWh of electricity in 2008 are presented in Appendix 2.

For some applications simply having the carbon dioxide equivalents is more useful than having the list of inputs and outputs. We therefore used the software package SimaPro7 to calculate the global warming potential for the dataset presented here. Using a 100-year horizon (IPCC 2007), the calculation resulted in approximately 0.36 $kgCO_2eq/kWh$ of delivered electricity.

The relative contribution of the different electricity generation methods for the production and delivery of one kWh of electricity produced in New Zealand is presented in Figure 3.

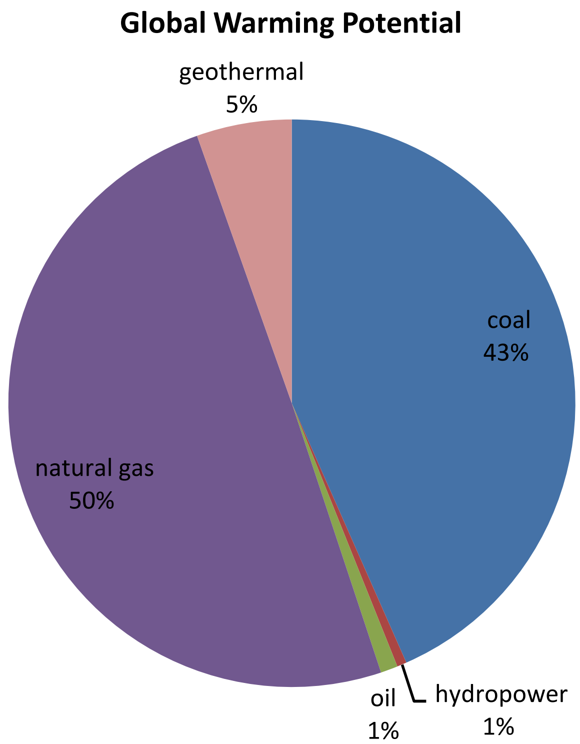

Figure 3 Share of the global warming potential (IPCC 2007, 100 years time horizon) of 1 kWh of electricity produced.

The primary sources of greenhouse gas emissions are from the electricity generation methods that utilise fossil fuels; gas (50%) and coal-derived electricity (43%) are particularly influential.

5.2 Adaptation check

For verification purposes, a model for New Zealand's electricity mix for 2008, with no adaptation of the New Zealand specific greenhouse gases, was created. After applying the IPCC (2007) characterisation factors, gas and coal-fired electricity were found to be the sources that contributed most to global warming; the majority of this contribution was caused by combustion processes. The emissions of CO_2, CH_4, and N_2O dominated the calculated carbon footprint for the non-adapted model. Results indicate the combustion processes (that use New Zealand-specific data in this study) provide the greatest contribution to the carbon footprint showing the adaption work was targeted correctly.

5.3 Sensitivity analysis

To investigate how sensitive the model is both to the composition of the electricity generation mix and to the efficiency of the gas power plants, three scenarios were modelled. First, the 2008 mix was maintained but gas power plants were assumed to have 43% efficiency, a figure suggested by MED during feedback on this study. An efficiency of 43% for gas power plants is not explicitly included in the published MED literature examined during the study but is within the range of European plant efficiencies. The other two scenarios alter the composition of the electricity generation mix to be representative of 2009 using the default 30% gas power plant efficiency and alternative 43% gas power plant efficiency figure suggested by MED during discussion of the results. The results (Figure 4) show that the model presented in this report is the worst case of the options examined, suggesting that the mix and the efficiency of the gas power plant are important factors in the adaptation of the life cycle inventory of electricity in New Zealand.

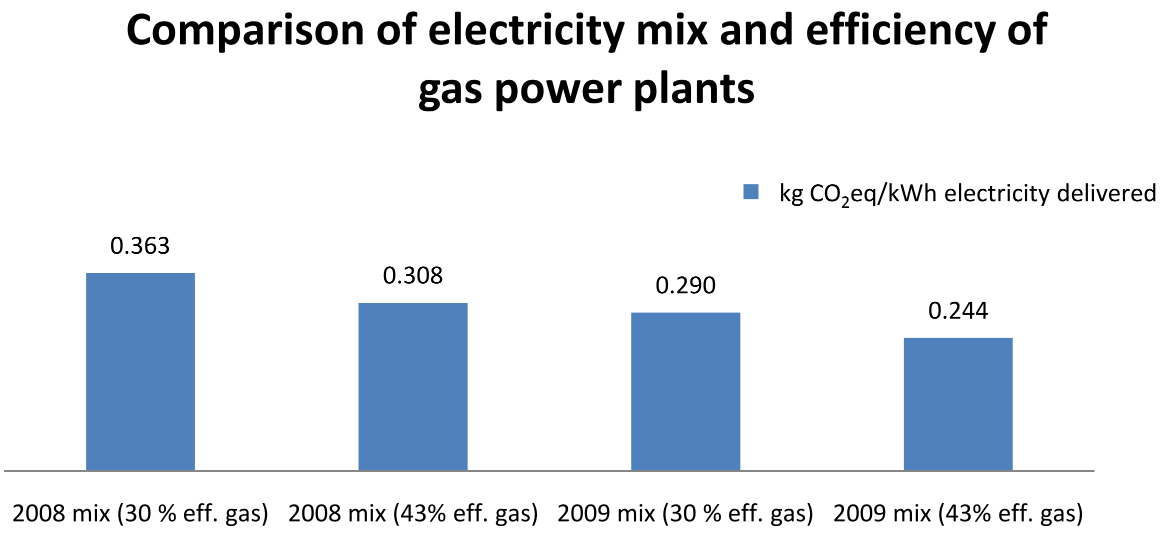

Figure 4 Emissions of CO_2eq per kWh of electricity delivered for different options of mix composition and efficiencies of the gas fired power plant.

It is also important to understand the impact assessment results for this dataset differ in scope and data sources to previous work freely available in the public domain. It is beyond the scope of this study to compare the differences of this dataset and those compiled for other New Zealand projects.

6 Discussion

As the inventory data included in this model were aggregated into a systems process, it is not possible to examine the individual flows and their associated emissions in detail. The systems process provides a single list of inputs and outputs, as shown in Appendix 2. As a comprehensive explanation of the adaptations made to the ecoinvent data and all the top-level processes included in this dataset are documented in this report, those with access to the source data for the dataset (i.e. ecoinvent database v2.0) should be able to build the same inventory and eventually implement any changes they may find appropriate to update the dataset.

This dataset is a valuable step in the process of building a New Zealand ILCD database. Electricity is one of the most widespread commodities in the New Zealand economy and therefore this dataset could potentially form a cornerstone of a New Zealand ILCD database.

The unit process information of the data used for the background process (in the ecoinvent dataset) allowed the creation of the inventory. Although the system process made for the inventory does not allow the user to verify or alter the data, the methodology outlined in this report should allow LCA practitioners to replicate and critically evaluate the work.

It is noteworthy that the carbon footprint detailed in this study (0.36 kg CO_2eq/kWh) is significantly higher than that of any other scenario modelled in the sensitivity analysis; this is due to different grid mix and efficiencies of gas power plants. Future inventory updates should take into consideration an updated electricity mix, and the efficiencies of the electricity generation plants should also be re-assessed or calculated, rather than using the default values. These two issues are particularly influential on the final carbon footprint results calculated as shown in Figure 4. Also worth noting are the observations made in regard to the appropriate share of run-of-river and reservoir-derived hydroelectricity and emissions of GHG from reservoirs as described Section 4.2.

Finally, how datasets are maintained and updated should also be considered at this early stage of database assembly because the ILCD system is cumbersome and time-intensive.

7 Conclusion

In this project, a large share of project time was dedicated to learning about dataset format exchange, which is a valuable output from building the dataset. As part of the overall project, further information on this topic is reported in a separate document from the New Zealand Life Cycle Management Centre.

The dataset presented in this document models the greenhouse gas emissions from New Zealand’s electricity mix, distribution and transmission, although several emissions are based on processes from other parts of the world. As the major greenhouse gases emissions are New Zealand specific, it can be concluded that this inventory, although adapted, is a fair representation of the New Zealand electricity mix, and fulfils the needs for entry-level ILCD datasets. However, it should be noted that the dataset relates to 2008, the modelled efficiencies are likely to be underestimated, and numerous processes are adapted from European data. The comparison of the electricity mix in a different year, as well as assumptions of more efficient gas plants, indicate that the results of this dataset models what is likely to be a worst case scenario.

It is likely that an increase in the number of inventory studies in different areas of interest in New Zealand will serve to improve underlying data quality. This in turn will strengthen the subsequent data quality of future LCA studies and associated work. This report is therefore a crucial step in the initial stages of development of a New Zealand-focused ILCD database.

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Appendix 1 – Created and adapted processes

The processes included in the electricity mix production are presented in Figure 5. The original processes are derived from the ecoinvent database, e.g., Germany (DE); solid boxes represent the ecoinvent process, underneath in italics are the modified inputs or emissions. The dashed line and grey-shaded boxes represent processes created for the purpose of this study.

The mix composition is the electricity mix for 2008; the efficiencies of fossil-fuel-fired electricity generators were altered to 30% (12 MJ to produce 1 kWh). The emissions of CO_2, CH_4 and N_2O were drawn from the New Zealand Greenhouse Gas Inventory (MfE 2011), and for geothermal electricity emissions the Contact Energy sustainability report (Contact 2010) was also used as a reference.

The input of electricity into the hard coal supply mix, heavy fuel oil at storage and at refinery, and natural gas high pressure were adapted to New Zealand electricity. Note that all the processes (e.g., other GHG emissions related to this process accounted for in the ecoinvent or background process, such as steel for the infrastructure of the plants and the emissions for its production) are included in this study.

The diagrams in Figures 5 and 6 include the top-level process and any alteration to these processes. The aim of these diagrams is to provide a clear picture of the altered process to facilitate the adaptation carried out so this project can be reproduced.

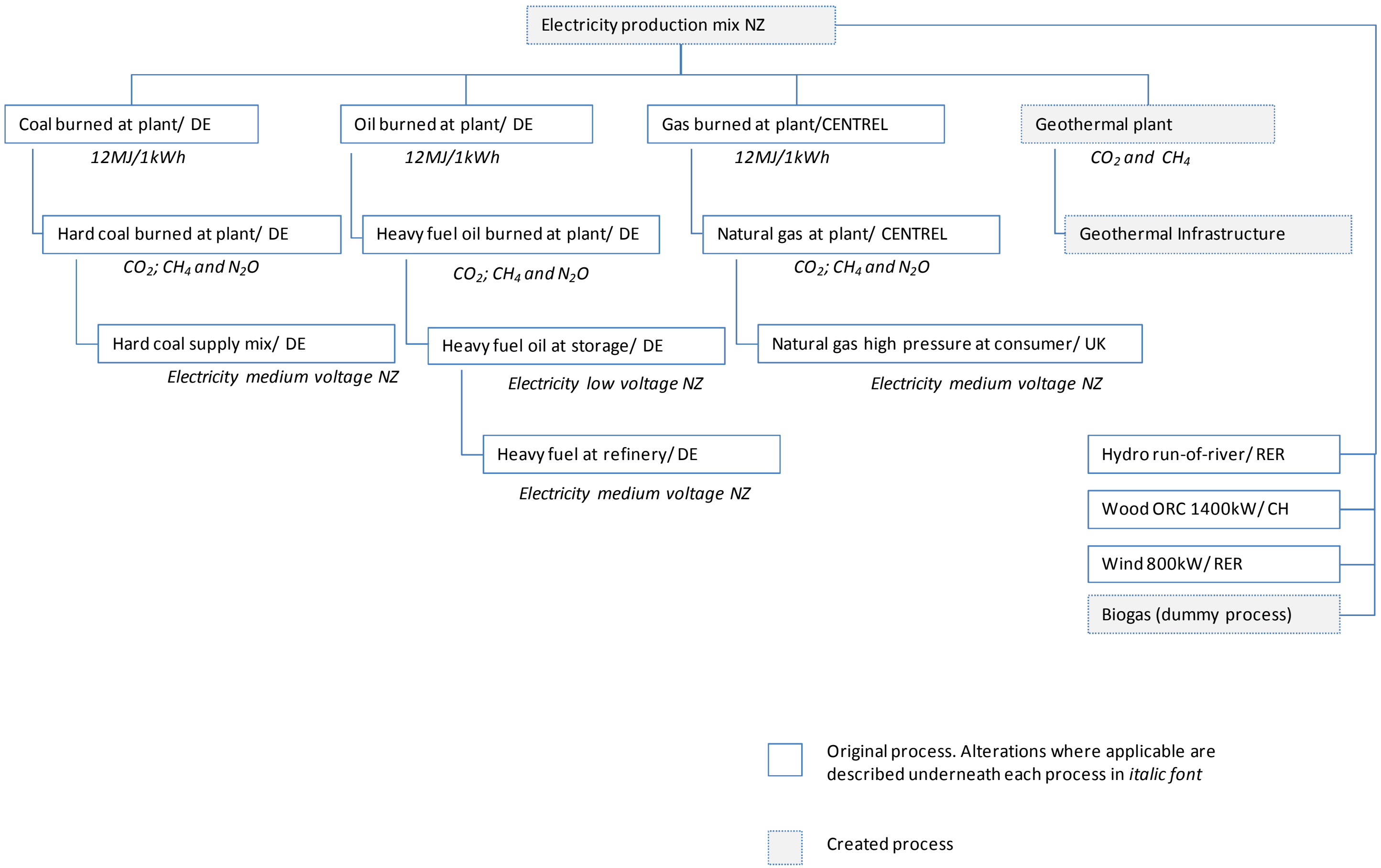

Figure 5 Adapted electricity mix for New Zealand. Solid boxes are the top-level processes from ecoinvent that were included; italics are the modified processes and inputs; nomenclature after '/' shows the origin of the process: DE Germany, CENTREL central Europe, UK United Kingdom, RER regional Europe, and CH Switzerland. NZ represents the process created for New Zealand.

Similarly, the adapted process for transmission and distribution are presented in Figure 6.

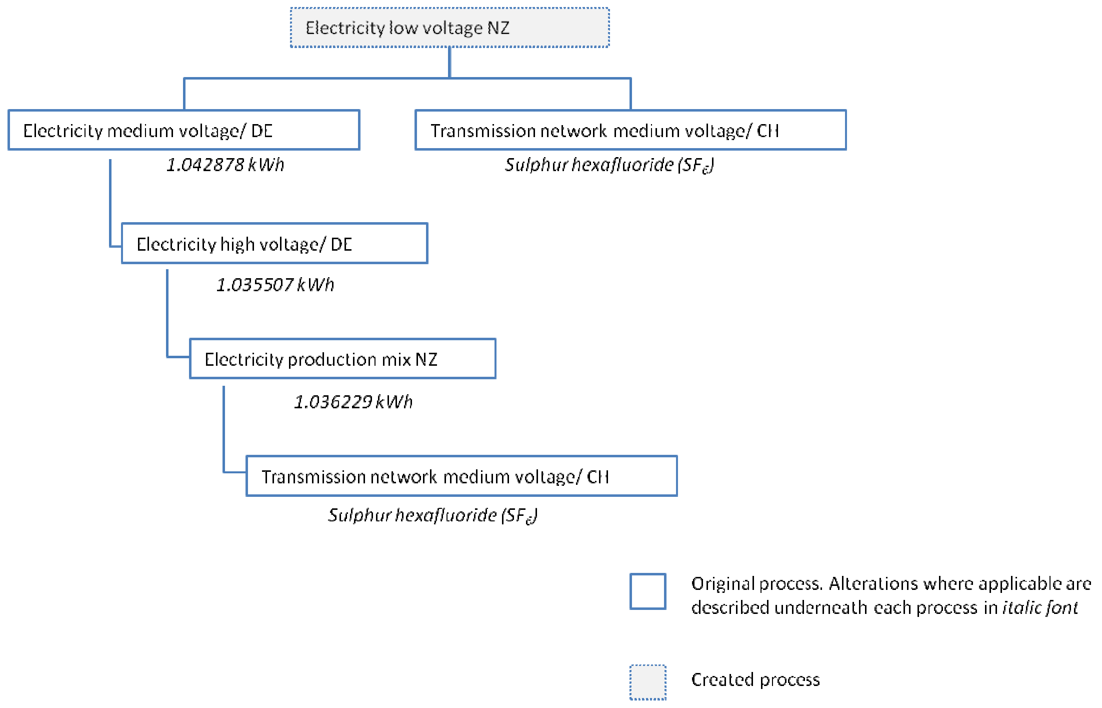

Figure 6 Transmissions and distribution adapted process. Nomenclature after '/' shows the origin of the process: DE Germany, and CH Switzerland, NZ represents the process created for New Zealand.

Geothermal infrastructure

The plant details and material requirements reported per MW for an “Enhanced Geothermal System” with capacity of 50 MW (EGS-50) operating over a 30-year lifetime were multiplied by 50 (to calculate materials per plant) followed by the necessary adjustments (such as conversion for volume and density to match entries in the ecoinvent database).

Table 2 Geothermal plant materials requirements (calculated using Sullivan et al. 2010)

Materials input (from ecoinvent database v.2.0)	*Given data (Sullivan et al. 2010)*	*Calculated*	*Calculation*	*Description*
	Amount unit/ MW	Amount unit/ 50 MW plant		
Concrete, normal, at plant/CH U	460 t	9.66E+03 m^3	$(460\times10^3/2380)*50$	460 t/MW concrete for the plant, 2380 kg/m^3 for normal concrete, 50 MW plant
Cement, unspecified, at plant/CH U	987 t	4.94E+04 ton	(970+17)*50	cement for 6-km well with 3 lines and cement for well to land 1000 of piping, 970 t/MW for well and 17 t/MW for well to plant
Diesel, burned in building machine/GLO U	240500 l	4.28E+08 MJ	(240500*0.832/ 0.0234)*50	240 500//MW diesel, 0.832 kg/l density of diesel, 0.0234 conversion from kg diesel to 1 MJ (from ecoinvent background process)
Aluminium, production mix, at plant/RER U	42.6 t	2.13E+03 ton	42.6*50	50 MW plant
Reinforcing steel, at plant/RER U	1175 t	5.88E+04 ton	1175*50	50 MW plant

Based on data from USA, of EGS –50 (Enhanced Geothermal Systems), life time 30 years. Data provided in the literature in per MW, for a plant of 50 MW.

Appendix 2 – Inventory results list

The inventory contains the cumulative results from the life cycle inventory of 1 kWh of electricity delivered, at consumer, representing the average mix of 2008. Dataset built based mainly on European process data; all New Zealand specific data are stated elsewhere in this report.

Electricity, low voltage at grid NZ 2008		
Inputs		***unit***
Carbon, in organic matter, in soil	3.43E-08	kg
Carbon dioxide, in air	0.018131214	kg
Outputs		
Electricity, low voltage, at grid	3.6	MJ
Carbon dioxide	0.014315786	kg
Carbon dioxide, biogenic	1.73E-02	kg
Carbon dioxide, fossil	0.322613024	kg
Carbon dioxide, land transformation	6.29E-07	kg
Carbon monoxide, biogenic	5.77E-06	kg
Carbon monoxide, fossil	1.36E-04	kg
Chloroform	2.06E-12	kg
Dinitrogen monoxide	8.90E-06	kg
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	8.56E-14	kg
Ethane	1.18E-05	kg
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	2.96E-12	kg
Ethane, 1,1,1-trichloro-, HCFC-140	1.71E-14	kg
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	3.14E-14	kg
Ethane, 1,1-difluoro-, HFC-152a	3.36E-12	kg
Ethane, 1,2-dichloro-	3.15E-08	kg
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	4.96E-11	kg

Electricity, low voltage at grid NZ 2008		
Outputs (cont.)		
Ethane, hexafluoro-, HFC-116	1.35E-09	kg
Methane	1.26E-04	kg
Methane, biogenic	1.29E-06	kg
Methane, bromo-, Halon 1001	6.06E-19	kg
Methane, bromochlorodifluoro-, Halon 1211	1.06E-09	kg
Methane, bromotrifluoro-, Halon 1301	1.51E-10	kg
Methane, chlorodifluoro-, HCFC-22	3.33E-09	kg
Methane, dichloro-, HCC-30	1.24E-11	kg
Methane, dichlorodifluoro-, CFC-12	6.65E-12	kg
Methane, dichlorofluoro-, HCFC-21	2.61E-16	kg
Methane, fossil	7.47E-04	kg
Methane, monochloro-, R-40	4.56E-13	kg
Methane, tetrachloro-, CFC-10	5.90E-11	kg
Methane, tetrafluoro-, CFC-14	1.21E-08	kg
Methane, trichlorofluoro-, CFC-11	4.24E-16	kg
Methane, trifluoro-, HFC-23	8.32E-14	kg
NMVOC, non-methane volatile organic compounds, unspecified origin	1.74E-05	kg
Sulfur hexafluoride	7.72E-08	kg

Appendix 3 – Review

SCION
forests · products · innovation

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New Zealand

7th September 2011

"New Zealand's Electricity Mix Life Cycle Inventory for Carbon Footprints"

To whom it may concern,

I find this document compliant with the entry-level reporting requirements for the international reference life cycle data system.

After numerous iterations and reviews, this report shows:

1. The methods used to carry out the life cycle assessment are consistent with the international reference life cycle data system handbook guide,
2. The data used are appropriate and reasonable,
3. The interpretation reflects some of the limitations identified.

It should be noted that the final greenhouse footprint calculated in this study is significantly larger than those calculated in other studies.

James McDevitt