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Comparative Energy and Greenhouse Gas Emissions of New Zealand's and the UK's Dairy Industry

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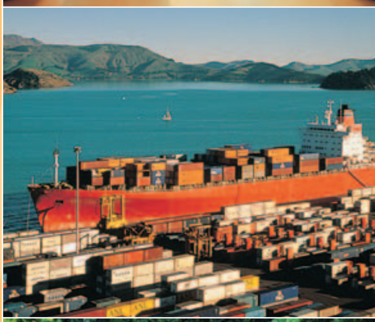

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List of Abbreviations

Energy & Power

J	joule	basic unit of energy
kJ	kilojoule	1,000 joules
MJ	megajoule	1,000,000 joules
GJ	gigajoule	1,000,000,000 joules
W	watt	basic unit of power = 1 joule per second
kW	kilowatt	1,000 watts
kWh	kilowatt-hour	3.6 MJ

Others

ha	hectare (10,000 square metres)
g	gram
kg	kilogram (1,000 grams)
tonne	1,000 kilograms
t	tonne
ml	millilitre
L	litre (1,000 millilitres)
p	UK pence
CO_2	carbon dioxide
ai	active ingredient
MAF	Ministry of Agriculture and Forestry
IPCC	International Panel on Climate Change
MED	Ministry of Economic Development

Conversions

1 ha = 2.47 acres

1 kJ = 239 calories

1 kW = 1.34 horse-power (HP)

Preface

This report is an extension of the Food Miles report published in July 2006 (Saunders Barber and Taylor report number 285). The report takes the results of the dairy sector from the Food Miles report and adds in greenhouse gas emissions for the dairy sector. This shows that NZ is still more efficient at dairy production than the UK even when other emissions are accounted for.

This research is part of ongoing research in the AERU which monitors economic, environmental and social factors affecting agriculture and our trade. This includes research under the ARGOS (Agricultural Research Group on Sustainability) programme jointly with The AgriBusiness Group and Otago University.

Professor Caroline Saunders
Director
AERU

Executive Summary

- This report expands on the earlier report on Food Miles. That report considered the energy and associated carbon emissions of some key New Zealand export products. These calculations of emissions were based upon a life cycle assessment (LCA) type approach and include the energy use and CO_2 emissions associated with production and transport to the UK. These were then compared to the next best alternative source for the UK market.

- The original report compared the energy used and CO_2 emissions between NZ and UK Dairy production. This found that the UK uses twice as much energy per tonne of milk solids produced than NZ, even including the energy associated with transport from NZ to the UK. This reflects the less intensive production system in NZ than the UK, with lower inputs including energy.

- This report adds greenhouse gas emissions associated with methane and nitrous oxide to the emissions associated with energy use in the food miles report. The calculations of methane and nitrous oxide emissions use the same methodology, but country specific coefficients, for both the UK and NZ as was the case for energy emissions in the original food miles report. This found that the UK had 34 per cent more emissions per kilogram of milk solids and 30 per cent more per hectare than NZ for dairy production even including the shipping to the UK.

- The report assumes that it is possible for the UK and other countries to supply the UK market at current cost with production to replace NZ imports. This, of course, may not be the case given limited capacity of production and different production environments.

Chapter 1
Introduction

This research report builds upon the AERU Research Report No. 285 on Food Miles - Comparative energy/emissions performance of New Zealand's agriculture industry (Saunders et al. 2006). That report was concerned with assessing the validity of the Food Mile argument. Food Miles is an issue which has arisen in the United Kingdom, Germany and other countries over food transportation and reflects concern for the environment, especially in regard to greenhouse gas emissions such as carbon dioxide and climate change arising from this. The argument is that the longer the transport distance (food miles), the more energy is consumed, the more fossil fuels are burned and consequently the more greenhouse gases are released into the atmosphere, which cause global warming. Therefore the solution proposed by food miles campaigners is to source food from as close to where it will be finally consumed as possible.

New Zealand has attracted a lot of attention in the food miles debate clearly because of its distance from markets especially the UK. It is generally the first or main supplier which is held up as an example of the exporter to the UK in the Food Miles debate whose products have to travel the furthest to market. The Food Miles research report argued that it is the total amount of energy used to produce and deliver a product to the market and the greenhouse gas emissions associated with it (such as CO_2) which are important, not just the delivery cost captured by the 'food miles'. The food miles argument takes no account of the energy use/CO_2 emissions in the production phase and assumes that a given product is produced to the same level of energy efficiency no matter where it is produced.

The Food Miles research report therefore compared key New Zealand sectors which export significant quantities to the UK, and compared to the next best alternative source for the UK market. The calculation of energy use was based upon a life cycle assessment-type approach and covered the impact categories of energy use and CO_2 emissions and from production to plate.

The results of that analysis showed that NZ was more energy efficient in the production of dairy, apples, onions and lamb even including shipping cost to the UK. The report showed that NZ production was twice as efficient in the case of dairy, and four times as efficient in case of sheep meat. In the case of apples NZ is more energy efficient due mainly to significantly higher yields. In the case of onions, the UK is more energy efficient in production than NZ. However, when storage costs are included for UK onions to replace imports from NZ the UK is less energy efficient than NZ.

The research therefore compared, using the same methodology, production systems in the UK with those in NZ; specifically to assess the validity of the food mile argument. There were a number of areas where this research could be expanded in particular the inclusion of greenhouse gases from methane and nitrous oxide emissions. Therefore this report adds these greenhouse gases for the dairy sector again using the same methodology for both the UK and NZ.

This report presents first a review of the literature into life cycle assessment as well as others which have assessed energy use and emissions associated with agriculture. The report then outlines the methodology used and then presents a summary of the results of the energy and emissions associated with the CO_2 for dairy and the emissions associated with methane and nitrous oxide.

Chapter 2
Literature Review

2.1 Life cycle assessment

The studies reviewed do not take all aspects of the production of these goods into consideration. An assessment of the environmental effects a product or service has during its lifetime, from cradle to grave, is known as a life cycle assessment (LCA). According to the LCA Food Database (2005) all the important processes during the product's lifecycle are included in any calculation of environmental effects.

In this definition, 'cradle to grave' refers to all of the inputs into the product being assessed, from the raw materials which are brought in and used on the farm (the cradle), until the product is finally disposed of and the waste is dealt with (the grave).

Tan and Culaba (2002) report that early forms of LCAs were used in the late 1960s in the United States, but it was not until the 1990s that they emerged in their current form when international standards were imposed, first by the Society for Environmental Toxicology and Chemistry in 1991 and more recently by the International Organization for Standardization (ISO). Currently LCA is part of the IS0 14040 series, which covers the principles, the analysis, interpretation and the reporting of the results, (see Berlin (2003) for details).

LCA studies were originally developed for industrial products but are now being conducted on the primary sector (Barber, 2004b), and also for manufactured foods and beverages. Much of the recent work on LCA in these sectors has come out of Scandinavia, especially Sweden, and a relatively large number of studies have been conducted on the dairy industry (Cederberg and Flysjö, 2004).

Bassett-Mens et al. (2005) conducted a cradle-to-gate LCA study of NZ dairy production and compared the results using five potential impact categories (greenhouse warming potential, acidification, eutrophication, energy use and land use) with European LCA studies.

Cederberg and Flysjö set out to ascertain the environmental impact of Swedish milk production, in terms of resource use and emissions. They surveyed 23 dairy farms in south-western Sweden, over three types: conventional high output farms, conventional medium output farms, and organic farms.

The study is a cradle-to-gate analysis with inputs both from within and outside of the farm being included, but not after the milk is produced, thus the transport of the product off the farm is not included.

The study calculates environmental impacts for one kilogram of energy-corrected milk (ECM). The impact categories which the authors chose to consider include energy, land use, climate change, eutrophication and acidification. The study excluded farm buildings and machinery from the analysis, along with some other less significant items.

The dairy farms from which data were collected were all specialised dairy farms and this helped to reduce some allocation problems (when the inputs into the process go towards more than one type of output). However, the issue of co-products (e.g. the slaughter of stock) still arose, and was handled by splitting the environmental impacts of the products according to the relative income earned by the activities. Therefore in their life cycle inventory the authors split the farms into areas of animal production, crop production for fodder, and concentrate production.

For animal production, the average milk yield, feed consumption, manure production, gas emissions from the animals and the use of electricity on the farm were calculated by farm type. The diesel, fertiliser and pesticides inputs and the emissions associated with them were attributed to the milk indirectly through the categories of feed consumption (calculated for the crop and concentrate production, which includes inputs from outside of the farm). That is, the amount of diesel for example which was used in the production of animal feed, was attributed to the milk output based on how much feed was consumed by the cows per volume of milk they produced.

The crop and concentrate production is very detailed and covers a number of different types of crops and two main types of concentrate which are fed to the cows. The concentrates are broken down into their individual components (e.g. barley, wheat and rapeseed) which are assessed for their resource use and environmental impacts. These impacts are attributed back to the concentrate through a weighting procedure according to the proportion the particular component is of the total concentrate.

These authors generally use internationally recognised impact coefficients from the IPCC for the farm inputs which they assess, although they sometimes refer to results in other studies. These coefficients measure the environmental impacts of resource consumption, for example, the amount of energy consumed and CO_2 emitted per kilogram of nitrogen fertiliser.

In terms of energy consumption, the authors use the concept of secondary (consumer) energy. This is just the actual energy contained in the fuel/electricity (e.g. diesel), as opposed to the concept of primary energy which also includes the energy costs of extracting and supplying (e.g. transporting) the fuel, and losses which occur through the process. This was the same approach that Wells (1998) originally used but was discarded in the subsequent study (Wells, 2001) as it mixes primary and consumer energy coefficients when the results are aggregated.

Finally they sum over the specified impact categories in terms of the function unit (1 kg of energy-corrected milk) and conduct one-way ANOVA analyses to test for significant differences between the three types of dairy farms. For example, these tests showed that the total energy use of organic farms per unit of production was significantly less than each of the two conventional types of farms, while no significant difference was found between these conventional types. A similar picture emerged for CO_2 emissions.

Brentrup et al. (2004a) constructed a LCA approach for arable crop production which is applied to a theoretical system of winter wheat production, in a companion paper (Bentrup et al., 2004b). This approach starts by using standard LCA methodology, to assess the impacts of various production intensities which are characterised by different levels of fertiliser and fossil fuel inputs. The impacts are measured over the categories of depletion of abiotic resources (e.g. fossil fuels, phosphate rock and potash), land use, climate change, toxicity (human and ecosystems), acidification and eutrophication (terrestrial and aquatic). Energy use is one item which is not included in any of these impact categories, although the authors do use a primary energy-type definition in that they measure the impacts associated with the extraction of raw materials and the production of farm inputs used in the system. The methodology in this study is a cradle-to-gate analysis, meaning that transport and waste disposal components of the product's life cycle are not considered after they leave the farm gate.

After these impacts are recorded, they are put through a normalisation procedure to assess the importance of the impacts relative to each other. These normalised values are then used to construct two indicators through a weighting procedure, one for resource depletion (RDI) and the other for environmental impacts (EcoX). The weights are arrived at by applying the 'distance-to-target' principle, in which higher weights are given to the impact categories which are closest to reaching a certain target level (e.g. total depletion of oil). The indicators attempt to quantify the overall impacts of the particular production intensities, in the two categories (i.e. resource depletion and environmental impacts). For example in the actual study the authors carried out on winter wheat production (Bentrup et al., 2004b), the EcoX indicator showed that at low production intensities (low levels of nitrogen fertiliser), the overall environmental effects were moderate, but the land use impact contributed more than one-half of the total effect and aquatic eutrophication only a small amount. However, at high production intensities (high levels of nitrogen fertiliser) this situation was reversed, and the overall environmental impact was high.

In New Zealand, a number of energy use studies into agricultural production were carried out between 1974 and 1984, following the first 'oil shock' in 1973 (Wells, 2001). But from that time until the mid-1990s, very little energy use research into this sector was conducted. From the mid-1990s onwards the research programme resumed with work by Wells (e.g. Wells (2001)) and Barber (who has applied Wells' methodology to other farming sectors – Barber (2004b)) being prominent.

Wells (2001) surveys the New Zealand dairy industry in terms of the production of milk solids and arrives at the average energy use and CO_2 emissions per kg of milk solids (the functional unit). Wells' approach will now be reviewed:

Wells breaks the energy inputs of the production process down to three major components:

1. Direct – the energy supplied directly in the form of fuels and electricity.

2. Indirect – the energy used on fertilisers, agrichemicals, seeds, and animal feed supplements.

3. Capital – energy used to manufacture items of capital equipment such as farm vehicles, machinery, buildings, fences and methods of irrigation.

As with Cederberg and Flysjö (2004), Wells' paper could be considered a cradle-to-gate analysis (not a full LCA), which in addition to on-farm inputs includes such items as the manufacture and transport of fertiliser and supplementary feed as indirect inputs into the system and the manufacture of vehicles and farm machinery as capital inputs. However it factors in the primary energy used in the process (which is a more complete measure of the total energy inputs and their corresponding CO_2 emissions), compared to the secondary energy for the former paper. Further, it is not a LCA in the strictest sense since it does not satisfy all of the formal requirements for one, although it follows a similar approach.

In the study itself, over the period 1997/98 to 1998/99 150 dairy farms were surveyed across the major dairying regions in New Zealand, and which included both irrigated and non-irrigated operations. The quantities of the various inputs on each farm were recorded and converted to primary energy and CO_2 emissions, based on rates assumed in national and international studies, in accordance with International Panel on Climate Change (IPCC) guidelines. They were then summed together to arrive at the total energy and CO_2 emissions for that farm, as well as a set of what Wells calls 'indicators' which include: production intensity (kg MS/ha), total energy intensity (GJ/ha), overall energy ratio (MJin/MJout), gross CO_2 emission intensity (tonnes of CO_2/ha) and the percentage of renewable energy. These observations were then used to arrive at regional average dairy farms (for eight regions) based on simple averages from the farms surveyed, a national average dairy farm in terms of the energy inputs and CO_2 emission levels, by applying a weighting system (based on regional herd sizes from the annual agricultural census), and this average was also split between the average irrigated and non-irrigated farms. Wells also used hypothesis testing methods to test whether each indicator from each region was significantly different from the national average (excluding that region), and a confidence interval approach to provide bounds for the national figures arrived at based on the uncertainty of the sample employed. It is also worthwhile to mention the fact that Wells included in his analysis of CO_2 emission levels a sequestration calculation, which is presented in the form of an average net CO_2 emission statistic.

Overall, there have been relatively few LCA-type studies performed. Perhaps one of the reasons why this is the case could be that relevant data can be very hard to find and that often they can only be obtained by conducting an ad hoc survey. Moreover, energy use/environmental impact figures are not usually included in sets of official statistics, although this may change in the future as environmental concerns become more pressing, and with the requirement for certain indicators to be monitored in line with international agreements such as the Kyoto Protocol (e.g. greenhouse gas emissions). LCA-type approaches look set to form a considerable part of the environmental literature.

Chapter 3
Methodology

This report builds upon the methodology used in the Food Miles report. That is it uses the methodology developed by Wells and applies this to data on NZ dairy production systems and those for the UK, in order to compare the relative efficiencies of such operations in these countries. However, the approach used in this report will differ from Wells (2001) in a number of ways. It will not include surveys, regional weighting, hypothesis testing or confidence intervals. Further, the number of indicators which Wells constructed will not be included in this paper. There are two major extensions to Wells' methodology, that is, the inclusion of a transport distances necessary to export the product to the UK are included in the analysis of environmental impacts and the inclusion of the emissions associated with methane and nitrous oxide. The transport of the finished product within New Zealand, the UK and any other country involved is not included within the boundaries of the analysis i.e. only the transport between countries is included. This is unlikely to affect the conclusions reached however, as these distances will tend to cancel each other out, especially since New Zealand and the UK are similar-sized countries.

3.1 Wells' methodology

Wells separates energy inputs used in the production process into three major components: direct, indirect, and capital (items included in each of these components are listed near the end of this section). Each of these inputs must be quantified initially and then the respective coefficients applied, to obtain the total primary energy use and CO_2 emissions.

Farm inputs in this analysis may include factors such as energy used to power tractors, the energy embodied in capital items such as the tractors themselves and farm buildings/sheds, as well as fertilisers and pesticides used on the farm, and animal feed.

Off-farm inputs include the shipping of NZ product from NZ to the UK. This paper is essentially a cradle to gate analysis plus the impact of shipping. Transport to the processor, processing, and the transport of the finished product within New Zealand, the UK and any other country involved is not included within the boundaries of the analysis i.e. only the transport between countries is included.

The inputs at each stage of the product's life must then be added together to enable the overall environmental impacts in each category to be quantified.

Chapter 4
Energy and Associated Emissions of Key Inputs into Dairy Production

4.1 Direct energy inputs

Direct energy includes liquid fuels and electricity used by the farmer. It has two components, consumer energy which is that energy used directly by the operation, i.e. the energy available in a litre of diesel to do work, plus the energy it takes to supply the fuel. Total energy includes the energy contained in the fuel/electricity (consumer energy), plus the energy for extracting, processing, refining and supplying (e.g. transportation for diesel) the fuel, and losses which occur through the process. The values of these are illustrated in Table 1. The primary energy content, which includes an allowance for the fuels production and delivery, adds a further 23 per cent for all these types in NZ (Wells, 2001) and 16 per cent in the UK.

The carbon emission for NZ and UK fuel is very similar. The carbon emissions for electricity are higher in the UK due to the greater proportion of fossil fuel used whereas NZ generates 64 per cent from renewable sources.

Some of the UK farm budgets used to derive energy inputs had expenditure on contractors for such operations as mowing and cultivation. For the purposes of this study the fuel was assumed to be 12 per cent of the cost and this was then converted into litres of diesel.

4.2 Indirect energy inputs

Indirect energy inputs used in agricultural production include fertilisers, agrichemicals and supplementary animal feed. Table 4.1 illustrates the energy and associated emissions for the main inputs into agricultural systems. Fertiliser is the most significant indirect energy input. The energy component in fertiliser comes mainly from its manufacture and transport. The energy component and the CO_2 emissions from fertilisers use the data presented by Wells (2001). It is assumed here that these are the same for the UK and NZ.

As in the case of fertilisers the energy component of agrichemicals is mainly from their manufacture and transport. The energy component and carbon dioxide emissions were adapted from a detailed study of the energy in chemical manufacture and use (Pimentel, 1980) and data on carbon dioxide emissions is from Wells (2001) and Barber (2004b). The energy requirement to manufacture agrichemicals ranges considerably as shown in Table 4.1.

An important input into livestock systems in the UK is concentrate feed especially when compared to NZ. For the purposes of this study it is assumed that concentrates have the same energy profile as barley. This is likely to be an underestimate of the energy in the concentrate as it ignores other supplements in the feed. A simple analysis of the energy and CO_2 emissions in producing barley feed was therefore undertaken and reported in detail in Saunders et al (2006). This gave a lower bound on the embodied energy in barley concentrate of 3,361 MJ per tonne of barley. The associated emissions are 207 kg of CO_2 per tonne of barley.

The energy emissions and carbon dioxide emissions for fodder were taken from Wells (2001) and this was 1.50 MJ/kg dry mater (DM) for grass silage and hay with an emission rate of 0.058 kg CO_2/MJ.

Table 4.1
Energy requirement for key inputs and the associated CO_2 emissions

	Energy Use (MJ/kg)		**CO_2 Emissions (kg CO_2/MJ)**	
	NZ	UK	NZ	UK
Diesel (per litre)	43.6	41.2	68.7 [a]	65.1 [c]
Petrol (per litre)	39.9	37.7	67.0 [a]	61.3 [c]
Oil (per litre)	47.4	44.8	35.9 [a]	33.2 [c]
Electricity (per kWh)	8.14	10.37	19.2 [b]	41.5 [c]
N	65	65	0.05	0.05
P	15	15	0.06	0.06
K	10	10	0.06	0.06
S	5	5	0.06	0.06
Lime	0.6		0.72	
Herbicide (Paraquat, Diquat and Glyphosate) (kg ai)	550	550	0.06	0.06
Herbicide (other) (kg ai)	310	310	0.06	0.06
Insecticide (kg ai)	315	315	0.06	0.06
Fungicide (kg ai)	210	210	0.06	0.06
Plant Growth Regulator (kg ai)	175	175	0.06	0.06
Oil (kg ai)	120	120	0.06	0.06
Other (kg ai)	120	120	0.06	0.06
Concentrates (per tonne) (barley equiv)	3,360	206.9		
Fodder	1.50		0.058	
Vehicles	65.5		0.09	
Implements	51.2		0.10	
Buildings (m^2)	590		0.10	
Shipping (per tonne km)	0.114		0.007	

The energy and carbon dioxide emissions associated with machinery include the embodied energy of the raw materials, construction energy, an allowance for repairs and maintenance, and international freight. As Table 4.1 shows, the embodied energy of vehicles and implements used in this report is 65.5 MJ/kg and 51.2 MJ/kg respectively (Barber & Lucock, 2006). This is based on a simplification of the approach used by Audsley et al. (1997) and incorporates New Zealand data for steel and rubber. This is lower than the figure reported in Wells (2001) but more akin to that used by Doering (1980) who estimated a value of around 70 MJ/kg.

Table 4.1 also gives the energy coefficients and CO_2 emission rates for farm vehicles and implements. For both New Zealand and the UK a dairy shed model constructed by Wells (2001) was used. The capital energy of the dairy shed is related to a single parameter, the number of sets of milking cups.

4.3 Transport

The transport distances included in this report were be done are on distances between NZ and the UK. For New Zealand dairy this involves refrigerated sea freight to the United Kingdom, a distance of 17,840 km according to the Department for Transport (2003).

A review of the literature on the energy and emission coefficients for refrigerated sea transport did show general consistency with one or two exceptions and the figure chosen here is the 0.114 MJ per tonne km. This has been calculated from shipping having carbon dioxide emissions of 0.007 $kgCO_2$/t-km (Department for Transport, 2003), and the carbon content of diesel being 2.68 $kgCO_2$/L. Dividing the shipping emissions by the carbon content per litre of diesel equals 0.0026 L/t-km. Multiplying this figure by the primary energy content of NZ diesel (43.6 MJ/L), given that the ships refill in NZ, gives a rate of 0.114 MJ/t-km.

Chapter 5
Energy and Carbon Dioxide Emissions Associated with Production in NZ and the UK

This chapter calculates the energy and carbon dioxide emissions associated with the production of NZ Dairy and the alternative source of supply in the UK. Information is then needed on the type and level of inputs used in the production system as outlined in Chapter 3. Information on this was not so readily available especially on consistent data between countries. In general information on NZ production systems and input use was available in more detail enabling a more thorough calculation of the energy embodied and emissions associated with NZ production. However, this has led to the results underestimating the energy and emissions associated with production in the UK compared to that in NZ.

5.1 Dairy

This section presents the results of energy use and carbon dioxide emissions from energy for NZ and UK dairy. The functional unit for is a kilogram of milk solids (MS).

Data for agricultural LCA's are often from a limited number of farms or are conducted as desktop exercises using various models. As a result they often do not account for the large variation in management, regional differences and resource use by farmers. This research reflected the range of dairy systems in both countries to ensure the dairy industry was correctly represented. Clearly there is variation between the systems in each country. Wells' found that at the 95 per cent confidence interval for total energy use was ± 6 per cent of the national average.

5.1.1 NZ dairy

The dairy information presented here is based upon the study conducted by Colin Wells in his 2001 study of the Dairy Industry (Wells 2001). This involved the comprehensive survey of 150 dairy farms from throughout NZ. Where some of the detail in the Wells report was not shown, due to the figures being aggregated, we were able to disaggregate by interrogating to the raw data. In this report the energy and carbon dioxide coefficients were updated given more recent sources of information and so that they were consistent across all the production systems studied. The average yield for dairy herds in the Wells report was 840 kg MS/ha while the average farm size was 91 hectares with 246 cows.

5.1.2 UK dairy

No single source of information on dairy production systems in the UK was available giving the detailed information required to compare energy use in this sector with that in NZ. Therefore a number of sources have been used to obtain and verify the information used. The key sources were the report on the Economics of Milk Production, Colman et al. (2004). This was supplemented with Nix's Farm Management Pocket Book (2004) and other sources as cited below. A summary of the data used is given in Table A.1 in the Appendix.

The average yield for dairy herds which is used in this study is 6,665 litres of milk per cow per year (Colman et al., 2004), this is equivalent to 968 kg MS per hectare. This is based on average farm size of 86.5 cows per farm and a 1.72 per hectare stocking rate (which implies an average farm size of 50 hectares).

5.1.3 Comparison of NZ and UK dairy production

The energy and carbon dioxide emissions associated with dairy production in NZ and the UK are summarised in Table 5.1. This is an updated version of Table 7.1 from the original Food Miles report. The key difference is that the UK figures are now based on 7.1 per cent milk solids rather than 8.4 per cent, see section 6.2. The NZ pesticide figure has been corrected and adjustments made to the quantities per hectare.

Table 5.1 does highlight the different types of production in the two countries with the first two columns of data identifying the quantity of input per hectare. It must also be noted that data on certain inputs was either not available on a comparable basis for the two countries or not available at all.

The total energy use is presented in the third and fourth columns in Table 5.1 and shows that the UK uses considerably more energy per tonne of milk solids produced. The UK uses 80 per cent more fuel per tonne of milk solid that NZ does although less electricity is used in the UK than in NZ. The major difference in energy input however is in the use of concentrates and forage which in the UK is significantly higher than that used in NZ, reflecting the different production systems. It should also be noted that the concentrates in the UK were assumed to be barley equivalent and thus likely to be an underestimate of the energy embodied as it ignores other supplements

In the UK a total of 57,497 MJ of energy is used per tonne of milk solid compared to 22,074 in NZ, over two and a half times as much. Including shipping at 2,030 MJ per tonne milk solids still makes NZ production much more energy efficient at 24,104 at 42 per cent of that in the UK.

When the carbon dioxide emissions associated with dairy production in the UK are compared to that in NZ, even when transport is included from NZ to the UK, the UK emits over two and a half times that of NZ. Thus, the UK emits 3,472 kilograms of carbon dioxide per tonne of milk solids compared to just 1,371 in NZ (including transport to the UK).

Table 5.1
Total energy and carbon dioxide indicators for NZ and UK dairy production

Item	**Quantity/hectare**		**Energy MJ/Tonne MS**		**CO_2 Emissions kg CO_2/Tonne MS**	
	NZ	UK	NZ	UK	NZ	UK
Direct						
Fuel use (L of Diesel) (including contracting)		245		12,397		807.1
Diesel (L) (including contracting)	57.3		2,990		205.4	
Petrol (L)	22.9		1,093		73.2	
Lubricants (L)	0.9		50		1.8	
Electricity use (kWh)	556.7	378	5,425	4,818	104.0	194.4
Direct sub total	**-**	**-**	**9,558**	**17,215**	**384.5**	**1,007.0**
Indirect						
Nitrogen (kg)	73.5	149	5,712	11,891	263.7	594.5
Phosphorus (kg)	58.8	14	1,055	248	63.3	15.0
Potassium (kg)	57.2	38	684	468	41.0	28.2
Sulphur (kg)	63.7		381		22.9	
Lime (kg)	294.9	175	212	130	151.7	93.0
Pesticides (kg ai)	0.8	1.8	299	666	17.9	39.9
Cleaning Chemicals (kg)	3.2	3.1	458	456	27.5	27.5
Animal remedies (e.g. drench, bloat aids) (kg)	0.5		64		3.8	
Other chemicals (kg)	1.3	1.6	193	216	11.6	13.0
Forage, Fodder and Bedding (kg grass silage)	397	4,954	662	9,122	38.5	529.1
Cereals/concentrate (kg of dry matter)	85	3,849	231	15,884	13.5	977.9
Grazing-off (ha)	0.2	-	413		24.8	
Aggregate (kg)	1,094		131		9.0	
Indirect sub total	**-**	**-**	**10,494**	**39,082**	**689.0**	**2317.8**
Capital						
Vehicles (kg)	4.7		368		29.4	
Implements (kg)	5.5		336		30.2	
Dairy shed (cups)	-		527	653	52.7	65.3
Other farm buildings (m^2)	0.3	-	185	544	18.5	81.8
Fences (m)	4.0	-	169		17.0	
Races (m)	1.2	0.4	110	1	7.6	0.1
Stock water supply (ha)	0.0		85		6.0	
Irrigation (ha)	0.0		120		3.7	
Effluent disposal system (m^3)			123		7.7	
Capital sub total	**-**	**-**	**2,023**	**1,199**	**172.8**	**147.2**
Total Production	**-**	**-**	**22,074**	**57,497**	**1,246.3**	**3,471.9**
Yield (kg Milk Solids)	**836**	**968**				
Shipping (NZ to UK) (17,840 km)	-	-	2,030		124.9	
Total Production Energy Input/Emissions	**-**	**-**	**24,104**	**57,497**	**1,371**	**3,472**

Chapter 6
Greenhouse Gas Emissions Associated with Dairy

This chapter calculates the total emissions associated with dairy production in NZ and the UK including those from methane and nitrous oxide. These can be expected to be significant and are an important issue especially in NZ where nearly half the total emissions come from the pastoral sector.

The three greenhouse gases considered in this analysis are carbon dioxide CO_2, methane CH_4 and nitrous oxide N_2O. Global Warming Potential for a 100 year time horizon (GWP_{100}) was calculated according to the GWP_{100} factors used by the IPCC in kilograms of carbon dioxide equivalent ($kgCO_2eq$), $CO_2 = 1$, $CH_4 = 21$, $N_2O = 310$.

The greenhouse warming potential has been calculated using the IPCC methodology and factors as described in the NZ and UK Greenhouse Gas Inventories (MfE, 2006; Baggott et al., 2007). The same methodology has been used for both the NZ and UK production systems in line with the Food Miles report to ensure that the comparisons are consistent. However, it must be stressed that there is still considerable uncertainty and consequently on-going research into determining accurate CH_4 and N_2O emission models and coefficients. Countries are developing their own emission factors and thus a mix of measured emissions and IPCC defaults are used.

All resource use and environmental impacts have been allocated to milk production to remain consistent with the original report. This is not always the case in other studies, for example, Cederberg and Mattsson (2000) allocated impacts between the co-products milk and meat at a rate of 85:15 using biological causality. This allocation rule (85:15) was also used in a NZ Dairy LCA study by Basset-Mens et al. (2005) and has been used for comparison purposes in parts of this report. However, allocating 100 per cent of the impacts to milk does not change the relative results between NZ and the UK.

Carbon dioxide is the only greenhouse gas considered from energy emissions with the energy based methane and nitrous oxide emissions excluded from this analysis. Their contribution is only very small, even once added they will only affect the overall result by less than 1 per cent. For example, CO_2 is 98 per cent of the greenhouse gas emissions from diesel and 92 per cent of NZ's electricity emissions. The UK liquid fuels will be similar, while they are likely to have a larger proportion of CH_4 and N_2O emissions in their electricity generation due to their larger proportion of thermal (coal and gas) powered generation.

6.1 New Zealand dairy

To determine the methane and nitrous oxide emissions it is necessary to use stocking rate and replacements rate for the herds. The NZ stocking rate used is 2.77 cows/ha (Wells, 2001). There are 0.54 replacement cows per hectare based on the MAF Waikato Model Farm having 58 replacement heifers for a 107 ha farm (MAF, 2006). Production is 836 kgMS/ha (Wells, 2001).

6.1.1 Methane

Methane emissions from enteric fermentation for dairy cows and cattle are 79.4 and 56.2 kgCH_4/head respectively (MfE, 2006 worksheet 4.1). Methane emissions from manure management for dairy cows and cattle are 0.889 and 0.909 kgCH_4/head respectively (Ibid). Total methane emissions are 248 kgCH_4/ha or 6.2 kgCO_2eq/kgMS.

6.1.2 Nitrous oxide

Nitrous oxide emissions are a combination of direct and indirect emissions from synthetic fertiliser and animal waste. Based on the application of 73 kgN/ha less the 10 per cent fraction emitted as NO_x and NH_3 equals 66 kgN/ha. The fraction of direct emissions from synthetic nitrogen fertiliser to soil (EF_1) is 0.01 (Ibid, Table 4.18). Direct emissions are 0.7 kgN_2O-N/ha which converts to 1.0 kgN_2O/ha or 0.385 kgCO_2eq/kgMS.

The nitrogen excreted (Nex) from dairy and non-dairy cattle is 117.0 and 72.5 kgN/head/yr (Ibid, worksheet 4.1). Based on the stocking rate and less the 20 per cent fraction emitted as NO_x and NH_3 this equals 259 kgN/ha and 31 kgN/ha excreted from dairy cows and replacements respectively. The direct emission factor (EF_3) from waste for dairy cows is 0.0096 being a combination of 95 per cent pasture, range and paddock (Ibid, worksheet 4.1) at 0.01 and 5 per cent anaerobic lagoons at 0.001 (Ibid, Table 4.18). Cattle have a direct emission factor of 0.01 being 100 per cent pasture, range and paddock. This equates to 4.4 kgN_2O/ha or 1.63 kgCO_2eq/kgMS.

Indirect N_2O emissions come from the atmospheric decomposition of the volatilised synthetic nitrogen fertiliser and animal waste. Of the 73 kgN fertiliser applied per hectare 7.3 kgN/ha (10 per cent) volatilises and of the 363 kgN/ha excreted 73 kgN/ha (20 per cent) volatilises. The indirect emissions from volatilising nitrogen is 0.01 (Ibid, Table 4.18) equalling 0.8 kgN_2O-N/ha or 1.3 kgN_2O/ha. On a carbon dioxide equivalent basis this is 390 kgCO_2eq/ha or 0.47 kgCO_2eq/kgMS.

A second source of indirect N_2O emissions comes from leaching. Of the 357 kgN/ha (fertiliser and animal waste less volatilised nitrogen) 7 per cent is lost through leaching and run-off (Ibid, Table 1.17) of this the indirect emission factor is 0.025 (Ibid, Table 4.18) equalling 0.62 kgN_2O-N/ha or 1.0 kgN_2O/ha. On a carbon dioxide equivalent basis this is 304 kgCO_2eq/ha or 0.36 kgCO_2eq/kgMS.

Therefore total nitrous oxide emissions are 7.7 kgN_2O/ha. On a carbon dioxide equivalent basis this is 2,375 kgCO_2eq/ha or 2.84 kgCO_2eq/kgMS.

The total greenhouse warming potential is 8,738 kgCO_2eq/ha (85 per cent allocation = 7,427) or 10.45 kgCO_2eq/kgMS (85 per cent = 8.88).

6.2 UK dairy

The UK stocking rate is 1.72 cows/ha with 0.57 replacements/ha based on Nix (2004), for each dairy cow a third of a replacement unit is required as used in the original report. Production is 6,665 litres of milk per cow (Colman et al., 2004) which is equal to 11,464 L milk/ha.

In the original Food Miles report the UK milk solids (MS), fat and protein, was assumed to be the same as NZ at 8.4 per cent. However, in response to comments from the UK, and the results of further analysis indicated that this may be an overestimate and therefore the lower figure of 7.1 per cent MS (fat, casein plus whey protein) is used here (www.milknet.sac.ac.uk/industry/moreaboutmilk.html). On this basis production is 814 kgMS/ha (originally it was 968 kg MS/ha).

6.2.1 Methane

Methane emissions from enteric fermentation for dairy cows and cattle are 103.5 and 48 $kgCH_4$/head respectively (Baggott et al., 2007 Table A3.6.2). Methane emissions from manure management for dairy cows and cattle are 25.4 and 6.0 $kgCH_4$/head respectively (Ibid). Total methane emissions are 253 $kgCH_4$/ha or 6.5 $kgCO_2$eq/kgMS.

6.2.2 Nitrous oxide

Nitrous oxide emissions are a combination of direct and indirect emissions from synthetic fertiliser and animal waste. Based on the application of 149 kgN/ha, less the 10 per cent fraction emitted as NO_x and NH_3, equals 134 kgN/ha. The fraction of direct emissions from synthetic nitrogen fertiliser to soil (EF_1) is 0.0125 (Ibid, page 337). Direct emissions are 1.7 kgN_2O-N/ha which converts to 2.6 kgN_2O/ha or 1.0 $kgCO_2$eq/kgMS.

The nitrogen excreted (Nex) from dairy and non-dairy cattle is 105.5 and 58.8 kgN/head/yr (Ibid, Table A3.6.6). Note these figures include the 20 per cent N volatilising as NOx and NH_3 to make them comparable to the NZ figures, whereas Table A3.6.6 excludes them. Based on the stocking rate and less the 20 per cent fraction emitted as NO_x and NH_3 this equals 145 kgN/ha and 27 kgN/ha excreted from dairy cows and replacements respectively. The direct emission factor (EF_3) from waste for dairy cows is 0.013 and other cattle is 0.017. Table 6.1 shows how these emission factors were determined. This equates to 3.7 kgN_2O/ha or 1.42 $kgCO_2$eq/kgMS.

Table 6.1
UK direct emissions from waste management

	Liquid system	Daily spread	Solid storage and dry lot	Pasture, range and paddock	Weighted average
EF_3 [1]	0.001	0.01 [2]	0.02	0.02	
Dairy [3]	30.60%	14.10%	9.80%	45.40%	0.013
Other Cattle > 1 yr [3]	6%	23%	20%	51%	0.017

[1] Ibid Table A3.6.9
[2] In the UK inventory this is shown as zero as it is later recorded under agricultural soils.
[3] Ibid Table A3.6.8

Indirect N_2O emissions come from the atmospheric decomposition of the volatilised synthetic nitrogen fertiliser and animal waste. Of the 149 kgN fertiliser applied per hectare 14.9 kgN/ha (10 per cent) volatilises and of the 215 kgN excreted 43 kgN/ha (20 per cent) volatilises. The indirect emissions (EF_4) from volatilising nitrogen is 0.01 (Ibid, page 340) equalling 0.6 kgN_2O-N/ha or 0.9 kgN_2O/ha. On a carbon dioxide equivalent basis this is 280 $kgCO_2eq$/ha or 0.35 $kgCO_2eq$/kgMS.

A second source of indirect N_2O emissions comes from leaching. Of the 320 kgN/ha (fertiliser and animal waste less volatilised nitrogen) 30 per cent is lost through leaching and run-off (Ibid, page 340) of this the indirect emission factor (EF_5) is 0.025 (Ibid, page 341) equalling 2.3 kgN_2O-N/ha or 3.6 kgN_2O/ha. On a carbon dioxide equivalent basis this is 1,120 $kgCO_2eq$/ha or 1.37 $kgCO_2eq$/kgMS.

Table 6.2
NZ and UK dairy greenhouse gas emissions

	GWP_{100} $kgCO_2eq$/ha		GWP_{100} $kgCO_2eq$/kgMS	
	NZ	UK	NZ	UK
CO_2				
Energy	1,145 [1]	2,825	1.37 [1]	3.47 [2]
CH_4				
Fermentation and manure mgmt	5,320	5,310	6.36	6.52
N_2O				
Direct emissions N fert. input to soil	320	815	0.39	1.00
Direct emissions N excretion to soil	1,360	1,150	1.63	1.42
Indirect emissions atm. decomposition fert. N and excretion	390	280	0.47	0.35
Indirect emissions leaching fert. N and excretion	305	1,120	0.36	1.38
Total (100% allocation to milk)	**8,840**	**11,505**	**10.58**	**14.13**
Total (85% allocation to milk)	**7,530** [3]	**9,775**	**9.01** [3]	**12.01**

[1] Landed at a UK port
[2] Adjusted from original report where it was 2.92 based on 8.4 per cent MS to 3.47 based on 7.1 per cent MS.
[3] Includes 100 per cent of shipping CO_2 emissions

Table 6.2 above, summaries the total emissions associated with dairy production in the UK and in NZ and the emissions from shipping dairy products from NZ to the UK. This shows that even when all emissions are included in the analysis the UK produces 34 per cent more greenhouse gas emissions than NZ per kgMS and 30 per cent more per hectare.[1]

[1] Feedback on the emission factors used in this report by Harry Clark, AgResearch NZ raised the issue around the NZ methane emission factors and Nex figures, and that these should be adjusted upwards by 10 per cent. Concern was also raised about different years used for production and emission calculations, adjusting these results in the production being increased by 4 per cent and nitrogen fertiliser use increased to 110kgN/ha. Incorporating these suggestions results in NZ emissions per kgMS increasing by 6 per cent.

Note that until countries agree on standard methodologies for estimating emissions, figures will remain highly disputed (Clark, H, (2007) per. comm.). Revised figures incorporating these changes are available on request.

Chapter 7
Conclusions

The earlier Food Miles research report addressed some of the spurious claims that the further food travels the worse it is for the environment by comparing the energy use and CO_2 emissions associated with a production system in NZ and that in an EU country. That report showed that dairy production NZ uses half the energy, even including the transport cost, than the UK.

This research report expanded that work by including greenhouse gas emissions from methane and nitrous oxide in the analysis for dairy. As in the original report the same methodology was used both for the UK and NZ. This found that even when all emissions are included in the analysis UK dairy produces 34 per cent more greenhouse gas emissions than NZ per kgMS and 30 per cent more per hectare.

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Appendix

Table A.1: Dairy Production system for the UK

	Outputs/inputs
Yield	6665 litres of milk 86.5 cows per farm 1.72 stocking rate
Fuel and Oil	£27 per cow
Electricity	220 kWh/cow or £11 per cow
Nitrogen fertiliser	149 kg per hectare
Phosphorus fertiliser	31 kg per hectare
Potassium	46 kg per hectare
Concentrate	2.238 tonnes per cow £241 per cow or £415 per hectare
Miscellaneous Variable Costs which include: Bedding Vet. and Med. A.I. and Bull Hire Recording,	 £38 per cow £23 per cow £12 per cow £30 per cow
Bought in fodder	£72 per cow
MCPA Herbicide	£5 per cow and £9 per hectare
Machinery Depreciation	Machinery costs £120 per cow or £205 per hectare (incl. forage machinery)
Contract	£60 per cow excl. forage
Buildings	£39 per cow or £67 per hectare

Source: Colman et al (2004) and Nix (2004)

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