Life Cycle Assessment Data sets Greenhouse Gas Footprinting Project:
Diesel

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Executive Summary

Quantifying environmental performance is of increasing importance to businesses and consumers alike. Among the tools available to evaluate environmental performance, Life Cycle Assessment provides a holistic approach to evaluate environmental performance by considering the potential impacts from all stages of a supply chain. Life cycle assessment generally comprises four major components: Goal and Scope definition; Life Cycle Inventory - data collection and calculation of an inventory; Life Cycle Impact Assessment - analysis of data to evaluate environmental impact; and Interpretation - where data are analysed.

This study has been conducted according to the requirements of ISO 14044:2006 and the international life cycle database handbook. The project aimed to compile a life cycle inventory data set—for one kilogram of diesel consumed by a tractor during a spraying process on a New Zealand kiwifruit orchard. The purpose of the study is to contribute to the beginning of a New Zealand database of life cycle inventory data sets, evaluate the international life cycle inventory methodology and upskill the Life Cycle Management Centre members in the area of international life cycle inventory data sets.

It was decided at an early stage in the project development that only chemical flows pertaining to the global warming potential impact category will be included in the data set. Life cycle impact assessment was done using characterisation factors from IPCC (2007). A review of data from published and confidential sources enabled the compilation of this data set.

In total 34 flows were compiled and these result in a greenhouse gas footprint of 3.7 kg CO_2e/kg of diesel used for a tractor spraying. A significant portion (85%) of the greenhouse gas emissions are from combustion in the tractor. The greenhouse gas emissions of diesel production when the system boundary is at the Marsden point gate is 0.57 kg CO_2e/kg diesel; compared with data from a literature review this figure is only 10% lower than the maximum value.

In compiling these data sets we found several issues with the use of third party programmes and data quality. Nevertheless adopting the international life cycle inventory database methodology will enhance the credibility of life cycle assessment studies conducted in New Zealand and contribute to continued improvement in the environmental performance of key products.

Technical Summary

Diesel represents 42% of the direct primary energy used in primary industries with horticulture and fruit growing contributing 7% of that value (Statistics New Zealand, 2011). This project aimed to compile a life cycle inventory data set in accordance with the guidelines detailed in ISO 14044:2006 and the international life cycle inventory database handbook. The quality of a data set—and the extent to which the data can be used—depends on the criteria used to compile the data set. The international life cycle inventory database methodology is espoused by the European Union as the standard by which future data sets will be measured and it is intended to be a benchmark for the databases around the world. Currently New Zealand does not have a life cycle inventory database, and it is likely that in the future life cycle inventories will be compiled in accordance to the international life cycle inventory database handbook.

At an early stage in the project it was decided that only chemical flows relevant to the global warming potential impact assessment category, at 100 years time horizon in accordance with the IPCC characterisation list, will be collected. The data set is applicable to the production and processing of one kilogram diesel through the Marsden Point refinery, and the transport and use of this diesel for a typical tractor during a spraying process on a kiwifruit orchard in New Zealand.

Thirty four chemical flows were quantified in the data set. A life cycle impact assessment revealed that at the Marsden Point gate the greenhouse emissions are 0.57 kg CO_2e/kg of diesel, which is higher than the greenhouse gas emissions from diesel product compared data review values from a literature review. The overall greenhouse gas emissions for one kg of diesel consumed by a tractor during a spraying process in a New Zealand kiwifruit orchard are 3.7 kg CO_2e. A significant portion (85%) of the emissions is from the combustion of diesel in the tractor.

The development of a high quality international life cycle inventory database is a considerable undertaking. The compilation of the New Zealand diesel data set to international life cycle inventory database format has revealed a number of methodological issues. Some of the key issues identified are: ownership of data; use of third party software and software compatibility and data exchange; data quality; and full transparency in reporting. Nevertheless, this project is a significant step forward towards a harmonised protocol for a New Zealand life cycle inventory database. The compilation of such a database will enhance the credibility of life cycle assessment studies conducted in New Zealand; contribute to continued improvement in the environmental performance of products and help the penetration of New Zealand product’s in overseas markets.

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Introduction

Environmental issues have assumed an escalating importance for government, businesses and consumers alike. The emphasis has broadened from a site-specific focus to include product-specific attributes. Several regulatory schemes that address environmental issues regarding products have permeated the marketplace, and they are of ever-increasing significance. Therefore, product related environmental information is a part of many companies' and consumers decision-making process and is subsequently becoming an important non-market value.

Among the tools available to evaluate environmental performance is Life Cycle Assessment (LCA). Life Cycle Assessment provides a life cycle approach to evaluate environmental performance by considering the potential impacts from all stages of manufacture, product use and end-of-life stages, sometimes called the 'cradle-to-grave' approach. Life Cycle Assessment generally comprises four major components:

- Goal and scope definition;
- Life Cycle Inventory - data collection and calculation of an inventory of materials, energy and emissions related to the system being studied;
- Life Cycle Impact Assessment - analysis of data to evaluate contributions to various environmental impact categories; and
- Interpretation - where data are analysed in the context of the methodology, scope and study goals and where the quality of any study conclusions is assessed.

Life Cycle Assessment has a number of limitations, not least the difficulty in making legitimate comparisons. One of the principal constraints to making comparisons is heterogeneity in system boundaries, data used and reporting protocol. To address this, the European Union (EU) has set up the European Life Cycle Database (ELCD) hereafter referred to as the International Life Cycle database (ILCD) because it is envisaged that the ELCD will form the basis of the ILCD in time.

The ILCD core database comprises Life Cycle Inventory (LCI) data from leading EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. The focus is laid on data quality, consistency, and applicability. The target users of these data sets are experts/practitioners in LCA. The data sets are accessible free of charge and without access or use restrictions for all LCA practitioners. The data sets of the ILCD database are foreseen to contribute key European data to the upcoming international ILCD Data Network and in complement of other data sources.

Diesel is a ubiquitous commodity that is one of the many products that originates from crude petroleum. Crude petroleum is a naturally occurring flammable liquid that can be extracted from mineral deposits. The process of refining crude petroleum essentially involves breaking up large complex hydrocarbon molecules into smaller, simpler molecules that are separated into different product fractions by a distillation and reforming process. One of these products is diesel of which New Zealand uses approximately 2.2 million tonnes of diesel per annum (MED 2001). The majority of diesel is processed through the Marsden Point refinery which is owned and operated by the New Zealand Refining Company (NZRC) and has been operating since 1964 (MED, 2001). The main distinction between diesel and other liquid fuels are the engines that require diesel to work. Compared with regular grade petrol typically diesel has a higher calorific value but produces more carbon dioxide equivalents (CO_2e) per volume combusted.

This report presents a summary of the first attempt at compiling a data set relevant to diesel production and consumption in New Zealand. It provides an explanation of the methodology, results and interpretation of the life cycle inventory data and the report is intended to complement the data sets produced.

Method

In November 2010 MAF in conjunction with Zespri agreed to commission several LCA studies that aim to compile data sets using the ILCD handbook. Accordingly this study has been conducted according to the requirements of ISO 14044:2006 and the ILCD handbook.

Goal of the study

The goal of this study is to produce a data set that details the *chemical emissions from one kilogram of diesel consumed by a tractor during a spraying process in a New Zealand kiwifruit orchard*[a] therefore this is the functional unit of the study. Accordingly the reference flow for the data reported in the inventory section will be to one kilogram of diesel. In addition, experiences acquired from this study will contribute to a bigger report on the use of ILCD database format in NZ. The target audience of the study will be other LCA researchers in NZ and abroad and people associated with the kiwifruit supply chain. This study is not intended to be used to support comparative assertions intended for public disclosure.

Scope of the study

This study is a cradle to tailpipe study, that is, it covers all of the production steps from raw materials (i.e. the cradle) to the combustion of diesel in a tractor. The system boundary from this study is detailed in Figure 1. For each unit process included in the system boundary the chemical emissions that relate to global warming potential (using the IPCC (2007) characterisation list) will be quantified.

[a] Additional data sets will be provided that correspond to the production and delivery of diesel to Wiri and Nelson. These data sets will use the same life cycle inventory data detailed in this report but for the sake of clarity detail and analysis of these data sets is omitted from this report.

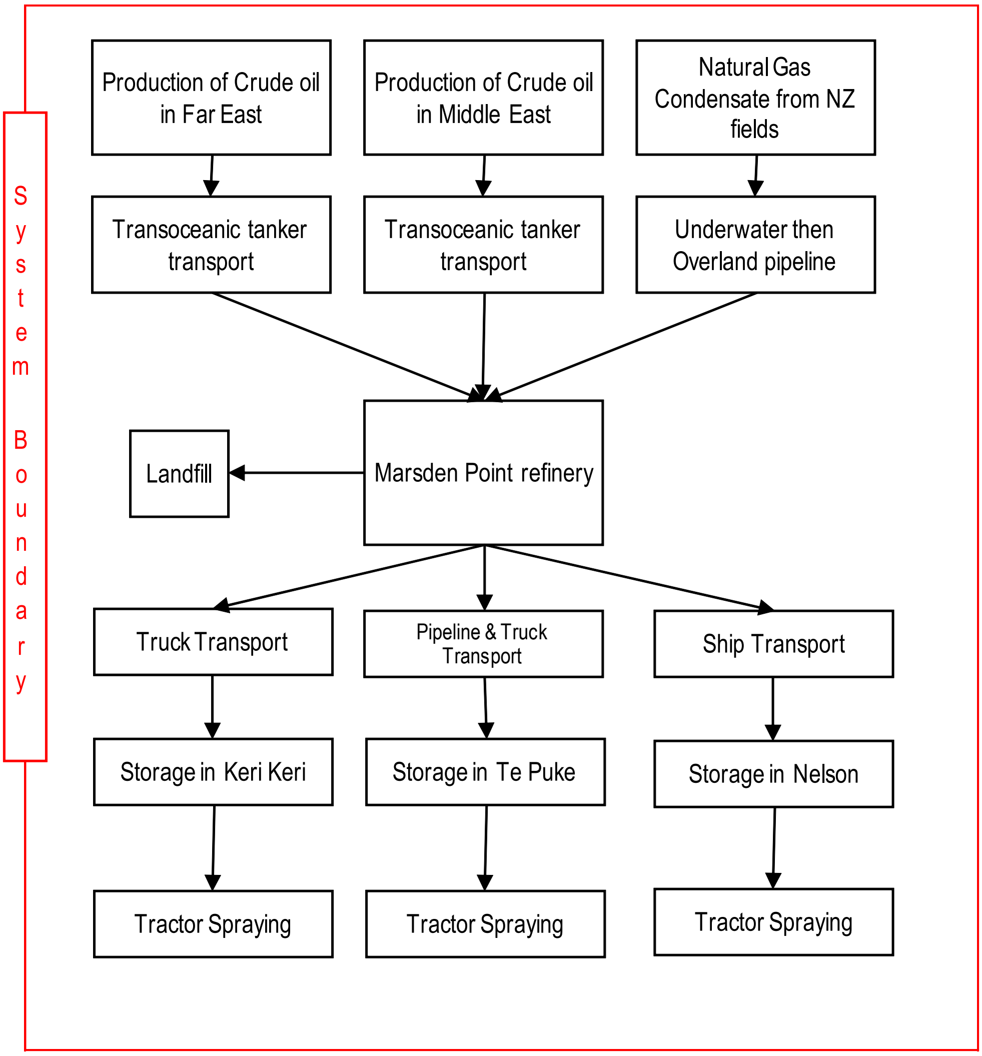

Figure 1: A simplified diagram showing the system boundary of the study.

The delimitation of the system boundary was defined to ensure consistency in the LCA. Excluded are the capital, emissions from employees in the supply chain and nebulous unit processes—such as “other” feedstock and diesel that is refined in undefined countries. The cut-off criteria are influenced by the practicability of completing the project in the time available. Estimating the completion and impact of the cut-off presents a paradoxical problem. The problem arises that the impact of such a cut-off is difficult to quantify; it is fatuous yet necessary to state that the reported chemical flows are something of an underestimate compared to a more complete life cycle inventory. The ILCD handbook does not stipulate a minimum data quality standard. Whilst the best available data is sourced where possible and is preferable, a pragmatic approach has been taken in this study.

Life cycle impact assessment methodology

The LCIA and chemical flows are confined to Global Warming Potential at a 100 year time horizon (GWP_{100}), and the characterisation factors used in the LCIA are from IPCC (2007). The characterisation factors relate to radiative forcing of a chemical, and they are expressed as CO_2e. Radiative forcing is a concept used to make quantitative comparisons of the strength of different human and natural agents in causing climate change. The radiative forcing of a chemical is calculated by quantifying the retained heat due to the presence of a particular gas. It should be noted that any LCIA results calculated in this study are relative expression and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks when included in a LCA. No further modification of the GWP_{100} characterisation factors was done beyond the calculation of CO_2e in this study.

Global warming potential was chosen because there is more readily available data that details elementary flows for this impact category; collecting a full data set wasn't practical for some of the members of the wider project group because they don't own LCA software; GWP_{100} currently is seen as the main sustainability indicator by MAF and Zespri who have commissioned the study; and by limiting the data collection to GHG permits the study to be completed in the financial constraints. Furthermore the 100 year time horizon was chosen—as opposed to a 20 or 500 year time horizon—because it is the most commonly applied time horizon for GHG LCA studies.

Life Cycle Inventory Analysis

Data Collection

The data for this study was collected between March 2011 and May 2011. The reference year for the present study is 2010. This was chosen because of the high quality data for the refinery process for this year. Original industry data were used in preference, but if needed, relevant literature data were used. For filling the data gaps, literature data published between 1976 and 2010 were considered as valid for the reference year 2010.

The data was collected from primary sources and literature review; in some cases data has been supplemented with information from personal communications. Every effort has been made to disclose all data sources—but full transparency is limited by a number of confidentiality agreements.

Foreground Data

The data will be reported following the sequence of unit processes involved in the supply chain from cradle to tailpipe.

Production of Diesel

The majority (90%) of diesel consumed in New Zealand comes through the Marsden Point refinery and the remainder comes from direct imports of the finished product (10%) (MED, 2001). The Marsden Point Refinery processes around 5 million tonnes of feedstock each year (mostly crude oils, but also some residues and semi-refined streams). It is essentially a 'middle distillate' refinery, configured primarily for the production of jet fuel and diesel, rather than petrol. Various feedstocks from around the world are used by the Marsden Point site and they are detailed in Table 1. Diesel is the main output, by volume, and constitutes 38% of the annual output; the next largest outputs are regular grade petrol (22%) and jet fuel (17%) (MED, 2001).

Table 1: Contribution and origin of the feedstocks used by Marsden Point refinery (MED, 2001) (Note: numbers do not add to 100% due to rounding).

Feedstock	Characteristics	Typical proportion of total feedstock (by tonnage)
Middle East crudes	Medium to high sulphur, high residue	45%
Far East crudes	Lower sulphur, waxier, richer in middle distillates and more expensive	35%
Residues	Upgraded by vacuum distillation	8%
Condensates	Kapuni, Maui and imported condensates - sources of naphtha	13%

The chemical inventory of crude petroleum extraction from the Middle East[b] was calculated using unit processes from ecoinvent that detail emissions from on- and offshore rigs (Jungbluth, 2007). Using data from 1993, 81.3% were onshore and 18.7% were offshore (West, 1993) the overall chemical emission for crude oil production was weighted accordingly. The distance between the Middle East and Marsden Point (15,939 km) was calculated using a distance between the principal port near the oil fields and the closest international port to Marsden Point (Searates, 2011) and weighted depending on average annual production for each of the oil fields using data from West (1993).

The chemical inventory of crude petroleum extraction from the Far East[c] was calculated using unit processes from ecoinvent that detail emissions from on- and offshore rigs (Jungbluth, 2007). Using data from 1993, 75.7% were onshore and 24.3% were offshore (West, 1993) the overall chemical emission for crude oil production was weighted accordingly. The distance between the Far East and Marsden Point (9497 km) was calculated using a distance between the principal port near the oil fields and the closest international port to Marsden Point (Searates, 2011) and weighted depending on average annual production for each of the oil fields using West (1993).

All of NZ known natural gas reserves are located in the Taranaki region (Eng et al., 2008). The principal sources are the Pohokura (36%), Maui (30%), and Kapuni (14%) fields; the McKee, Turangi, Mangahewa, Maari, Tui, Kaimiro, Ngatoro, Rimu and Kauri fields all make a minor contribution (MED, 2009). The harvest of gas from the gas fields is done by semi submersible drilling rig (Gregg and Walrond, 2009). The rigs are modelled as being powered by diesel generators; and the emission were calculated using an adapted energy figure from Jungbluth (2007). The emissions from the diesel generators were calculated using the emission factor for a stationary engine detailed in MfE (2007). The transmission distance of condensate from the rig to shore was calculated using the distance from New Plymouth and the individual rigs weighted on the average annual production using statistics (IEA, 2010). The energy demand for the transmission of condensate—0.54 MJ/tkm—was adapted from Macleod (1976). Natural gas is reticulated further around the North Island by pipeline (Eng et al., 2008). It's assumed the energy for transmission from New Plymouth to Marsden Point (approximately 496 km) comes from the national grid and the energy demand for overland reticulation is 0.0612 MJ/tkm from DeLuchi (1991).

The emission and resources used for the operations of the Marsden Point site are from the New Zealand Refinery Company annual report (NZRC, 2010) which details an annual input of 4.796 MT of feedstock per annum. Using this we can calculate: the electricity demand (4.1×10^{-5} MJ/kg); water use (0.332 kg/kg);

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[b] The Middle East being: Abu Dhabi, Dubai, Egypt, Iran, Iraq, Jordan, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, Syria, Yemen.

[c] The Far East being: Australia, Brunei, China, India, Indonesia, Japan, Malaysia, Burma, Philippines, Taiwan, Thailand,

sulphur dioxide emissions (8.6 x 10^{-4} kg/kg); carbon dioxide emissions (0.24 kg/kg); and waste to landfill (2.8 x 10^{-7} kg/kg) for the site operations.

Diesel that is distributed around the North Island—below Auckland—is reticulated from Marsden Point to Wiri (Auckland) and then trucked to a regional storage facility. Diesel that is distributed around the North Island to a point North of Marsden Point—leaves the Marsden Point site and is trucked to a regional store. Diesel that is distributed to the South island is sent by ship.

Approximately 85% of kiwifruit are grown in the Bay of Plenty region, 10% in the Keri Keri region and 5% in the Nelson region (Clothier, 2011).

Transport to Te Puke (Bay of Plenty)

Diesel is distributed around the North Island by truck tanker (IEA, 2010). The tanker was modelled as a 37 t truck and trailer that is 50% utilised. The tanker is modelled as a EURO3 in accordance with the guidelines given in MoT (2010). The distance from Wiri to Te Puke is 211 km.

Transport to Keri Keri

Diesel is distributed around the North Island by truck tanker (IEA, 2010). The tanker was modelled as a 37 t truck and trailer that is 50% utilised. The tanker is modelled as a EURO3 in accordance with the guidelines given in MoT (2010). The distance from Marsden Point to Keri Keri is 115 km.

Transport to Nelson

Diesel distributed to the South Island is usually done so using ships (IEA, 2010). The coastal shipping unit process was extracted from the GaBi database (PE International, 2009). The distance from Marsden Point to Nelson is modelled as 1174 km[d] (Searates, 2011).

Tractor use: Spraying

Once at a regional store it is assumed the diesel is decanted into the tractor. The average tractor size for spraying is 80 hp (60 kW) (Barber and Benge, 2006). The fuel use is calculated using the horsepower rating and is detailed in Equation 1.

$$\text{Fuel use (L/hour)} = 0.221 \times \text{Tractor Horse Power} - 0.8$$

Equation 1: The tractor fuel use from Barber and Benge (2006).

Using Equation 1 a fuel use of 16.9 L/hr is calculated for the spraying tractor and using a specific gravity of 0.836 this corresponds to 14.1 kg/hr. It is assumed that the tractor operates at 50% of operational speed and power and the emissions profile are in line with assumptions detailed in the GaBi database (PE International, 2009).

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[d] Actually modelled as Auckland to Nelson because there was no option to choose Marsden Point in searates.com, and Auckland is the nearest port to Marsden Point that features in searates.com.

Background data

The background system may be defined as the unit process that are not under direct control of the system under consideration (Baumann and Tillman, 2004). The emissions from light fuel oil production are from the GaBi database (PE International, 2009). The chemical emissions from tap water were calculated in McDevitt et al. (In Press). The GHG emissions profile from a NZ landfill is adapted from the GaBi database (PE International, 2009) and the GHG emissions from the NZ electricity panorama are from an associated ILCD study carried out by Landcare Research.

Assumptions in the background data

There has been no allocation between the production of electricity and co-products such as amenity value of hydroelectric lakes or aquaculture. Further, no credit has been given for co-products that arise from waste disposal.

Allocation

Where a system generates products with different functions, allocation procedures become more complex. One such example is the refinery process at Marsden point where several products are produced. According to ISO 14040 standard series, allocation has been avoided by expanding the system boundaries as much as possible. Physical allocations were used in any other parts of this study.

Data Review

Descriptions of data quality are important to understand the reliability of the study results and to properly interpret the outcome of the study. Data quality requirements are specified to enable the goal and scope of the study to be met. Data quality is characterised by quantitative and qualitative aspects as well as the methods used to collect and integrate the data. Data will be evaluated under the sections; technology coverage; time-related coverage and geographical coverage. For each section, data will be evaluated for its precision; completeness; representativeness; consistency and reproducibility.

Technological Coverage

The technological coverage of a data set relates to how well the inventory data represents its technological or technical characteristics of the unit processes documented in the life cycle inventory section.

The precision of unit processes relating to the on- and offshore production of crude oil in this study is questionable because the data is heavily influenced by European data—particularly Norway—due to data accessibility problems (Jungbluth, 2007). Therefore this data may not satisfactorily represent conditions in the Middle and Far East crude oil extraction sites. Furthermore, the proportion of on- and offshore extraction sites and the annual production figures may not fully represent the process involved in crude oil extraction although without detailed knowledge of the actual quantity of extracted oil from on- and offshore sites in these areas it is difficult to evaluate.

The gas fields in the Taranaki region have several wells and these are tapped depending on the reserves and the nature of the extraction (Gregg and Walrond, 2009). Accordingly the energy for extraction changes depending on conditions. Therefore the energy figure used in this study may not be precisely representing the actual gas extraction—until primary data is collected we will not know for sure. The energy values for the reticulation of gas condensate from oil wells to Marsden Point are from data sources over 15 years old. However, despite being old data, it is unlikely that the energy for gas reticulation will have changed much and as such the data is of acceptable quality.

The data concerning the refinery process in this study is technologically representative of the unit process studied because it is primary data that relates to the actual operations of the modelled system. Whilst there might be variation in technologies due to annual variation in market demand it is beyond the scope of this study to quantify this.

There are several transportation/vehicular phases included in the supply chain of diesel. New Zealand is one of the few OECD countries without emission controls on vehicles (MoT, 2010). Therefore the emission factors detailed in the Emission Inventory Guidebook (EMEP/CORINAIR, 2007)—which is the work behind the majority of the data used—is somewhat redundant. The same is true for the tractor emissions—although it should be noted that there isn't a large difference in the emission profile between the range 35-115 hp (26-86 kW - Barber and Benge, 2006) of tractors relevant to the kiwifruit orchard survey using the Emission Inventory Guidebook (EMEP/CORINAIR, 2007). However the GHG emissions from tractor use are also dependent on the workload and time in use, which is only arbitrarily factored into the calculated data set.

In several unit processes data from Ecoinvent or the GaBi database was used. Therefore the data is accessible to anyone who has the appropriate licence and conversely not accessible to those without one. The copyright agreements Scion has with Ecoinvent and PE International prevents complete disclosure of the exact data and consequently some unit processes of this data set are not reproducible.

Temporal Coverage

The temporal coverage of a dataset is related to the technological coverage (is as much as technologies are developing all the time) but also relates the time related aspect of the data described for unit processes in the LCI section. There are elements to temporal coverage; annual variation and the date of data used.

There is likely to be significant annual variability in several of the data sets used. Unit processes that are likely to exhibit significant annual variations are; electricity and tap water production (due to seasonal change) and the use of a tractor (due to external conditions and workload). The data used in this study are averaged data and therefore the variation associate with annual changes is hidden from the data set, thus reducing the representativeness and precision of the data set.

There are several data sources that are from studies that are over 10 years old. Notably: the energy for reticulation; emissions profile from the tractor; proportion and output of on- and offshore well in the Middle and Far East are all quite old data sets. Whilst we recognise that using this data is far from ideal, it is unlikely that there will be large differences between older data and something that has been collected recently because of relative technological similarities between then and now.

Geographical Coverage

The geographical representativeness of a LCI identifies how well the inventory data represents it regarding the location (e.g. market, site(s), region, country, etc.) that is in the LCI section. The geographical coverage of a data set relates to individual unit processes as well as to the goal of the study.

Prominent unit processes that exhibit a spatial constituent are crude oil and gas condensate extraction. The only major gas condensate field in NZ are in the Taranaki region (Eng et al., 2008) and the major gas field (Kapuni and Maui) were modelled in this study. Therefore the geographical coverage of this unit process is good. Crude oil extraction is delimited into Middle and Far East. The regions encompassing Middle and Far East are vast and it is unlikely that Marsden Point will source oil in the way that is calculated in this study. Therefore whilst the geographical coverage might be considered good for these processes the precision, completeness and representativeness of the data is inadequate.

Approximately 85% of New Zealand's kiwifruit are grown in the Bay of Plenty region, 10% in the Keri Keri region and 5% in the Nelson region (Clothier, 2011). Therefore the geographical coverage of the data set in relation to the functional unit is excellent.

Life Cycle Impact Assessment Results

Thirty four flows that are characterised for GWP_{100} which are emitted from the use of diesel in a tractor on a kiwifruit orchard have been collated in this study. Using the IPCC characterisation factors the overall GWP_{100} of one kg of diesel used for a tractor for spraying is 3.7 kg CO_2e/kg of diesel used. Hotspot analysis revealed that 85% of the GHG emissions come from the combustion of diesel in a tractor (Figure 2).

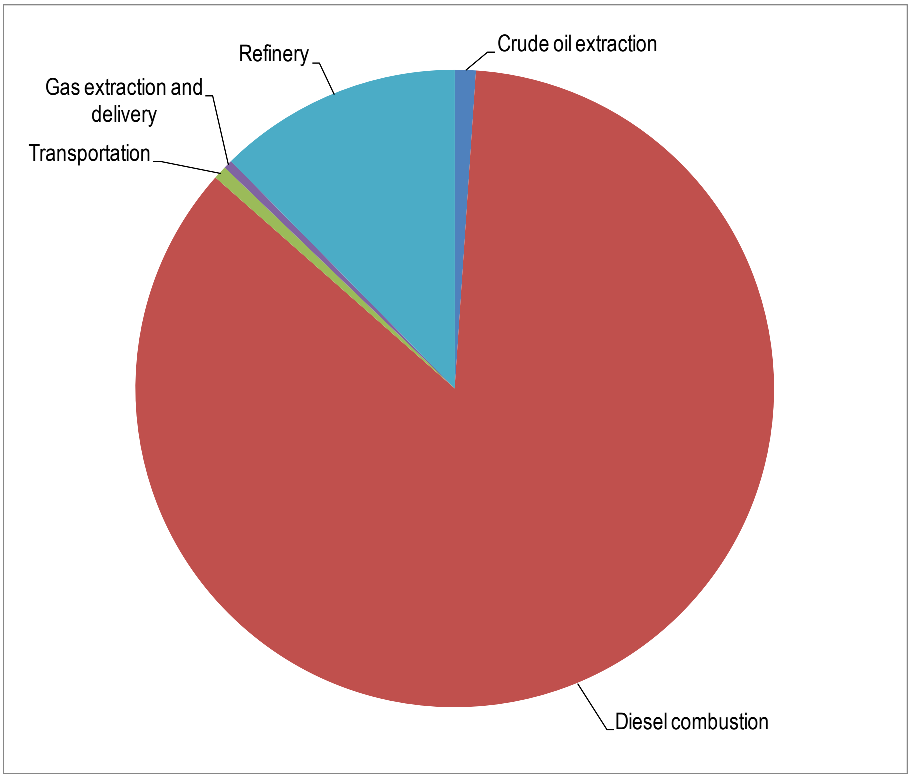

Figure 2: GHG hotspots emissions from one kilogram of diesel consumed by a tractor during a spraying process in a New Zealand kiwifruit orchard.

Assessment of the GWP_{100} of diesel in this study (0.57 kg CO_2e/kg) compared with figures from a literature review of diesel production (0.45 kg CO_2e/kg, n = 6) at the refinery gate shows that the GHG emissions are on the higher end of the range (Figure 3). Furthermore the GHG emissions from this study are 10% lower than the maximum value and 50% higher than the minimum value found in the literature review.

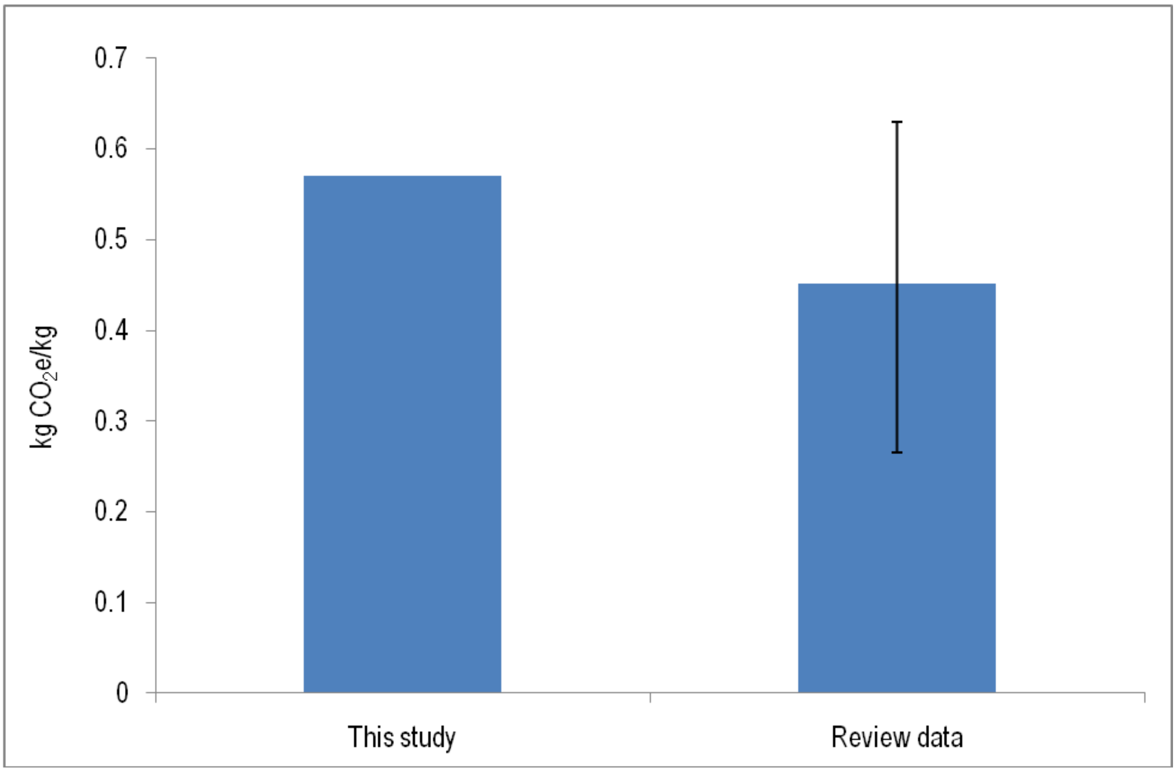

Figure 3: The GHG emission from one kg of diesel refined in Marsden Point (this study) compared with diesel refined in other refineries from the literature review. Error bars show the range of data found.

Life Cycle Interpretation

The function of this section is to evaluate, in accordance with ILCD handbook, the overall data set and significance of methodological choices to the LCI results reported in the associated data set.

In this study 34 chemical flows, associated with the use of diesel for tractor spraying on a kiwifruit orchard in NZ, have been quantified. Compared with other values for diesel production (at the refinery gate) the value calculated in this study (0.57 kg CO_2e/kg) is higher than the average literature value (0.45 kg CO_2e/kg) yet broadly in line with the 0.55 kg CO_2e/kg figure reported in Barber (2011). However, only limited conclusions can be made because the system boundaries and underlying assumptions in the other data sets are unknown. This is particularly relevant for comparisons between the GHG emissions from combustion of diesel in a tractor. Nevertheless, the main source of emissions is from combustion in the tractor (Figure 2), which, given the focal impact category is not surprising and this finding corroborates other studies.

Overall the quality of the data included in this study—whilst not preclusive for ILCD entry level requirements—is a concern. There are exceptions however; the data concerning the operations of the Marsden Point refinery, for example, is excellent. Of note is the data quality to do with diesel combustion in a tractor. This process dominates the GWP_{100} emissions and small changes (entirely feasible ones) to the emission profile will have a profound effect on the data set. Ultimately the data quality of this study limits the conclusions and insight that can be ascertained from the study.

A number of assumptions were necessary to compile the data set. In the background data it was assumed that there was no need for allocation between the electricity generation and other products that arise from this process. This is unlikely to be a fair representation of reality because there are significant co-products from electricity generation methods, notably the amenity value of hydro-electric lakes and aquaculture from geothermal plants. Furthermore there is likely to be a significant diurnal and annual variation in the makeup of the electricity panorama which is not accounted for. The system boundary employed in this study is also imposes limitations. A significant portion (10%) of NZ diesel is imported directly as refined diesel and a portion (8%) of the feedstock for refining is described as “other” (or residues depending on source). Whilst it is reasonable to exclude these unit processes because of the lack of relevant information about these process/products, the combined omission from the data set is likely to be important.

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Conclusions

This has been a comprehensive and technically rigorous LCI study, employing consistent data collection, methodology, and processing in order to provide a sound foundation to further LCA studies involving diesel. The data sets, methodological and technical issues developed are freely available for third party use. Therefore this study reflects MAF's and Zespri's dedication to transparent reporting of enviro-metrics, and commitment to enhancing the national skill set to continue to utilise non-market values for environmental performance improvement.

In completing this study Scion has acquired some insight into the ILCD LCI methodology. It is noteworthy that a number of third party freeware programs are useful for the compilation of the data sets. It would be cavalier to assume that these are fully functional and translate data perfectly, so at present a significant amount of time-intensive cross checking is necessary. A number of compatibility issues have been identified, for example, data that has an area, time or financial aspect to it cannot be imported directly and therefore requires extra attention. The compatibility of data sets with existing LCA programs such as GaBi and SimaPro is flawed —to date we are unable to upload completed ILCD data sets satisfactorily. All data sets could be enhanced substantially by improving the data quality; in NZ data quality is particularly poor because of the relative isolation of the country and immaturity of the LCA field relative to most European countries. Furthermore there is no method to quantify variability and uncertainty in unit process data in the ILCD methodology. Being able to quantify variability and uncertainty will facilitate meaningful analysis and insight in data sets—and will enhance the uptake of LCI data.

An increase in the number of LCI studies in NZ will improve the underlying data quality used in studies which in turn will strengthen the data quality of subsequent studies. Consequently, decisions dependent of LCI data sets will become more reliable and thereby more commonplace. This study represents a significant step forward in the integration of LCA into mainstream decision making in NZ and whilst there are specific issues with the methodology and data sets produced—they don't detract from a commendable overarching initiative.

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Annex A: Inventory data set

Chemical Flow	Input / Output	Mass (kg)
Carbon dioxide [Renewable resources]	Input	0.000556
Carbon, in organic matter, in soil [Non renewable resources]	Input	4.39E-07
1,1,1-Trichloroethane [Halogenated organic emissions to air]	Output	3.76E-14
Butane [Group NMVOC to air]	Output	5.89E-05
Butane (n-butane) [Group NMVOC to air]	Output	6.01E-09
Carbon dioxide [Inorganic emissions to air]	Output	3.714209
Carbon dioxide (biotic) [Inorganic emissions to air]	Output	0.000513
Carbon dioxide, land transformation [Inorganic emissions to air]	Output	5.33E-06
Carbon monoxide [Inorganic emissions to air]	Output	0.014098
Carbon monoxide (biotic) [Inorganic emissions to air]	Output	9.21E-07
Dichloroethane (1,2-Dichloroethane) [Halogenated organic emissions to air]	Output	4.91E-09
Dichloromethane (methylene chloride) [Halogenated organic emissions to air]	Output	1.90E-12
Hydrocarbons, aromatic [Group NMVOC to air]	Output	1.05E-07
Hydrocarbons, chlorinated [Halogenated organic emissions to air]	Output	3.93E-10
Methane [Organic emissions to air (group VOC)]	Output	0.000531
Methane (biotic) [Organic emissions to air (group VOC)]	Output	4.82E-07
Nitrous oxide (laughing gas) [Inorganic emissions to air]	Output	3.18E-06
NMVOC (unspecified) [Group NMVOC to air]	Output	0.003968
Pentane (n-pentane) [Group NMVOC to air]	Output	7.30E-05
Propane [Group NMVOC to air]	Output	6.10E-05
R 11 (trichlorofluoromethane) [Halogenated organic emissions to air]	Output	2.41E-11
R 113 (trichlorofluoroethane) [Halogenated organic emissions to air]	Output	6.60E-14
R 114 (dichlorotetrafluoroethane) [Halogenated organic emissions to air]	Output	1.89E-10
R 116 (hexafluoroethane) [Halogenated organic emissions to air]	Output	1.78E-10

R 12 (dichlorodifluoromethane) [Halogenated organic emissions to air]	Output	6.23E-12
R 13 (chlorotrifluoromethane) [Halogenated organic emissions to air]	Output	3.26E-12
R 134a (tetrafluoroethane) [Halogenated organic emissions to air]	Output	9.74E-12
R 152a (difluoroethane) [Halogenated organic emissions to air]	Output	1.23E-11
R 21 (Dichlorofluoromethane) [Halogenated organic emissions to air]	Output	7.23E-16
R 22 (chlorodifluoromethane) [Halogenated organic emissions to air]	Output	4.69E-10
R 23 (trifluoromethane) [Halogenated organic emissions to air]	Output	2.30E-13
Sulphur hexafluoride [Inorganic emissions to air]	Output	2.14E-09
Trichloromethane (chloroform) [Halogenated organic emissions to air]	Output	6.15E-12
VOC (unspecified) [Organic emissions to air (group VOC)]	Output	3.00E-09

Annex B: Reviewer comments

I find this report to be compliant with the reporting requirements outlined in the (ILCD Handbook) Specific guide, section 10.3.

In addition and in accordance with the purpose of the critical review (see Specific guide chapter 11), I find this report to show:

1. The methods used to carry out the LCA are consistent with both the Specific Guide and with ISO 14040 and 14044
2. The methods used are technically and scientifically valid
3. The data used are appropriate and reasonable
4. The interpretations reflect the limitations identified and the goal of the study

Overall the report is transparent and consistent, but there are 3 points in this document where further clarification is required or where revisions are needed.

1. In the introduction to Life cycle impact assessment methodology (under Figure 1) the paragraph needs to more clearly state that only greenhouse gases are being considered in this study.
2. The section on Technical Coverage (pages 11–12) the discussion regarding the similarities of emissions profiles between international and local literature would benefit from a rewrite to more clearly illustrate the point.
3. The chemical flows discussed in the Annex are not referred to in text

Incorporation of these changes will complete compliance.

Robyn Sinclair, Landcare research (3/6/11).

Life Cycle Assessment Data sets Greenhouse Gas Footprinting Project: Diesel

Review

Questions to assess:

1. The methods used to compile the life cycle inventory data are scientifically and technically valid
2. The data used are appropriate and reasonable in relation to the goal of the study
3. The study report is transparent and consistent

Dear Alistair,

I have been through the report. I have used track changes in the document as it was quicker to do it that way and probably easier to follow.

I have made a number of comments and minor edits.

The point to think about the most is the functional unit, *one kilogram of diesel consumed by a tractor during a spraying process*. The source of the combustion emissions is not specified and given that it accounts for 85% of the emissions this should be made clearer. I assume the combustion emissions are from the MED emission factor for diesel. If so this does not account for engine type. In which case I would interpret the results as being LCA GHG emissions per kg of combusted diesel, rather than specifying that it is GHG emissions from a kg of diesel combusted by a tractor during a spraying process.

I also looked closely at the front cover and could not see any tractors crossing the Auckland Harbour Bridge at the time of the photo. This cover probably better reflects the actual functional unit.

Best regards,

Andrew Barber

AgriLINK New Zealand