Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry

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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

Food miles is currently a very topical issue which has the ability to affect our export trade. Food miles measures the distance food travels from producer to consumer. Food that has travelled long distances is perceived as being harmful to the environment and has some media attention in our key markets, especially in Europe. However, this report argues that it is not the distance that should be assessed but the total energy used, production to plate including transport. The results of this analysis show that NZ products compare favourably with lower energy and emissions per tonne of product delivered to the UK compared to other UK sources. In the case of dairy NZ is at least twice as efficient; and for sheep meat four times as efficient.

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

Executive Summary

- Food miles is a very simplistic concept relating to the distance food travels as a measure of its impact on the environment. As a concept food miles has gained some traction with the popular press and certain groups overseas. However, this debate – which only includes the distance food travels – is misleading as it does not consider total energy use, especially in the production of the product.

- The food mile concept has potential to threaten New Zealand exports given New Zealand's geographical location. The solution proposed by food miles campaigners is to source food from as close to where it will be finally consumed as possible. Thus as 50 per cent of NZ exports are in food and beverages, of which approximately a third go to EU markets, the potential risk is significant.

- This study looks at the environmental impact of some key New Zealand export products. The environmental impact calculations are 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. This is a much more valid comparison than just distance travelled as it reflects the differences in countries' production systems. These were then compared to the next best alternative source for the UK market. The products examined were dairy, apples, onions, and lamb.

- The analysis therefore first identified the farm production system in New Zealand and the relevant EU country which could be used as an alternative source of supply to the UK market. In general, data on production systems and energy use was much more comprehensive for New Zealand than for the alternative EU country. This has led to the New Zealand estimates of energy use and emission associated with production being more inclusive than those for the alternative EU country.

- **Comparison of energy used and CO_2 emissions between NZ and UK Dairy.** 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.

- **Comparison of energy used and CO_2 emissions between NZ and UK Lamb.** The energy used in producing lamb in the UK is four times higher than the energy used by NZ lamb producers, even after including the energy used in transporting NZ lamb to the UK. Thus, NZ CO_2 emissions are also considerably lower than those in the UK.

- **Comparison of energy used and CO_2 emissions between NZ and UK Apples.** NZ is also more energy efficient in producing and delivering apples to the UK market than the UK is. NZ energy costs for production are a third of those in the UK. Even when transport is added NZ energy costs are approximately 60 per cent of those in the UK. Consequentially the CO_2 emissions per tonne of apples produced are also higher in the UK than in NZ, reflecting the higher energy use but also the lower emissions from NZ electricity generation.

- **Comparison of energy used and CO_2 emissions between NZ and UK Onions.** The energy associated with onion production is higher in NZ compared with the UK. However, when storage is included for the UK, so they can supply the same market window as NZ can, the UK energy costs rise to 30 per cent higher than those in NZ, even accounting for transport.

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

Chapter 1
Introduction

‘Food miles’ is a relatively recent issue which has arisen in the United Kingdom, Germany and other countries over food transportation. A simple definition of this concept would be: ‘the number of miles (kilometres) a product has to be transported from the farmer/grower to various stages of production until it reaches the supermarket and finally the plate of the consumer’. It has been born out of concern for the environment, especially in regard to greenhouse gas emissions such as carbon dioxide and the global warming 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 air, 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.

In the EU and especially the UK (the country which this report focuses on) there are two types of concerns over this issue - intranational and international food miles. That is there are concerns about the number of food miles particular products clock up within the UK and also the miles travelled by imports to the UK, both within a country and in transport to the UK, especially those which are transported by air.

New Zealand has attracted a lot of attention in the food miles debate, for three main reasons. Firstly, due to its geographical location relative to the EU, New Zealand products imported by the EU have to travel a very long distance, making the apparent food miles high. The second reason is that the EU, especially the UK, have traditionally been important high value markets for NZ exports. Third, the similar climates of NZ and, in particular the UK, mean that the land is suitable for similar farming activities. This leads to the argument that the EU can substitute a significant proportion of what New Zealand exports to their country to a lesser or greater extent with home-grown produce. Apples are an example of a New Zealand export product to the UK which has been targeted, for the reasons mentioned (Women’s Environmental Network, 2004). The debate on food miles therefore represents a risk to New Zealand exporters, not only to apple growers (which exported $105.6m worth of produce to the UK in the June year 2004 – Statistics NZ (2004)), but to other industries such as dairy ($62.7m in exports to the UK over the same period (Statistics NZ, 2004) – this includes casein, but not butter, which is exported to Denmark and a proportion of this is packaged and re-exported to the United Kingdom (MDC Datum, 2005). However, Stroudgate (2002) report that in the 2000/2001 year New Zealand sold $159m worth of butter to the UK, while MDC Datum (2004) record the trade balance in butter as 22,993 tonnes in New Zealand’s favour in 2002.

New Zealand has greater production efficiency in many food commodities compared to the UK. For example New Zealand agriculture tends to apply less fertilisers (which require large amounts of energy to produce and cause significant CO_2 emissions) and animals are able to graze year round outside eating grass instead large quantities of brought-in feed such as concentrates. As Wells (2001) mentions, European dairy farms involve housing animals for extended periods of time. The fact that New Zealand farmers do not require subsidies to be internationally competitive, unlike their British counterparts, indicates these efficiencies of production in this country.

Thus, 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 everywhere it is produced, when there is strong evidence to show that this is an unjustified assumption.

In this study key New Zealand sectors will be evaluated concentrating upon those which export significant quantities to the UK, and compared to the next best alternative source for the UK market. The calculation of energy use will be based upon a life cycle assessment-type approach, however this will just cover the impact categories of energy use and CO_2 emissions and from production to plate.

This report presents first a review of the literature, this is in two parts: firstly the background and history to the food miles concept and descriptive reports which have been produced to provide the context for the debate. The second part reviews studies which include life cycle assessment as well as others which have assessed energy use associated with agriculture. The report then outlines the methodology used and then presents the results for the dairy, apple, onion and lamb sectors.

Chapter 2
History of the Food Miles Debate

One of the earliest reports on the 'food miles' debate was a 1994 report by the SAFE Alliance (now called Sustain: The Alliance for Better Food and Farming) – *Food Miles Report* (SAFE Alliance, 1994). Sustain (1999) wrote that:

> "… [it] for the first time, comprehensively illustrated the environmental and social implications of the rapid escalation in the distance that our food was travelling, 'from the plough to the plate'. It was widely reported on and created a whole spectrum of responses and actions by industry, government and the public. During the past 5 years the SAFE Alliance has continued to publicise the issue and give the public the opportunity to learn about what they can do to combat Food Miles …".

There are various aspects and arguments used in the 'food miles' debate. Some groups are simply concerned that food that could be produced in the UK is imported (causing unnecessary food miles, and also a loss of income to British farmers). Kirsty Righton of the Soil Association (a NGO) was quoted in the Guardian newspaper as saying: "It is environmentally wasteful and damaging to import food that could be easily grown here."[1]

Other arguments used to support the campaign against food miles include issues such as British consumers being too demanding in their choice of food – wanting food that is produced in the UK to be available even when it is out of season – necessitating the importation of it, when they could simply adjust their consumption habits according to season which would be better for the environment (Garnett, 2003). Other arguments include the concern that UK is able to import some food products cheaply because workers overseas are being exploited by poor wages and working conditions. The belief is that if these workers were treated fairly, the product would cost more. Another argument is against the extremely energy intensive practice of air freight, from which significant negative externalities arise, and this is sometimes related to the fact that in the UK aviation fuel is untaxed, compared to the extremely highly taxed petrol and diesel. A further argument appears to be against multi-lateral international trade, the concern being over why a product is imported when it is also being exported from the United Kingdom (e.g. in 1997, 126 million litres of liquid milk and 23,000 tonnes of milk power were imported and over the same period 270 million litres of liquid milk and 153,000 tonnes of milk powder were exported (Lucas and Hines, 2001)) – this is seen as unnecessary from a food miles point of view (unnecessary pollution and a waste of non-renewable fossil fuels, which are being depleted rapidly at current rates of consumption).

New Zealand, being on the other side of the world to the UK, has naturally attracted a significant amount of attention. For example, the food miles debate has included New Zealand apples which have been contrasted to British apples which supposedly grow well in the climate there (Women's Environmental Network, 2004), but the production of which had decreased considerably over the last 20-30 years in the UK due, among other reasons, to imports capturing an increasing share of the British market (Simons and Mason, 2003). While some varieties that are imported from New Zealand are not produced in the UK, British consumers are being encouraged by some food miles campaigners to only buy the local varieties, even though they may not be the preferred option. Consumers are encouraged to do

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[1] The Guardian: December 8, 2004, *You've come a long way, turkey.*

this because of the perceived environmental damage the transport of New Zealand apples to the UK causes. The Women's Environmental Network went as far as to say that importing apples from New Zealand is "insanity" (Women's Environmental Network, Undated). Simons and Mason (2003) however provide evidence that the CO_2 emissions from the production and storage of British apples are slightly greater than the production and transportation emissions of New Zealand apples imported to the UK.

A report by Sustain in 1999 expresses concern about what they call "cheap imports" which are replacing the "home-grown" variety, and imply that these are helping to erode the incomes of British farmers, while consumers are paying the same price at the supermarket and food miles are being increased unnecessarily. They also mention a survey which shows that farmers believe they would be better off by a return to farmers' markets, where farmers sell their produce direct to the public, thereby bypassing the supermarkets.

The Sustain report does however try to make it clear that their desire is not to attack all international trade, which they acknowledge could possibly threaten the livelihoods of farmers in developing countries but that "[o]ur principle target is the unnecessary transportation of food, and that can just as easily occur with food produced and consumed in this country as it can in international trade." However they qualify this by also reporting that international trade cannot be justified because it supports these people, since producers, the environment or both can be exploited by multinational companies involved in processing and retailing. Thus this report suggests a need for standards on ethical trade and supports initiatives by UK-based NGOs in developing the 'Fair Trade' symbol which is supposed to signify that farmers have received a fair price for the produce on sale.

This group continue to be prominent in the debate. As they note on their website in relation to the food miles issue:

> "Sustain is now represented in a range of government and agency programmes, such as the Countryside Agency's *Eat the View* and the Food Industry Sustainability strategy of the Department for Environment, Food and Rural Affairs (Defra). We are also working with the Defra Food Procurement Unit on the sustainable procurement initiative." (Sustain, 2005)

The Royal Society for the Protection of Birds is another NGO which has engaged in the food miles debate. They had this to say on their website:

> "Why are there apples from South Africa, France, New Zealand and the USA on the shelf [of our supermarkets] when the UK has a strong tradition of growing apples? What does it mean for global warming if lamb has been transported from the other side of the world to our shelves and yet lamb is produced locally only a few miles from the supermarket?" (Royal Society for the Protection of Birds, 2004a).

They advise people who care about birds, the countryside and who want to demonstrate this through the food they buy to:

1. Buy locally, and in particular directly from producers.
2. Buy British, which will reduce food miles and therefore the effects of food transport on global warming (Royal Society for the Protection of Birds, 2004b)

The Women's Environmental Network (2004) is another organisation, as mentioned above, which has reported on the food miles debate. They provide a longer list of strategies for the consumer to avoid food miles, when making purchases. Their "top five most ethical choices" are (in order):

1. Organic, Local, Seasonal
2. Local
3. Fairtrade and Organic
4. Organic
5. Fairtrade

In addition to these they advocate that consumers grow their own food, and join or start a food co-operative, and they have actively promoted farmers' markets with the Soil Association (Women's Environmental Network, Undated).

On the issue of international trade, the Women's Environmental Network (2004) suggest that the reason why some food that is ideally suited to the British climate is imported and flown long distances is because the cost of aviation fuel is artificially low since it is not taxed. They quote figures that in November 2000 the cost of a litre of petrol was 80p while a litre of aviation fuel was 18p. In addition to this they lament the fact that greenhouse gas emissions of air and sea freight are not included in international inventories, such as the Kyoto Protocol[2], of any country (Women's Environmental Network, 2004).

NGOs, such as those cited above, with an interest in the food miles debate have produced various types of information on the subject. However, little of this is rigorous and does not analyse total energy use.

Some farmer/producer groups, for example the National Association of Farmers' Markets, have been supportive of the food miles concept. This may be because it aids the marketing of their own produce. In addition to food miles, another argument which these groups employ in support of farmers' markets is an economic development one, that when locally produced food is consumed locally, local economies are stimulated, creating employment opportunities. (National Association of Farmers' Markets, Undated)

The food miles debate which was started by environmentally orientated NGOs, has gained enough traction for government departments and agencies to become involved such as Defra, the Advisory Committee on Consumer Products and the Environment, and the Sustainable Development Commission. Defra, which pursues sustainable development made this comment:

> "One possible indicator of environmental sustainability within the broader food chain is provided by food miles. The distance and mode by which food is transported is a significant element of energy use within the food chain as well as being associated with pollution from vehicle emissions." (Defra, Undated a)

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[2] The Kyoto Protocol on climate change which was signed in 1997 and ratified recently (February 2005), aims to reduce the greenhouse gas emissions of industrialised countries by 5.2 per cent below 1990 levels by 2012.

However Defra expressed some doubts about claims made over local food, such as it reduces food miles and that it is more environmentally friendly:

> "The evidence to support these claims is not conclusive. Delivering locally in small vehicles may not involve fewer food miles than longer but fewer trips with larger vehicles. In any case, reducing food miles may not always be the most environmentally preferable solution in terms of reducing overall energy consumption." (Defra, Undated b)

The UK is not the only EU country in which there have been developments in the food miles debate. The (German) Federal Ministry of Consumer Protection, Food and Agriculture has been pushing for EU legislation requiring food labelling, regarding the origin of the product. The following is an English translation of part of a report on their website after their minister Renate Künast attended the EU Agriculture and Fisheries Council meeting in Brussels (28 February 2005):

> "Supported by several other member states, Federal Minister Künast again called for a more comprehensive designation of origin on food products. More and more consumers wished to take the product's origin into account when they made their choice, to consider environmental and development aspects. For instance, consumers would be able to choose products that have only been transported a short distance to the market, or which come from developing countries. … Federal Minister Künast asked the Commission members to think about this matter and to present solutions for better information for consumers. Commissioner Kyprianou and Commissioner Fischer Boel agreed to carry out immediately an assessment of how the regulations on food labelling might be improved with regard to the designation of origin, especially for products with raw materials from countries other than those where they were processed."

At this meeting, the Italian, French, Irish, Finnish and Portuguese delegations supported the German assertion that the food labelling rules were inadequate (Council of the European Union, 2005).

Renate Künast has also been reported in the *Berliner Zeitung* (a German newspaper, 17 January 2005) as making negative comments about New Zealand apples (translated to English):

> "I find that these polished standardised apples don't really taste that much. … The fact is though: regional products have many advantages. They don't just taste better. They're healthier and more environmentally friendly. Therefore a far-travelling apple from New Zealand is not so great for climate protection, is it? Regional products also secure jobs."

The organisations surveyed above generally only consider the transport component of the energy costs and emissions of a product, but not the production component. In doing this they are effectively making the presupposition that the UK (or the relevant home country) can produce food products as efficiently as anyone else, which is not necessarily true.

In the UK, even among those charged with investigating the 'food miles' issue there is misunderstanding. For example in a report prepared by the Working Group on Local Food, commissioned by Defra, they state that: "Food miles are now a readily recognised concept and a useful shorthand term for the energy costs associated with food production and transport." (Working Group on Local Food, 2003). The error is that they claim 'food miles' measures the energy costs associated with *food production*, which is completely untrue. It only measures the energy costs of transport.

Fertiliser use is one example where there can be differences in food production. The NZ dairy industry uses much lower quantities of fertiliser than the British industry, per unit of production. The Millennium Ecosystem Assessment (2005) highlighted fertiliser use as a major problem arising from farming activities around the world. According to this report:

> "… the potential consequences [of the excessive use of fertilisers such as nitrogen and phosphorus] include eutrophication of coastal and freshwater ecosystems, which can lead to degraded habitat for fish and decreased quality of water for consumption by humans and livestock."

In addition to these effects, the production of such fertilisers is also energy intensive and causes significant emissions of greenhouse gases such as CO_2. These concerns get swept under the carpet when debate over the environmental friendliness of food focuses mainly on how far it has travelled until it reaches the plate of the consumer.

Barber (2004b) recognises that concerns over energy use in food production have been driven by desires to improve sustainability and profitability, but suspects that the greatest reason could be for local market protection. He argues that a reduction in production subsidies could result in environmental standards such as 'food miles' being used as a barrier to New Zealand exports and advises exporters from this country to produce energy use audits on their products, and to continually improve on their energy performance. The latter will enable New Zealand exporters to maintain a competitive advantage (over and above the transport costs in terms of money, energy use and greenhouse gas emissions) which will be needed to continue selling to European markets such as the UK.

Barber discusses the nature of this competitive advantage which New Zealand enjoys:

> "NZ's natural competitive advantage derived from the climate, the opposite season to the northern hemisphere and social factors like a low population density combine to make NZ's products competitive in overseas markets."

However, despite the attention the issue is receiving from groups such as those mentioned, there has been little research into the issue. Most of the work that has been going on has been in the form of the lobbying of various parties (e.g. government authorities and supermarkets) and public awareness campaigns, by NGOs with ideological and/or financial interests in the subject. The debate thus far has however been relatively incomplete in that much of the information used has not taken into account the production processes in each country and the total energy use. It is important therefore that the existing literature in the area is reviewed, in order to establish where there are gaps in information and analysis. The following section will review the literature on the topic.

Chapter 3
Literature Review

There are two major groups of literature relating to food miles: firstly, literature concerned solely with food miles itself, and secondly a group of literature relating to energy use/life cycle assessment. Both of these groups of literature will be discussed below.

Food Miles

As discussed in some detail in the background section of this report, a number of NGOs in the UK and Europe have become concerned about the food miles issue, and have published information and reports on websites and in pamphlets. However the academic literature on the topic is minimal.

Transport 2000, an organisation which is concerned with sustainable transport, explored the issue of food miles and in particular their role in generating climate changing emissions (Garnett, 2003). This report focuses a large part on food transport within the UK and the efficiency of various distribution networks, but does not neglect the transport associated with imported food. However it could be argued that the analysis of the latter is not as thorough as that of the former. Within the UK the author considers the possibility that the most locally sourced food may not be the most efficient in terms of CO2 emissions (advocating regional rather than local sourcing), but a similar possibility is not given the same consideration in regard to food sourced from outside the UK. In her analysis on the life cycle of a product Garnett does mention the possibility that imported food could emit less greenhouse gas than the locally produced variety, but does not explore it adequately. Instead she says that "… where it appears 'better' to source products from far away, it may be preferable still not to source that product at all" and suggests that British people eat more seasonally.

In the report Garnett shows using the example of New Zealand apples, that raw food miles are not completely adequate, even as a measure of transport emissions of greenhouse gases:

> "When it comes to imported apples, the mode of transport makes a big difference. The environmental impact of transport from New Zealand by sea is not dissimilar to that of transport from southern Europe by road, even though the distance is far greater."

Air freight is viewed as the most environmentally damaging form of food transportation. The Food Standards Agency (2004) claim that air transport is the "worst offender", producing between 40 and 200 times the CO_2 emissions of marine transport.

Despite this limitation the author says that:

> "… transport mileage is itself a good indicator, or benchmark, of high energy use elsewhere … there appears to be a correlation between growth in one area and growth in another. Food needs to be packaged more because it travels more. Food needs to be refrigerated more because it travels more. And so forth. Action to reduce food miles can be seen as compatible with other attempts to reduce the CO_2 intensiveness of our food."

However, this study does not include energy use and greenhouse gas emissions in the production phase of the product, just energy use in the packaging, marketing and delivery phase. Garnett does recognise this and she is aware of the arguments made by major retailers and manufacturers against food miles as a measure of the environmental impacts of food, including the fact that the whole life cycle of a product needs to be considered (which the project failed to do because of time and monetary limitations). She cites the example that the "… energy used to heat glasshouses for local crop production might outweigh the energy used to transport products from sunnier countries where no glass-housing has been required." Also "… growing conditions in the UK might need more intensive use of fertilisers and pesticides, whereas an equivalent product grown in more favourable agricultural circumstances might require fewer inputs."

The author however generally concludes and recommends that the concept of food miles is a legitimate one and that effort should be made to reduce these where possible by sourcing products regionally (although not necessarily locally, as transportation can become inefficient)[3] and for consumers to change their purchasing habits in favour of seasonally available local (UK) produce rather than demanding out of season produce which would need to be imported:

> "Fresh produce grown during its natural growing season and well adapted to UK growing conditions will be less transport intensive and produce fewer overall CO_2 emissions than non-indigenous foods or those imported out of season."

As stated above, since the analysis contained in the report only covers transport and transport related parts (e.g. refrigeration) of the life cycle of a food product, this assessment can be criticised, as seems to be recognised by the author with the following quote:

> " ... we would argue that from a transport perspective at least, a reduction in overseas imports is perhaps the most significant challenge we have to address and as such we should concentrate on this rather than on the final thirty miles or so."

Overall this study is a partial analysis of energy and environmental costs of production in that it fails to identify and highlight the key issues in the food miles debate: the total energy use in food supply. The author quotes a US study on the environmental costs of food transportation (Pirog et al., 2001) in which the contribution of transport to total food chain energy costs is about 11 per cent. This highlights the importance of not just using transport alone in determining how energy intensive and greenhouse gas polluting a certain product is.

An earlier, joint international report by the OECD and the International Energy Agency (OECD/IEA, 2001) provides some support for the views expressed in Garnett (2003), but in the context of goods in general rather than food specifically. The report notes the possibility of more local and regional sourcing of goods to reduce energy use. The authors suggest that in the case of long distance shipping, although the cost savings from more local sourcing of products may be minimal, the potential savings in energy use (which they say is closely linked with oil use and CO_2 emissions) are dramatic. However they too neglect the production part of the life cycle of a product, implicitly assuming that products can be produced equally energy efficiently everywhere, when this may not be the case. It also makes

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[3] At the moment the author notes the influence of a small number of large food retailers and manufacturers which are able to supply consumers with a large range of product year-round, by sourcing from around the world and the implication is that this is at the cost of a large number of food miles.

no allowance for the mix of energy used in the life cycle stages of the product, from sourcing of raw materials, to production and delivery of the product to the consumer. Some producers of the product may use more renewable energy such as electricity generated from hydroelectric sources or wind, than others who may use more fossil fuels like oil.

In 2000, a major project by a group of 24 farming, conservation, labour, animal welfare, health and sustainable development NGOs (including Sustain and Transport 2000) was established called *Race to the Top*, with some government funding from Defra. Two of its major aims were: "To benchmark and track the social, environmental and ethical performance of UK supermarkets …" and "To catalyse change towards a greener and fairer food system." (Fox and Vorley, 2004)

Of major relevance to the current study is the module of the environment and the issue of climate change in the Race to the Top project. The indicators for this were energy use and emissions of CO_2.

They attribute the problem of climate change and other environmental impacts, to the failure of markets:

> "The prices we pay for our goods and services generally do not reflect the full/true costs of their production and consumption. External costs (or externalities) - such as the contamination of ground water, soil erosion, traffic congestion, poor urban air quality, global climate change and so on - are imposed on the rest of society - not the company, individual or organisation responsible for them. The final sales price of a carton of orange juice, for example, does not include the wider costs to society that can be (but are not always) associated with its production, transportation, and storage prior to sale … If [these costs were effectively internalised] everything changes - costs, what is and what is not profitable and consequently, what is produced, how it is produced and how it is transported …" (Race to the Top, Undated)

In relation to climate changing emissions of carbon dioxide, they offer these suggestions:

> "There are numerous options open to companies (and individuals) to reduce their carbon footprint. These include efficiency savings, - using less fossil fuel derived energy in the first place (ie doing more with less). For supermarkets this could be achieved by reducing food miles for example through sourcing more goods and services locally, especially fresh fruit and vegetables when in season, and exploring ways to inform and encourage consumers to choose these products." (Race to the Top, Undated)

Significantly, the authors do not mention energy and emissions associated with the production side of food in the latter quote, although it is briefly noted (twice) in the former.

Safeway is a company which had made efforts to reduce the food miles used in the delivery of its products and operates a regional distribution centre (RDC). Charlie Pye-Smith of the *Race to the Top* project notes that:

> “Environmentalists have long argued that the local sourcing of food will do much to reduce food miles, and that the retailers' RDC system encourages the long-distance transport of food. [Nicola Ellen of Safeway] contests this. She argues that if all producers and suppliers were to deliver their wares directly to stores then there would be gridlock on nearby roads.” (Race to the Top, 2002)

Tara Garnett of the *Wise Moves* project comments:

> "There is no doubt that Safeway has been a leader when it comes to distribution, but it is important to distinguish between distribution and sourcing. Making distribution of food more efficient can yield some gains, but when seen in the context of the global food supply, they are almost negligible." (Race to the Top, 2002)

Therefore Garnett is arguing that imports and imported components of UK manufactured food pose a far greater problem than the distribution of domestically produced food, within the UK. This is consistent with her argument in the *Wise Moves* report that the greatest challenge in reducing food miles is to reduce imports.

The *Race to the Top* project was however aborted prematurely and ultimately unsuccessful as it did not get the support of enough of the major supermarkets to make the exercise of continuing it worthwhile.

Recently an article was published (Pretty et al., 2005) which assessed the full costs to the UK consumer (in financial terms) of a basket of major food commodities bought, including valuations of negative externalities (positive ones were not assessed) (i.e. environmental costs – 19 categories of these were looked at) in the process and subsidies. The authors attempt to split these costs into various components of a product’s life cycle, which include farm production, transport of food from the farm to the shop (or from overseas to the shop), shopping transport, and finally transport from the home to landfill.

For the production side of the basket of goods used, the authors compare the current UK farming system with a scenario whereby all UK farming was organic, to test what environmental savings could be made if such a conversion was made. For example pesticide costs arising from the contamination of drinking water and the effects of this on human health are assumed to be zero under the all-organic scenario. This scenario is estimated to lead to cost avoidances of £1.13 billion per year.

In linking UK food production to the levels of consumption, allowances are made for trade in the model, so that prices and externalities relate to what is actually consumed in the UK, rather than what is produced.

The environmental costs calculated for production (adjusted for trade) are added to the expenditure on the basket of goods per person in the UK. For the current farming system, these externalities amounted to an extra 3.27 per cent on top of the price, while for a totally organic system it was only 0.77 per cent extra (assuming the same basket of goods was bought). But this does not allow for the premium on organic food, which they claim at supermarkets is 53 per cent and for local box schemes is 31 per cent.

Next the transport costs of delivery to the retail outlets are added on. These are calculated in financial terms for various modes of transport according to the environmental, social and health costs they impose. Following this, the transport relating to shopping trips by consumers and the disposal phase are factored in. In addition to this, the subsidies paid by the government to farmers are included as a cost to consumers, minus the amounts given towards rural development and agri-environmental schemes.

Overall, it is interesting to note that the externality costs incurred by transport for imports amount to only a tiny figure (0.005p per person, per week) compared to the amount for domestic road transport (75.7p per person, per week), which presumably also incorporates the transport of imports within the UK. This in itself could be an argument against food miles being used to discriminate against imports (at current levels of trade). Furthermore agricultural externalities are calculated to be 81.2p per person, per week (which includes costs for imported products). There is considerable room for this figure to be reduced with the increased consumption of more efficiently produced food, which could arise from importing this from places like New Zealand.

In the paper they make an acknowledgement along these lines:

> "… if the overseas production systems were more environmentally-beneficial in comparison with domestic ones, then there may be a net environmental benefit [from importing food] (after transport costs were also accounted for)."

However in a table in which they evaluate different transport systems, there are additional costs incurred if all food was imported by ship. The most efficient transport system (the one with the least externalities in monetary terms) is the local food system, whereby all food is sourced within 20 km of a retail outlet. But this finding contradicts Garnett (2003), which concluded that regional, rather than local sourcing was most efficient (although this was only in terms of GHG emissions).

Also recently, a report commissioned by Defra on food miles was released (Smith et al., 2005). This set out to investigate whether a valid indicator of sustainability based on food miles could be developed. Included in this concept of sustainability are the economic, social as well as environmental impacts of food miles. The authors say that food miles have a complex relationship to sustainability and that there can be trade-offs between the economic, social and environmental components of this concept.

The verdict was that one single indictor could not be developed, but multiple ones were needed to model the complexity of the issue (e.g. the greenhouse gas emissions from different modes of transport are vastly different and cannot simply be lumped together in one indicator based on the distance food travels). A set of four key indicators were proposed:

1. Urban food kilometres in the UK, split by car, light goods vehicle (LGV), and heavy goods vehicle (HGV).

2. HGV food kilometres (in both the UK and other countries)

3. Air food kilometres

4. Total CO_2 emissions from food transport (in both the UK and other countries)

The authors make the following comment about these indicators:

> "These indicators focus on the direct impacts of food transport, such as congestion, accidents and pollution. Wider economic and social issues such as local sourcing of food are not addressed directly by this indicator set."

These indicators are collated for the years 1992, 1997 and 2002 to provide a picture of how the situation has changed over time. Most significant over this period was the change in air food kilometres which more than doubled over the 10-year period. It is proposed that these indicators are updated annually.

While the report focussed on the transport component of the life cycle of food, the authors recognise that the issue is also not as simple as just minimising food transport. They acknowledge the importance of the production phase of food and that if this is efficient, one product can be more sustainable environmentally than another which travels shorter distances:

> "The impact of food transport can be offset to some extent if food imported to an area has been produced more sustainable than the food available locally. For example, a case study showed that it can be more sustainable (at least in energy efficiency terms) to import tomatoes from Spain than to produce them in heated greenhouses in the UK outside the summer months. Another case study showed that it can be more sustainable to import organic food into the UK than to grow non-organic food in the UK."

They also make another valid point, which is related to this:

> "… moving to a lower food miles system has possible implications for transport efficiency and energy efficiency. If there is a growth in business for smaller producers and retailers, there could be an increase in energy consumption or congestion as smaller vehicles are used and economies of scale in production are lost."

However, in general they conclude that an increase in food miles is correlated with negative sustainability outcomes, thus making the concept of food miles indicators, as measures of this sustainability, valid in principle.

> "The case studies we investigated showed that, in general, the exceptions to the link between decreasing food miles and increasing sustainability are either marginal or can be accommodated through an appropriate indicator set."

Life Cycle Assessment

The studies reviewed in the previous section 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 later by the International Organization for Standardization (ISO) in the late 1990s and beyond. Currently it is part of the IS0 14040 series, which covers the principles, the analysis, interpretation and the reporting of the results, 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).

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 to 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, and 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.

Regarding gas emissions, only raw emissions appear to have been considered. There is no documentation that suggests any allowances for sequestration have been made e.g. vegetation removes (sequesters) a certain amount of CO_2 from the atmosphere. Any vegetation on a farm (e.g. pasture) performs this role.

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 4
Methodology

In order to provide an objective perspective on the food miles debate, which takes into account the environmental implications of the production and transport of goods, it is necessary to systematically identify and quantify the energy use and impact of both production and transport. This study will focus on a selection of New Zealand's exports of primary and manufactured food/beverage products to the European Union, and in particular the United Kingdom, one of New Zealand's most important export markets. The method of analysis will systematically identify and make an inventory of the various aspects of the production process and quantify the *environmental impacts* in an objective and internationally recognised form.

This report will apply the basic LCA-type approach of Wells (2001). Wells' approach initially involved defining the basic farm units for comparability between farms. He then analysed data from a survey of MAF monitored farms, applying energy and CO_2 emission coefficients to farm inputs in order to calculate total primary energy use and CO_2 emissions arising from these inputs.

This report will therefore use the methodology developed by Wells and apply this to data on NZ production systems and those of an alternative source of supply in the EU for the UK market, in order to compare the relative efficiencies of such operations in these countries. The approach used in this report will differ from Wells (2001) in a number of ways however. It will not include surveys, regional weighting, hypothesis testing or confidence intervals (especially for the UK/EU food industries). Further, the number of indicators which Wells constructed will not be included in this paper. The major extension to Wells' methodology will be the inclusion of a transport component in the analysis of environmental impacts. This will be applied after the product leaves the farm gate (i.e. the impacts from the food miles themselves), making this a cradle-to-plate, rather than a cradle-to-gate analysis. However only the transport distances necessary to export the product to the UK are included. 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.

Wells' Methodology

Wells' methodology will be applied in a two-stage process. The first stage involves collecting farm input data for New Zealand food production systems, applying energy use/CO_2 emission coefficients to these inputs and then summing them. The second stage involves doing the same for the corresponding UK/EU industries.

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.

The energy and carbon dioxide in the output of the farm (in the case of dairy for example, milk, with meat as a secondary output) is calculated based on the composition of the product, and the energy and carbon dioxide in each of its composites.

Details of inputs that could be included in the analysis are discussed below:

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 these inputs include transport to a factory and the processes used to manufacture the product into its final form including the packaging used, if this phase is appropriate (e.g. turning milk into cheese). These inputs also include transport from the factory to a ship (or to the airport) used to export the product, which is followed by the transport between New Zealand and the country of destination. Following this analysis of transport from the farm to the factory/ship there is the transport used to deliver the product from the ship (airport) to a warehouse, and then from the warehouse to a supermarket/shop and finally the transport by the consumer from their house to the supermarket and back. The disposal and waste management phase of the product can also be considered, but it is unlikely that it would be relevant to the current study, since both New Zealand and EU - produced food of the same type would follow the same waste process, assuming either no packaging, or identical packaging (such an assumption would usually be reasonable in the absence of contrary evidence). Normally the inputs used to feed workers at various stages in the process are not included within the boundaries of such a study, but potentially they could be.

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. This is not a simple exercise for some of the impact categories, such as the amount of CO_2 gas emitted into the atmosphere. Vegetation (e.g. grass and crops) sequesters a certain quantity of CO_2 from the atmosphere, and this must be taken into consideration and subtracted from the raw quantity emitted to arrive at the net GHG emissions for the product.

When the energy embodied in the inputs of the production process are summed and calculated per unit of output then the total energy use can be assessed. This can be used to help make efficiency improvements in the desired categories. For example the consumption of some non-renewable fuel could be replaced by something that employs more renewable energy such as hydro-electric power. A more efficient way of applying fertilisers may be found, involving smaller quantities. Or a more economical/efficient transport system/route could be employed. However, of more relevance to this study, the calculations allow comparisons with similar systems outside the ones immediately being studied. An example of this would be the same industry in a different country, and this is one of the primary motivations for this research paper. That is, how New Zealand produce exported to the EU compares with similar products produced in the EU in terms of certain environmental impact categories.

However in this paper the full life cycle of each product will not be analysed. Instead of being cradle-to-grave, this analysis employs a cradle-to-plate approach which omits the disposal and waste management phase of the life cycle. As alluded to above, this phase is not considered to be relevant, since competing products consumed in the same location will go through the same disposal and waste management process. Further, New Zealand producers have little or no control over this part of the life cycle (except for the packaging used), in order to improve the environmental performance of their product.

Also, as mentioned earlier, it is not possible given data amiability to include all of the transport costs of a product once it leaves the farm gate will be included in this analysis. Only the transport distances necessary to export the product to the UK are included. 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.

Data will be collected for New Zealand through a combination of recent industry studies (e.g. Barber (2004a) for onions), field work, databases and farm management knowledge. Where the data for some industries is incomplete, such as the apple and onion industries, a preliminary set of indicators will be determined through an activities based methodology and validated by discussions with growers about their actual inputs. The methodology used in all the recent industry studies has followed that developed by Wells (2001), with the incorporation of more recent energy coefficients where these may have changed. Likewise the activity based approach will use the same methodology but differs only in the way the raw data is collected.

In addition to these inputs, the shipping allowance discussed above, will be factored in to transport a tonne or kilogram of each product to the UK. An inventory will be constructed from the inputs involved in shipping with the corresponding energy/CO_2 emission coefficients attached. The inputs will then be multiplied by these coefficients to arrive at the input energy use/emissions and finally these will all be summed to arrive at totals.

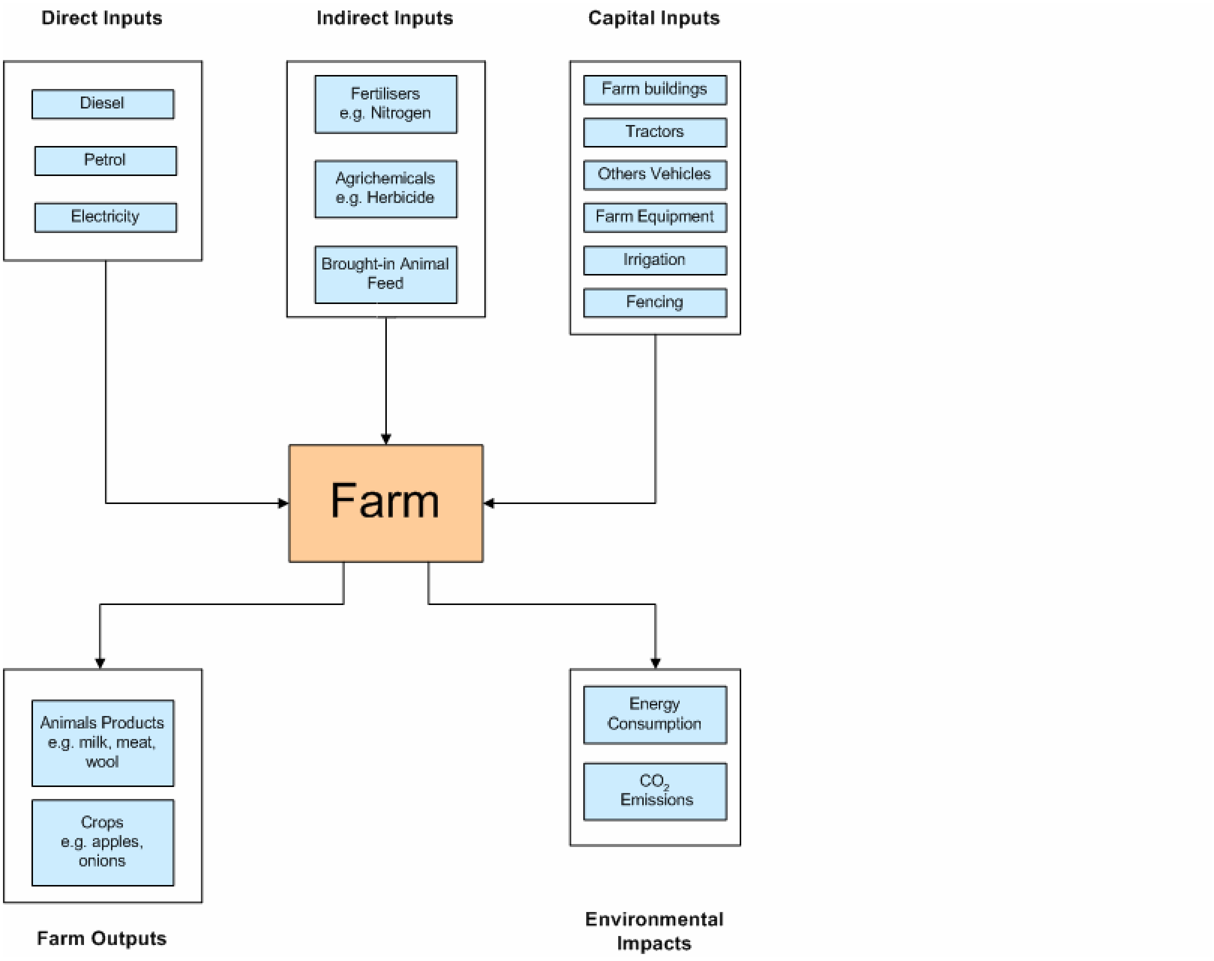
For the UK/EU products, data on farm inputs necessary to construct the inventories will be obtained using secondary data, mainly from statistics on UK/EU farm production including sources on farm management practices such as Nix (2004). Relevant published studies will also be consulted, but when statistics from these are used, care will be taken to ensure that the methodology is consistent with the approach taken in this report. However these statistics on UK/EU farm production do not in most cases to provide all of the information necessary to complete these inventories. To solve this problem a ‘bounds’ approach is employed, whereby lower bounds of the energy use and CO_2 emissions are attained based on the available data, while recognising that if the full data were available, the final levels would have been higher. If New Zealand has a significant efficiency advantage for a particular product this would in most cases still be sufficient to show that the New Zealand produced food is more environmentally friendly, in terms of these two impact categories (i.e. if the lower bound on the UK/EU product produces impacts greater than the total process for the New Zealand product). Usually the missing items from the input inventories will represent only a small proportion of the total energy use and CO_2 emissions of the system in question.

When the EU product supplied to the UK is not sourced domestically within the UK (i.e. it is imported), the energy use/CO_2 emissions from the transport distance to the UK will also be calculated, based on the most likely transport method and route.

The transport component of the analysis is calculated firstly by obtaining shipping distances and secondly obtaining energy use and carbon dioxide emission coefficients associated with transport per tonne km. These coefficients are then applied to the transport distances to arrive at the total energy consumption and carbon dioxide emissions for each mode of transport.

To summarise this methodology, a simplified flow chart representation of these inputs and the farm outputs, including environmental impacts, but excluding the transport occurring outside the farm gate is shown in figure 4.1.

Figure 4.1
Farm inputs and outputs



The inventory required to analyse the inputs into the production of the foods in this report is given in Table 4.1. This is a generic version of the items Wells includes, with the addition of a transport section.

In practice often there was only be a single representative (or hypothetical) farm based on available data from the country therefore not all the components can be calculated.

Table 4.1
'Generic inventory'

Direct	Diesel (L)
	Petrol (L)
	Lubricants (L)
	Electricity (kWh)
Indirect	Fertilisers
	Nitrogen (kg)
	Phosphate (kg)
	Potassium (kg)
	Sulphur (kg)
	Lime (kg)
	Dolomite (kg)
	Agri-chemicals
	Herbicide (kg)
	Fungicide (kg)
	Insecticide (kg)
	Plant Growth Regulator (kg)
	Acids and alkalis (kg)
	Animal supplements (e.g. magnesium, zinc) (kg)
	Animal remedies (e.g. drench, bloat aids) (kg)
	Other chemicals (kg)
	Other chemicals (kg)
	Seed (kg)
	Brought-in animal feed supplements (where applicable)
	Grass silage (tonne of dry matter)
	Maize silage (tonne of dry matter)
	Hay (tonne of dry matter)
	Cereals/concentrate (tonne of dry matter)
	Grazing-off (ha)
	Aggregate (kg)
Capital	Farm buildings (m^2)
	Self propelled vehicles
	Tractors (kg)
	Heavy trucks (kg)
	Light trucks/utilities (kg)
	Motor bikes (kg)
	Machinery (kg)
	Fences (m)
	Races (m)
	Stock water supply (ha)
	Irrigation
	Border strip (ha)
	Spray irrigation (ha)
	Drainage (m or ha)
	Effluent disposal system (m^3)
Transport to United Kingdom	Shipping
	Road transport

Chapter 5
Energy Analysis for Key NZ Exports to the UK/EU

The methodology described above is applied to the chosen New Zealand exports and the competing UK/EU products. The resource use and environmental impacts of each will be quantified and a decision will be made as to whether the UK/EU or New Zealand export varieties of the different products are more efficient from an environmental point of view.

The products chosen which will be analysed in the study are: dairy, sheep meat, apples and onions. The report concentrates upon the UK due to this being the major market for NZ exports and the EU country where food miles issues has a high profile. The total energy use and carbon dioxide emissions for NZ products will be calculated where possible from recent industry studies. However, to calculate the energy use for the alternative source of supply than NZ into the UK market requires firstly an assessment of the alternative source of supply. In the case of dairy products, sheep meat, apples and onions this is clearly the UK itself.

NZ Trade

The EU as a whole is an important export market for NZ products, particularly sheepmeat and apples, as illustrated in below.

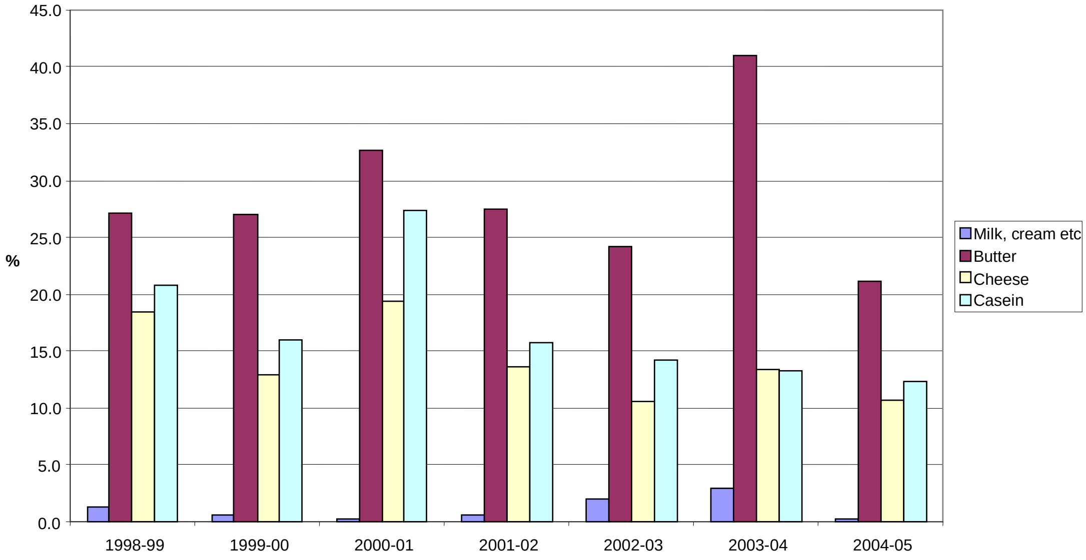
Figure 5.1
Value of NZ exports to EU as percentage of total NZ experts

Source: GTI (2005): World Trade Atlas 2005, Statistics NZ (2005)

Figure 5.1 shows the proportion of the value of NZ's total exports for sheepmeat and apples that go to the EU, since 1998/9. It can be seen that sheepmeat accounted for 66 per cent of total export value in 2004/5 year, while 57 per cent of the export earnings from apples were obtained from the EU in 2004/5. The EU is a significant export market for onions taking, in 2002/3, 32.5 per cent of total onion export earnings.

Dairy products are also significant, as illustrated in Figure 5.2, with the value of butter exports to the EU at 21 per cent of the value of total butter exports in 2004/5 (and this does vary, as can be seen in the figure). The value of cheese and casein exports to the EU are a slightly lower percentage of their total export value, at 10 and 12 per cent respectively in 2004/5.

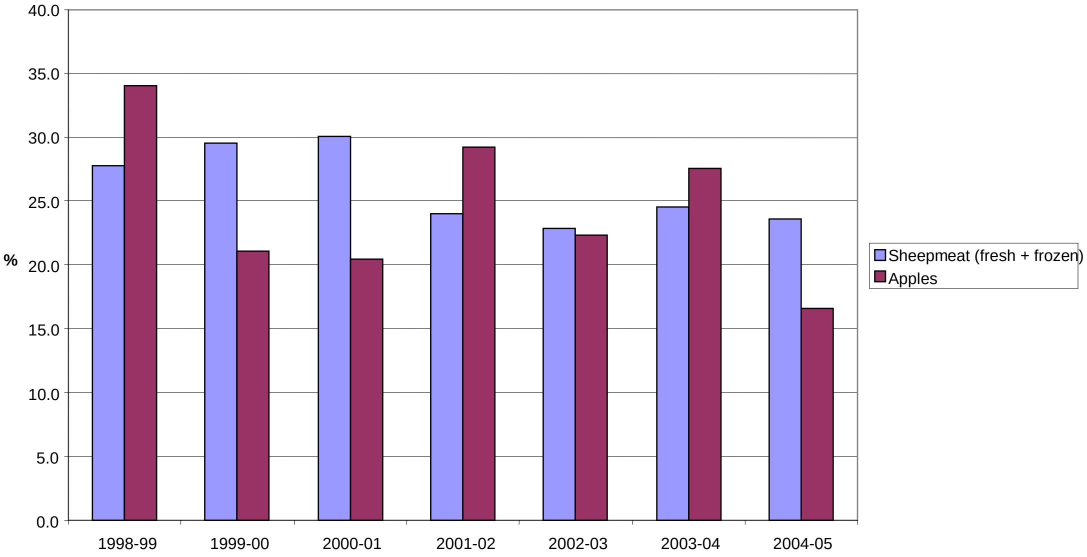
Figure 5.2
Value of exports to EU as percentage of total exports – dairy products



Source: GTI (2005): World Trade Atlas 2005, Statistics NZ (2005)

Within the EU, the UK is a particularly significant market for NZ. Figure 5.3 illustrates the value of exports of sheepmeat and apples to the UK in terms of their proportion of total exports from NZ. Nearly 24 per cent of the value of NZ's total exports of sheepmeat are gained in the UK market. The value of apple exports to the UK is also high, with 16.6 per cent of NZ's export earnings from apples coming from the UK in 2004/5. The UK is clearly an important market for NZ. However, NZ is an important source of supply for the UK filling their demands out of their own season.

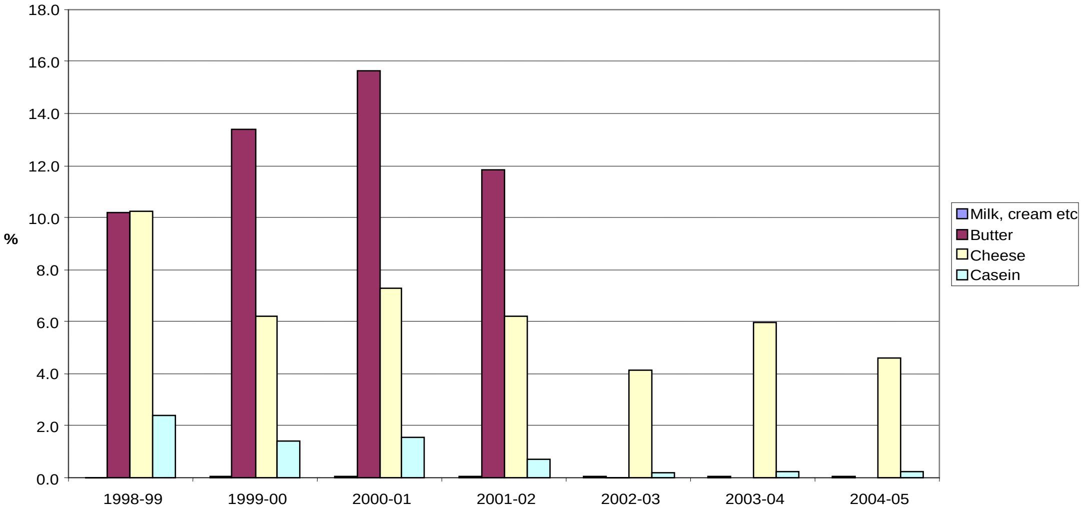
Figure 5.3
NZ exports to UK as a percentage of total value of exports



Source: GTI (2005): World Trade Atlas 2005, Statistics NZ (2005)

As with the EU, the UK is also a major market for NZ dairy products, accounting for 15.7 per cent of butter earnings and 7.3 per cent of cheese earnings in 2000/1, although these values have declined in 2004/5, as shown in Figure 5.4. These values are also slightly misleading, as a considerable quantity of dairy products from NZ are imported to the EU and then re-exported within the EU.

Figure 5.4
NZ dairy exports to UK as percentage of total dairy export value

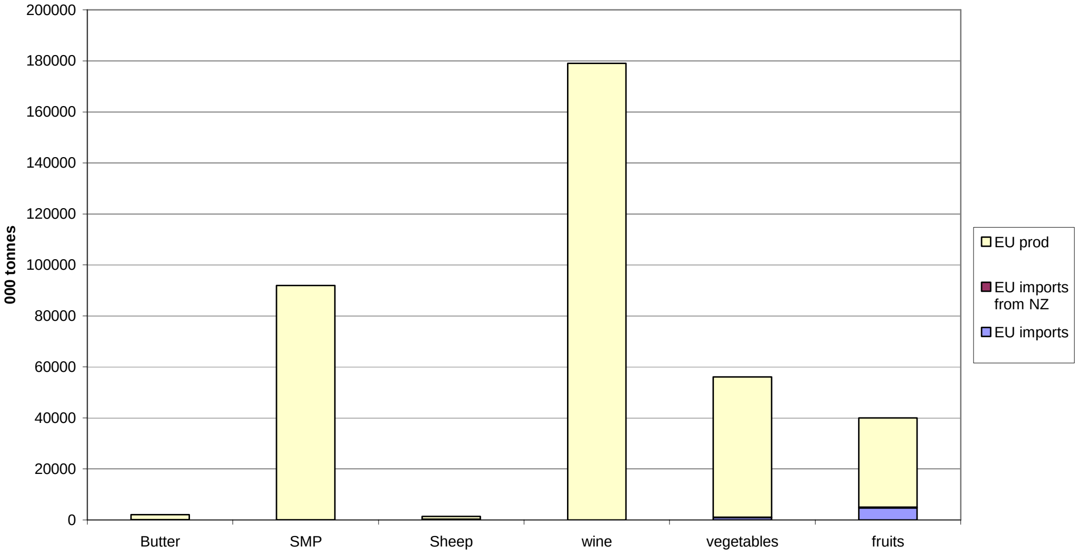


Source: GTI (2005): World Trade Atlas 2005, Statistics NZ (2005)

In terms of the EU as a whole, NZ is an important source of sheepmeat and butter in particular. Figure 5.5 shows the sources of selected agricultural commodities in the EU in volume in 2002, including their own production, total imports, and imports from NZ. Although EU production does dominate their supply, Figure 5.6 illustrates the percentages of the various components, with NZ imports of butter contributing 4.2 per cent of the EU's total butter supply, and sheepmeat nearly 17 per cent. Within the EU's total imports, 79 per cent of sheepmeat imports originate from NZ, while over 72 per cent of the EU's butter imports are from NZ.

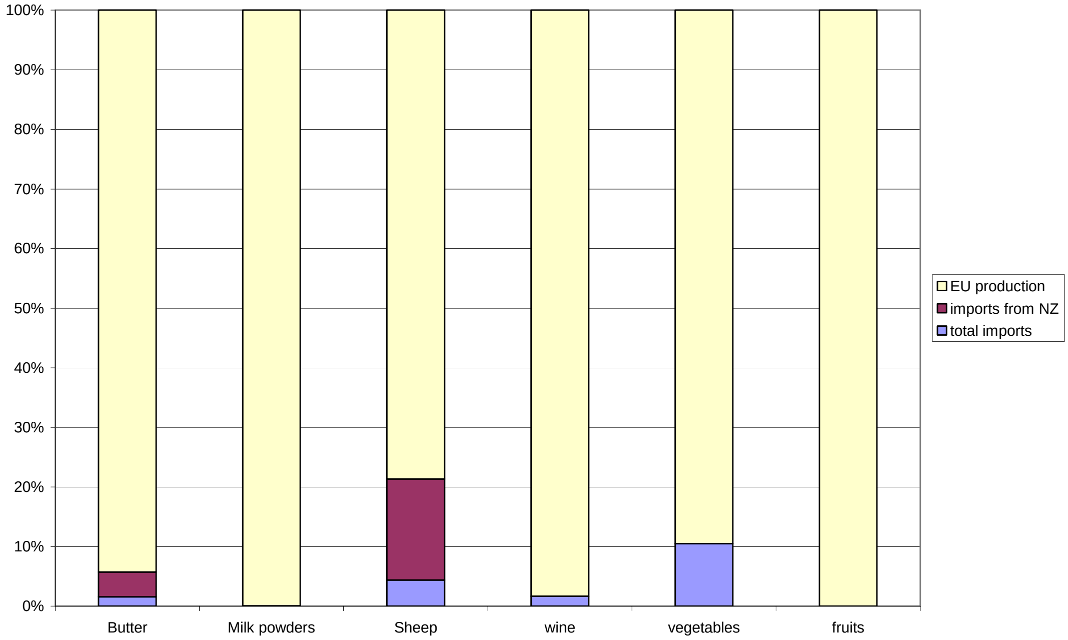
NZ milk and milk products (not including butter and cheese) are also an important source for the EU, at 31 per cent of total milk and milk product imports. Although data for apples individually was not available at this level, NZ vegetables as a whole contributed to 12 per cent of EU vegetable imports in 2002, while NZ fruits made up nearly seven per cent of EU fruit imports.

Figure 5.5
Components of EU total supply of selected agricultural commodities in 2002(thousand tonnes)



Source: Europa (2005)

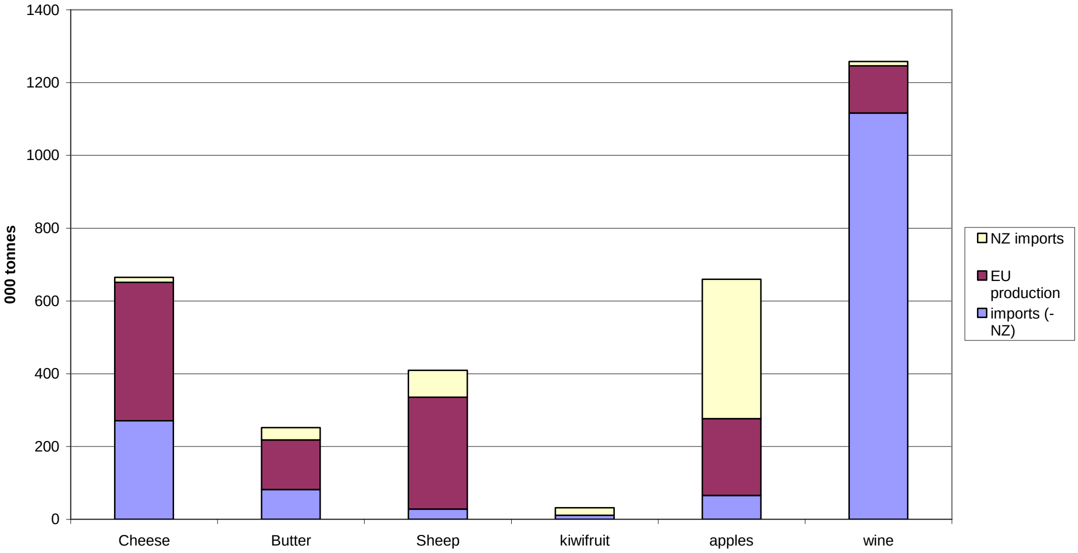
Figure 5.6
Components of total EU supply of selected commodities in 2002 (%)



Source: Europa (2005)

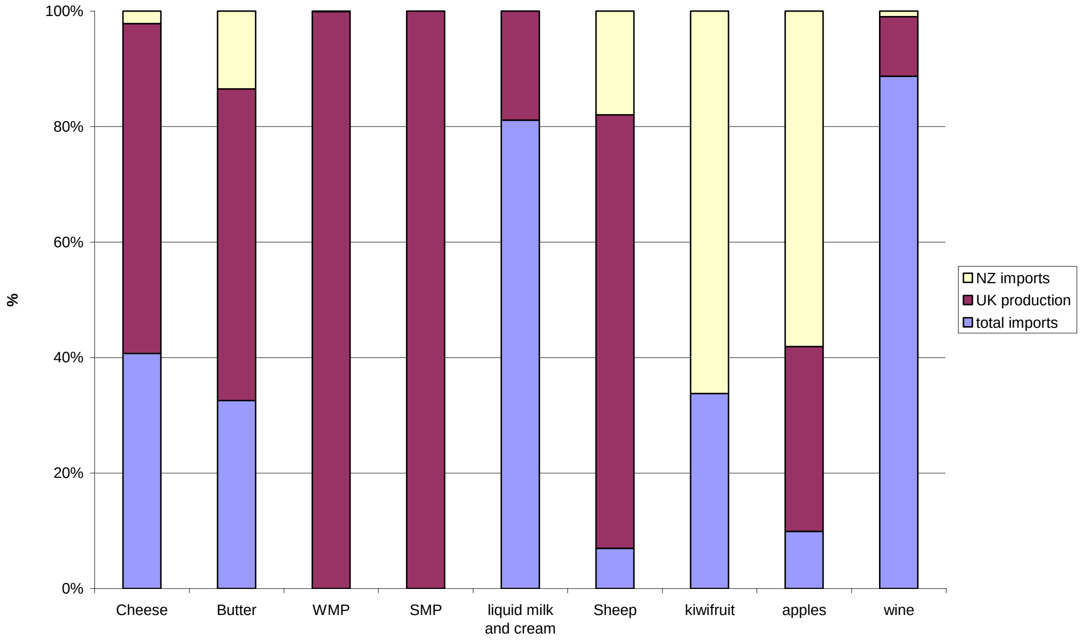
The UK is the main importer of NZ products in the EU. Figure 5.7 shows the components of the UK's total supply of selected agricultural products in 2002, in volume, including their own production, and Figure 5.8 shows the same data in percentages.

Figure 5.7
Components of UK total supply of selected agricultural commodities in 2002 (thousand tonnes)



Source: GTI: World Trade Atlas (2005), Statistics NZ (2005), MDC Datum (2004), Defra (2005a).

Figure 5.8
Components of UK total supply of selected agricultural commodities in 2002 (%)



Source: GTI: World Trade Atlas (2005), Statistics NZ (2005), MDC Datum (2004), Defra (2005a).

It can be seen from these graphs that NZ is a particularly predominant source of apples at 58 per cent of total supply respectively. Imports of NZ sheepmeat made up nearly 18 per cent of the UK's total supply of sheepmeat in 2002, while NZ butter contributed 13.5 per cent. Furthermore, of the UK's total imports, NZ apples make up over 85 per cent of the volume. Seventy two per cent of the total UK imports of sheepmeat originated from NZ in 2002. The predominance of NZ as a source of imports for the UK suggests that the UK would find it difficult to replace NZ as a source.

Chapter 6
Energy and Emissions Associated with Key Inputs in Agriculture

Energy Component of Key Inputs into Agricultural Production

In agricultural production there are a number of inputs which are common across the systems. This section therefore calculates the energy component and CO_2 emissions associated with these common inputs and the values are then applied in later sections when estimating the energy and CO_2 emissions associated with agricultural output.

These inputs are divided, as stated in the methodology section above into direct, indirect and capital inputs. Frequently the energy component of these inputs is readily available from secondary sources. However, in some cases detailed analysis is required to obtain the energy component as described below (e.g. concentrate).

Direct Energy Inputs

Direct energy is that energy used directly by the operation and is most easily recognised as energy e.g. diesel, petrol and electricity. The primary definition of direct energy includes the energy contained in the fuel/electricity (consumer energy), plus the energy costs of extracting, processing, refining and supplying (e.g. transportation for diesel) the fuel, and losses which occur through the process.

Fuel, Electricity and Oil

The consumer energy content of diesel, petrol and lubricants is readily available from a number of sources and its value is relatively uncontroversial, this is 35.4, 32.4 and 38.5 MJ/L respectively, (MED, 2002a). In NZ the primary energy content, which includes an allowance for the fuels production and delivery, adds an extra 23 per cent for all these types (Wells, 2001). This makes the total primary energy content for diesel, petrol and lubricants 43.6, 39.9 and 47.4 MJ/L respectively. These figures are summarised in Table 6.1.

Table 6.1
Consumer and primary energy content of direct inputs

Description	Consumer Energy (MJ)		Primary Energy (MJ)	
	NZ	UK	NZ	UK
Diesel (per litre)	35.4	35.4	43.6	41.2
Petrol (per litre)	32.4	32.4	39.9	37.7
Oil – Lubricant (per litre)	38.5	38.5	47.4	44.8
Electricity (per kWh)	3.6	3.6	8.14	10.37

While we assumed that the consumer energy content of fuel was the same in different countries, the primary energy content varies. UK's lower primary energy content is mainly due to the shorter distance that crude oil is transported from the Middle East. Table 6.2 shows how the primary energy of content diesel is determined for NZ and the UK.

Table 6.2
Primary energy content of diesel in NZ and the UK

	NZ Diesel		UK Diesel	
	MJ/l	% of consumer energy	MJ/l	% of consumer energy
Consumer energy content	35.4	100	35.4	100
Production	1.9	5.3	1.9	5.3
Shipping	4.3	12.1	1.4	3.9
Refining/distribution	2.0	5.6	2.5	7.1
Total	**43.6**	**123.0**	**41.2**	**116.3**

NZ being 15,000 km from the Middle East results in an additional 6.5 MJ/kg energy content of diesel. Based on importing 213.3 petajoules (PJ) of crude oil in 2000 (MED, 2002a) this added 12.1 per cent to every megajoule (MJ) consumed, or 4.3 MJ/L diesel. In the UK shipping adds 2.6 MJ/kg based on a distance of 6,000 km. In 2004 the UK imported 2,856[4] PJ of crude oil this added 3.9 per cent to every MJ consumed, or 1.4 MJ/L diesel.

Crude oil refining, own use and losses in NZ consumed 10.2 PJ (MED, 2002a). Divided by 226 PJ of oil consumption plus 9.2 PJ of refined exports less 54 PJ of already refined imports added 5.6 per cent or 2.0 MJ/L. In the UK refining and distribution losses add 7.1 per cent or 2.5 MJ/L. This was from 275 PJ of refining and distribution energy divided by consumer energy of 3,406 PJ plus 1,376 PJ of refined exports less 886 PJ of imported refined oil.

Production was assumed to be the same in NZ and the UK, and the difference between NZ's extra 23 per cent and the UK's 16 per cent is in shipping and refining.

In 2000 NZ electricity generation used 277 PJ of energy, of which 122 PJ was converted into useable electricity for the consumer (MED, 2002a). Conversion losses in generation accounted for 140 PJ and transmission losses were 12 PJ. For each kilowatt hour (kWh), or megajoule (MJ), of electricity consumed it takes 2.26 kWh (277/122) to produce. Therefore the primary energy content of electricity in NZ is 8.14 MJ/kWh (2.26 x 3.6 MJ/kWh).

In 2004 UK electricity generation used 3,528 PJ (84.3 Mtoe), of which 1,224 PJ (29.2 Mtoe) was converted into useable electricity for the consumer (Department of Trade and Industry, 2005b). Conversion losses in generation accounted for 2,103 PJ and transmission losses were 213 PJ. For each kilowatt hour of electricity consumed it takes 2.88 kWh (3,528/1,224) to produce. Therefore the primary energy content of electricity in the UK is 10.37 MJ/kWh (2.88 x 3.6 MJ/kWh).

Carbon dioxide is released when carbon is oxidised during the burning process of fuels. These emissions are primarily dependent on the carbon content of the fuel. Due to the molecular weight ratio of carbon dioxide to carbon (44:12), multiplying the weight of carbon by 3.6667 gives the quantity of carbon dioxide emitted when the carbon is oxidised. The quantity of carbon dioxide emitted from NZ diesel, petrol and oil is 68.7, 66.6, and 72.5 gCO_2/MJ (Baines, 1993). It was assumed that the fugitive emissions components were all

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[4] Converted from 68,214 thousand tonnes of oil equivalents (toe). One thousand toe = 0.04187 PJ

diesel, at a rate of 68.7 gCO_2/MJ, which alters the petrol and oil emissions on a primary energy basis slightly. It is assumed that 50 per cent of the oils carbon dioxide is emitted (Wells, 2001). The emission rates are shown in Table 6.3.

The carbon dioxide released during electricity generation comes from the mix of fuels used. In the UK 72 per cent of the energy required for generating electricity comes from coal and gas reserves. By contrast in NZ coal and gas contribute just 36 per cent, while renewable hydro energy is 32 per cent. Also note that due to large losses when converting fossil fuel to electricity, of the electricity generated in NZ 64 per cent comes from hydro.

Table 6.3
Carbon dioxide emissions rates of direct inputs

Description	**CO_2 Emission Rate g CO_2/MJ of Primary Energy**	
	NZ	UK
Diesel	68.7 [a]	65.1 [c]
Petrol	67.0 [a]	61.3 [c]
Oil – Lubricant	35.9 [a]	33.2 [c]
Electricity	19.2 [b]	41.5 [c]

Source:
[a] Baines (1993). Adjusted to include fugitive emissions. See description above.
[b] MED (2002b)
[c] Defra http://www.defra.gov.uk/environment/business/envrp/gas/05.htm

Contracting Fuel Use

Some of the farm budgets used to derive energy inputs had expenditure on contractors for such operations as mowing and cultivation, which could not be broken down further to either a quantity or monetary amount. To determine the fuel used by these contractors in such cases it was necessary to calculate what proportion of their cost was attributable to fuel. Two scenarios were investigated and both had similar results:

> Scenario 1: a contract mower using a 50 hp tractor charges approximately $60/hr. Based on a 50 hp tractor using 10.3 L/hr and a fuel cost of $0.70/L ($7.21/hr), fuel accounts for 12.0 per cent of the contract rate.
>
> Scenario 2: a contractor using a 100 hp tractor for ploughing charges approximately $110/hr. At a fuel use rate of 18.0 L/hr ($12.60/hr), fuel accounts for 11.5 per cent of the contract rate.

While fuel prices can fluctuate and affect the proportion of a contractor's costs, the contractor would be expected to increase their own rate, thereby keeping the proportions largely the same. For the purposes of this study a value of 12 per cent was assumed and this is then converted to a diesel equivalent and added to the diesel total.

Indirect Energy Inputs

Indirect inputs used in agricultural production include fertilisers, agrichemicals and different types of supplied animal feed (in livestock operations). For the first two categories secondary data was available on their energy component and emission profile and thus they are assessed in the same way as for the direct inputs, excepting for the fact that the energy contained in the product itself is not included in their assumed energy coefficients. The coefficients for the types of animal feed were arrived at by performing separate LCA-type analyses which include their individual direct, indirect and capital inputs.

Fertiliser

Fertiliser is the most significant indirect energy input, in particular nitrogen fertiliser (N), because of its high use (especially in the UK) and high energy use in its manufacture. However, other fertilisers are significant as well and thus energy components are also calculated for phosphorous (P), potassium (K), sulphur (S) and lime.

The energy component in fertiliser comes mainly from its manufacture and transport. The CO_2 emissions come from fuel use but also its interaction with the soil, for example, over 90 per cent of the carbon dioxide emissions from lime are in reaction with the soil.

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.

Table 6.4 shows the energy costs of manufacturing each component (Wells, 2001), and the associated CO_2 emissions. Clearly there are a range of different fertiliser production methods however these data are an average of these in absence of more detailed information.

Table 6.4
Energy requirement to manufacture fertiliser components
and the associated CO_2 emissions

Component	Energy Use (MJ/kg)	Emission Rate (kg CO_2/MJ)
N	65	0.05
P	15	0.06
K	10	0.06
S	5	0.06
Lime	0.6	0.72

Source: Wells (2001)

Sometimes the data obtained for the phosphorus (P) and potassium (K) - type fertilisers is not specified in quantities of these chemicals. It is instead specified in terms of P_2O_5 and K_2O respectively, and therefore the quantities of P and K need to be extracted. This is carried out based on the molecular weight of these chemicals - phosphorus has a molecular weight of 30.97, O a weight of 16.0 and K a weight of 39.1.

The total weight of P_2O_5 is: 2*30.97 + 5*16.0 = 141.94

The phosphorus proportion of this is: 2*30.97/141.94 = 0.436
Similarly, the total weight of K_2O is: 2*39.1 + 16.0 = 94.2

The potassium proportion of this is: 2*39.1/94.2 = 0.830

These two proportions are multiplied by the quantities of P_2O_5 and K_2O to obtain the quantities of phosphorus and potassium applied respectively. The energy and emission calculations can then be made based on these quantities by applying the standard coefficients from Table 6.4.

Agrichemicals

In agriculture there are a wide range of agrichemicals used for a variety of purposes. It is beyond the scope of this study to estimate the energy component of these in detail nor is information available about their use across the sectors. However, the study includes those chemicals which are significant in the production systems.

As in the case of fertilisers the energy component in chemicals is mainly from their manufacture and transport. However, again as in the case of fertilisers information is available on their energy component and it is assumed that this is the same for both the UK and NZ.

Table 6.5 shows the energy input and CO_2 emission rates for various agrichemical categories. The first three columns of data show. The energy component and carbon dioxide emissions are similar to those reported in Barber (2004b) which were adapted from a detailed study of the energy in chemical manufacture and use, Pimentel (1980). The final column on carbon dioxide emissions uses data from Wells (2001). However, there are two changes from the report by Barber (2004b) are to oil and other chemicals. The production energy of oil has been reduced from 60 to 5 MJ/kg ai, to better reflect the fact that the energy for production is just the cost of extraction. The previous estimate included a component of consumer energy. The “other” category of agrichemicals has had production energy reduced from 100 to 10 MJ/kg ai. This better reflects that most chemicals which fall into this group include biological control agents, for which most of the embodied energy is in formulation, packaging and transport.

As Table 6.5 shows, the energy requirement to manufacture agrichemicals ranges considerably, from between 5 MJ/kg to 440 MJ/kg of active ingredient (ai). Energy involved in formulating, packaging and transportation adds approximately a further 110 MJ/kg ai, and the CO_2 emission rate is constant across all types, per energy use.

Table 6.5
Energy used to manufacture agrichemicals and the associated Co_2 emissions

Agrichemical	Production of active ingredient (ai)	Formulation, Packaging and Transport	Total (MJ/kg of ai)	Emission Rate (kg CO_2/MJ)
Herbicide (Paraquat,Diquat and Glyphosate)	440	110	550	0.06
Herbicide (General)	200	110	310	0.06
Insecticide	185	130	315	0.06
Fungicide	100	110	210	0.06
Plant Growth Regulator	65	110	175	0.06
Oil	5	115	120	0.06
Other	10	110	120	0.06

Source: Barber (2004b)

Concentrate

An important input into livestock systems in the UK is concentrate feed especially when compared to NZ. However, unlike in the case of fertilisers and chemicals there is no secondary source of the energy component and emissions associated with concentrates. Therefore these had to be calculated separately, as stated above, for this study with a LCA type analysis. The composition of concentrates varies considerably, but generally has a grain base, supplemented with other sources of protein and minerals. For the purposes of this study it is assumed that concentrates have the same energy profile as barley. Whilst this is likely to be an underestimate of the energy in the concentrate, in the absence of detailed data on the ingredients of the concentrate mix it is the estimate used.

A simple analysis of the energy and CO_2 emissions in producing barley feed is therefore undertaken below. This requires information on the production system in the UK including information on the yield of barley, the inputs used by type and the associated energy and emission coefficients. Data on the production system was mainly obtained from Nix Farm Management Pocket Book, Nix (2004). Winter barley will be used in the calculations to ensure that the energy and emission figures arrived at are on the conservative side.

Table 6.6 below shows the yield and inputs for barley on a per hectare basis. To calculate the energy and emission component from the information in this requires converting the inputs into their physical quantities and in some case breaking them down further.

Table 6.6
Inputs and outputs in winter barley production

Item	Input/Output Per hectare
Barley Yield (average)	6.5 tonnes
Fuel and Repairs	£100
Fertiliser	£87.50
Sprays	£85
Seed	£37.5

Source: Nix (2004)

In calculating the energy component and emission associated with barley machinery repairs, seed costs and fixed costs were excluded. However this should provide a lower bound for the energy and emissions indicators of concentrate.

Fuel and Repairs

The cost of fuel and repairs for barley is £100 per hectare, as reported in Table 6.6. Nix does provide a more detailed breakdown of these expenses for total cereal production (of which barley is one). For the medium sized cereal production system (100-200 hectares) the cost of fuel, electricity and oil is £35 per hectare and the machinery repairs are £40 per hectare, Nix (2005). Therefore if we assume the same proportions for barley then 46.67 per cent of fuel and repairs is fuel, (35/75 = 0.4667). On this basis the input of fuel, electricity and oil is £46.67 given the £100 reported in Table 6.6 for fuel and repairs.

For the current analysis this will be converted to a diesel equivalent to calculate its energy requirements and the amount of carbon dioxide associated with this.

The price of diesel is assumed to be 24p per litre, which was sourced from the Department of Trade and Industry (2005a) and is the figure for August 2004 (approximately the time the Nix (2004) figures were compiled). This is for ‘red diesel’ (gas oil), which is only available to farmers and has very small rates of excise duty attached.

This gives a usage of diesel in barley production of £46.67/0.24 = 194.5 litres per hectare. Taking the energy coefficient reported above in Table 6.1 of 41.2 MJ per litre of diesel, this gives energy component equivalent to 8,012 MJ (i.e. 194.5*41.2). To obtain the energy component per tonne of barley this is divided by the yield reported in Table 6.6 of 6.5 tonnes per hectare giving 8,012/6.5 = 1,233 MJ per tonne barley.

To obtain the carbon dioxide emissions associated with barley production the emission factor reported in Table 6.3 of 65.1 is multiplied by the energy component per tonne given above of 1.233 MJ giving carbon dioxide emissions of 65.1/1,000*1,233 = 80.2 kg CO_2 per tonne of barley.

Fertiliser

Fertiliser is an important input into production of barley. As stated in Table 6.6 the fertiliser input is £87.50 per hectare, or given the yield of 6.5 tonnes a hectare, £13.46 per tonne of barley. However, Nix does not break this down into quantities by type of fertiliser therefore the British Survey of Fertiliser Practice was used which provides the actual UK application rates of fertiliser by crop (Chalmers et al. 2001). According to Chalmers the average application rates per hectare on winter barley are 146 kg of nitrogen, 21 kg of phosphorus, 51 kg of potassium and 223 kg of lime, (after making appropriate transformations to separate out the raw amount of the phosphorus and potassium from the P_2O_5 and K_2O figures respectively). The energy embodied in fertiliser and the carbon dioxide emissions for winter barley are calculated below, using the energy and emission coefficients from Table 6.4 above.

Nitrogen

The energy consumed per hectare in the 146 kg of nitrogen is: 65*146 = 9,490.0 MJ and this is:

9,490.0/6.5 = 1,460 MJ per tonne of barley.

The emissions are: 1,460*0.05 = 73.0 kg CO_2 per tonne of barley.

Phosphorus

The energy consumed per hectare in the 21 kg of phosphorus is: 15*21 = 313.9 MJ and this is:

313.9/6.5 = 48 MJ per tonne of barley.

The emissions are: 48*0.06 = 2.9 kg CO_2 per tonne of barley.

Potassium

The energy consumed per hectare in the 51 kg of potassium is: 10*51 = 506.3 MJ and this is:

506.3/6.5 = 78 MJ per tonne of barley.

The emissions are: 78*0.06 = 4.7 kg CO_2 per tonne of barley.

Lime

The energy consumed per hectare in the 223 kg of lime is: 0.6*223 = 133.6 MJ and this is:

133.6/6.5 = 21 MJ per tonne of barley.

The emissions are: 0.02*0.72 = 14.8 kg CO_2 per tonne of barley.

Total – all fertilisers

The total energy consumed in the use of all the above fertilisers is:

1,460 + 48 + 78 + 21 = 1,607 MJ per tonne of barley.

The total emissions are:

73.0 + 2.9 + 4.7 + 14.8 = 95.4 kg CO_2 per tonne of barley.

Sprays

The monetary cost of sprays per hectare associated with barley production, as reported in Table 6.6, is £85.00. Nix further breaks this down into the different types as: herbicides (54 per cent), fungicides (41 per cent) and others (5 per cent). Given the difficulty of assessing what the other sprays are, only the first two categories of these will be included in this study.

Herbicide

In the case of the herbicides these account for 54 per cent of the total expenditure on sprays (£85.00), that is £45.90 per hectare. In order to estimate the energy component this has to be converted to the quantity used. This requires information on the value of the chemical used and also their rates of application. In the absence of detailed information on type of herbicide used and therefore detailed price information it is assumed that all herbicide is MCPA (a general herbicide used for cereals) which is reported in Nix (2004) to cost £3-6 per hectare per application. To determine the rate of application the rate recommended for HY-MCPA was used, (sold in the UK by Agrichem International Limited). According to their website (Agrichem International, 2005), this product contains 500g of MCPA per litre and should be applied at a rate of 1.4 – 2.8 litres per hectare.

Therefore taking Nix's cost per application of MCPA for each hectare of £6 and the average application rate of 2.8 litres per hectare, the cost per litre is £6/2.8 = £2.14.

Using this product as representative of all the herbicides used, then dividing the total cost of £45.90 by the cost per litre estimated above, the number of litres per hectare is estimated to be £45.90/£2.14 = 21.42l. This contains 21.42*0.5 = 10.71 kg of the active ingredient MCPA.

The agrichemical section above lists the rates of energy inputs used in the manufacture packaging and transport of various agrichemicals (Table 6.5). However, data was not available on MCPA therefore the energy and emission profile were assumed to be the same as the herbicides with low profiles given in Table 6.5, (that is Herbicide – General) at 310 MJ per kg of active ingredient. Multiplying the quantity of active ingredient in MCPA by the energy coefficient above, the energy input for this herbicide is: 10.71*310 = 3,320.1 MJ per hectare, or 3,320.1/6.5 = 511 MJ per tonne of barley.

The CO_2 emission coefficient of 0.06, also given in Table 6.5, is 0.06 kg CO_2 per MJ which gives emissions of 3,320.1*0.06 = 199.21 kg CO_2 per hectare, or 511*0.06 = 30.6 kg CO_2 per tonne of barley.

Fungicide

The second group of chemicals used in the production of barley are fungicides. These account for 41 per cent of the total chemical cost of £85.00 per hectare of barley. Thus the estimated fungicide cost is 0.41*£85.00 = £34.85 per hectare. A commonly used fungicide for crops such as Barley in the UK is azoxystrobin, as reported in Nix. This is sold in the UK by Syngenta as Amistar. According to their website (Syngenta, 2004), the product contains 250g of azoxystrobin per litre and should be applied at 1 litre per hectare. They do not mention a price of the product, but Nix gives this at £26 per application.

To derive the physical quantity of fungicide use therefore the total cost on fungicides of £34.85 per hectare is divided by the cost per application of £26, giving an estimate of 1.34 applications per hectare or as average application is one litre per hectare 1.34 litres per hectare. Using conversion factors given above of 0.25 to obtain the amount of active ingredient this gives 1.34*0.250 = 0.34 kg per hectare of the active ingredient azoxystrobin.

Table 6.5 gives the energy input for the manufacture, packaging and transport of fungicides as 210 MJ per kg of active ingredient.

Therefore multiplying the active ingredient used per hectare of 0.34 by the energy component in this fungicide of 210 MJ/kg gives energy component of 0.34*210 = 70.37 MJ per hectare or 70.37/6.5 = 11 MJ per tonne of barley.

The corresponding CO_2 emission factor is given as 0.06 kg CO_2 per MJ of energy, as reported in Table 6.5 which gives 0.06*70.37 = 4.22 kg CO_2 emissions per hectare or 11*0.06 = 0.6 kg CO_2 per tonne of barley.

These figures for the agrichemical sprays are presented in Tables 6.7 and 6.8 below:

Table 6.7
Agrichemical applications rates, energy usage and CO_2 emissions for barley

Agrichemical	Application rate (kg per ha)	Energy Use (MJ per ha)	CO_2 Emissions (kg per ha)
Herbicide: MCPA	10.71	3,320	199
Fungicide: Azoxystrobin	0.34	70	4
Total	**-**	**3,390**	**203**

Total - Concentrate

Table 6.8 reports the summary of values associated with energy profile of barley production in the UK. It must be emphasised that these are lower bound estimates omitting inputs into the production process, not least fixed costs.

Table 6.8
Energy use and CO_2 emissions arising from the production of barley concentrate

Item	Quantity per hectare	MJ per tonne Barley	kg CO_2 per tonne Barley
Fuel, Electricity and Oil (Litres Diesel equivalent)	194	1,233	80.2
Nitrogen fertiliser (kg)	146	1,460	73.0
Phosphorus fertiliser (kg)	21	48	2.9
Potassium fertiliser (kg)	51	78	4.7
Lime fertiliser (kg)	223	21	14.8
Herbicide (kg ai)	10.71	511	30.6
Fungicide (kg ai)	0.34	11	0.6
Total	-	**3,361**	**206.9**

Totalling the components above gives a lower bound on the embodied energy in barley concentrate of 3,361 MJ per tonne of barley. The associated emissions are 206.9 kg of CO_2 per tonne of barley.

Fodder

Another key input into animal production systems is fodder. Coming under this definition is grass and maize silage, hay and animal bedding. Information on the energy emissions and carbon dioxide emissions were available from Wells (2001) and these are those used in the study for NZ.

Wells determined the energy requirements from the fertiliser nutrients removed with the silage, the direct energy to harvest the crop and an allowance for agri-chemicals. The energy use and carbon dioxide emissions for fodder for NZ are specified in Table 6.9 below.

Table 6.9
Energy and CO_2 emission coefficients of different types of fodder/animal bedding

Item	Energy Use (MJ/kg DM)	Emission Rate (kg CO_2/MJ)
Grass Silage/Hay/ Animal Bedding	1.50	0.058
Maize Silage	1.65	0.058

Source: Wells (2001)

Capital Energy Inputs

Capital items have a certain amount of energy embodied in them due to their extraction, manufacture and maintenance, which can be calculated by multiplying the mass of each component by an appropriate energy coefficient.

Machinery

Table 6.10 gives the energy and carbon dioxide emissions associated with machinery. These figures include the embodied energy of the raw materials, construction energy, an allowance for repairs and maintenance, and international freight (Wells, 2001). As Table 6.10 shows the embodied energy of vehicles and implements used in this report is 65.6 MJ/kg and 51.2 MJ/kg respectively. 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.

All vehicles are assumed to contain 95 per cent steel and 5 per cent rubber, while implements are 100 per cent steel (Audsley et al., 1997). In New Zealand the production of steel is 32 MJ/kg and rubber is 110 MJ/kg (Baird et al., 1997). Energy consumption for manufacturing and the percentage attributed to repairs was the average of three machine categories and two implement categories given by Audsley et al. (1997).

Table 6.10
Energy used in manufacture and maintenance of machinery

Machinery type	Energy in Materials (MJ/kg)	Energy Consumption for Manufacture (MJ/kg)	Energy Consumption for Repairs (per cent)	Total Energy (MJ/kg)
Vehicle	35.9	14.0	31.3	65.5
Implement	32.0	8.0	28.0	51.2

Table 6.11 gives the energy coefficients and CO_2 emission rates for farm vehicles and implements. To calculate the carbon dioxide emissions the same methodology was used as reported in Wells (2001) but with a lower energy content of steel assumed, as described above. It was assumed that on average the manufacture of all components requires inputs of fossil fuel energy with an average emission factor of 0.07 kg CO_2/MJ. In addition the IPCC (1996) guidelines recommend allowing additional emissions of 1.6 kg CO_2/kg of steel and iron products due primarily to the oxidisation of coke during the smelting process. As the majority of the mass of motor vehicles is steel, the carbon dioxide emission coefficient for vehicles was calculated by multiplying the energy coefficient (65.6 MJ/kg) by 0.07 kg CO_2/MJ and adding 1.6 kg CO_2/kg. This results in an overall emission factor of 6.11 kg CO_2/kg vehicle weight or 0.09 kg CO_2/MJ. Implements using the same methodology have emissions of 5.12 kg CO_2/kg or 0.10 kg CO_2/MJ.

Table 6.11
Energy coefficients of vehicles and implements

Capital Item	Energy Coefficient (MJ/kg)	Emission Rate (kg CO_2/MJ)	Working Life † (years)
Tractors	65.5	0.09	15
Heavy Trucks	65.5	0.09	15
Light trucks and utilities	65.5	0.09	15
Motor bikes	65.5	0.09	10
Farm implements	51.2	0.10	20

Source: † Wells (2001)

Buildings

Dairy Shed

For both New Zealand and the UK a dairy shed model constructed by Wells, and applied in Wells (2001) will be used. The capital energy of the dairy shed is related to a single parameter: the number of sets of milking cups. The following equation was estimated and will be used for prediction:

Capital Energy of Dairy Shed (GJ) = 24.2*sets of cups + 293

The corresponding CO_2 emissions are 0.1 kg per MJ.

Both of these figures arising from the model have to be allocated over a 20 year working life for the shed. They are summarised in Table 6.12 below.

Other Buildings

For all other farm buildings Wells (2001) assumes an energy requirement of 590 MJ/m^2 and the emission factor is 0.1 kg CO_2 per MJ. Again a 20 year working life for these building is assumed and this information is also included in Table 6.12.

Table 6.12
Energy and Co_2 emission coefficients of buildings

Item	Energy Use	Emission Rate (kg CO_2/MJ)	Working Life (years)
Dairy Shed	GJ = 24.2*sets of cups + 293	0.1	20
Other buildings	590 MJ/m^2	0.1	20

Source: Wells (2001)

Transport

As described in the methodology section due to the lack of data, the only transport distances for which analysis in this report will be done are on distances between countries, the export of the products. For all of the New Zealand commodities this involves sea freight to the United Kingdom, a distance of 17,840 km according to the Department for Transport (2003).

None of the British products analysed require any external transport as they are assumed to be consumed domestically.

A review of the literature on the energy and emission coefficients for sea transport did show general consistency with one or two exceptions. 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 (Defra http://www.defra.gov.uk/environment/business/envrp/gas/05.htm). 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. This is slightly higher than that reported in an earlier report (Commonwealth Government, 2001) of 0.09 MJ per tonne km., but lower than that used in Wells at 0.2 MJ per tonne km or the similar amount reported in Schilperoord (2004). Webb (2004) states that bulk shipping uses 0.2 MJ per tonne km, while BIMCO (2001) state that: “A fairly fast ship carrying around 25,000 tonnes of cargo at 18.5 knots uses only 0.12 megajoules per tonne-kilometre". Another study by the Technical Research Centre of Finland (2002) state that a container freight uses 0.28 MJ per tonne km and a bulk vessel 0.23 MJ per tonne km. Stadig (1997) in his study uses two scenarios – one where the energy consumed per tonne km is 0.2 MJ and the other 0.29 MJ per tonne km. These are high than those given in report by the Danish Government (2002) of slightly less than 1.0 MJ per tonne km. A figure outside these estimates is that reported in SAFE Alliance (1998) the energy consumed per tonne kilometre on a boat is 423 KJ (or 0.423 MJ/t-km).

For the road transport by truck within Europe, from Italy to the UK, a rate of 0.0102 litres of diesel per tonne kilometre was assumed. This is based on Defra (2005b) figure of 0.448 L/km for a fully loaded articulated truck, with a maximum weight of 44 tonnes, the EU limit for international movements. This is equivalent to 0.419 MJ per tonne kilometre, based on applying the UK diesel energy coefficient from Table 6.1 to this quantity of diesel. The carbon dioxide emissions are 0.027 kgCO_2/t-km based on the UK carbon emissions for diesel (Table 6.3). These results are summarised below in Table 6.13.

Table 6.13
Transport energy and CO_2 emission coefficients for international transport

Transport Type	Energy Coefficient (MJ per tonne km)	CO_2 Emission Coefficient (kg CO_2 per tonne km)
Shipping (NZ to UK)	0.114	0.007
Truck (Italy to UK)	0.419	0.027

This chapter has reviewed and calculated the key inputs which are used in agriculture and are applied in following sections to the production systems.

Chapter 7
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 Dairy, Apples, Lamb and Onions for NZ and the most appropriate alternative source of supply for the UK market. In the case of dairy, apples and onions this has been assumed to be the UK. This requires information on the outputs of the production system so that the energy and carbon dioxide emissions can be expressed per unit of output enabling comparisons can be made across the different countries. In general this information is readily available. Information is then needed on the type and level of inputs used in the production system as outlined in Chapter 4. Information on this was not so readily available especially not consistently between countries. In general information on NZ production system and detail of input use was available in more detail enabling a more thorough calculation of the energy embodied and emissions associated with production. For other countries it was not always possible to find comparable information. However, this has led to the results underestimating the energy associated with production in these countries compared to that in NZ. Finally the shipping costs were calculated and included allowing comparisons to be made between NZ and energy use and carbon dioxide emissions of other countries.

7.1 Dairy

This section presents results for dairy, NZ first then the UK and finally a comparison of the two systems and their associated energy use and carbon dioxide emissions. The unit for the dairy sector was milk solids (MS).

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 did have access 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.

Outputs

The average yield for dairy herds in the Wells report was 818.9 kg MS/ha while the average farm size was 91 hectares with 246 cows, or a stocking rate of 2.70 cows per hectare.

Direct Inputs

Fuel, Electricity and Oil

The quantities of all direct inputs were taken from the Wells survey. The coefficients used to derive the energy content and carbon dioxide emissions are described in Chapter 6.

Liquid Fuel Use

The liquid fuel inputs were diesel, petrol, and oil lubricants. This included all on farm operations as well as road transport using the farm utility or car. All personal transport was excluded.

Diesel and petrol use mainly for tractors, trucks, utilities and cars required 36.4 and 22.4 litres/ha. Based on the energy and carbon dioxide emission coefficients described in Chapter 6, total energy use was 2,483 MJ/ha or 3,032 MJ/tonne MS. A small amount of oil was also used, 40 MJ/ha.

Fuel use by contractors working on the farm was estimated from records of type of machine, hours of operation, areas worked, or amount of material carted or spread. It was assumed at all contractor work was conducted using diesel. Contractors used 19.7 L/ha, or 861 MJ/ha (1.051 MJ/tonne MS).

Carbon dioxide emissions from all liquid fuels was 230 kg CO_2/ha or 280.4 kg CO_2/tonne MS.

Electricity Use

The main electricity use was in the dairy shed and irrigation. Where possible actual meter readings were used from two electricity bills that were 12 months apart. Where the farmer did not have these, permission forms were used to go directly to the electricity supplier.

Most of New Zealand's electricity comes from renewable hydro generation. In 2000 72 per cent of electricity consumption came from renewable sources, however on a primary energy basis this drops to 32 per cent due to large conversion losses in our coal and gas generation.

Electricity uses including irrigation and the dairy was 545.4 kWh/ha. Of this the dairy shed accounted for 430 kWh/ha or 160 kWh/cow. The energy and carbon dioxide indicators for electricity are 4,443 MJ/ha (5,425 MJ/tonne MS) and 85 kg CO_2/ha or 104.0 kg CO_2/tonne MS.

Indirect Inputs

Fertiliser

Fertiliser use was taken from the Wells survey. Fertilisers were broken down into their N, P, K, S components. The energy and carbon dioxide emissions for each component was then calculated from the different coefficients described in Chapter 6.

The most significant fertiliser is nitrogen, accounting for just over 70 per cent of the fertiliser energy input.

Nitrogen

Nitrogen was found by Wells (2001) to be applied at a rate of 72.0 kg/ha. Using the energy coefficient of 65 MJ/kg energy, embodied energy in nitrogen is 4,678 MJ/ha (5,712 MJ/tonne MS).
Carbon dioxide emissions using the coefficient in Table 6.4 were 216 kg CO_2/ha or 263.7 kg CO_2/tonne MS.

Phosphorus

Phosphorous was found by Wells (2001) to be applied at a rate of 57.6 kg/ha. Using the energy coefficient of 15 MJ/kg energy, embodied energy in phosphorous is 864 MJ/ha (1,055 MJ/kg MS).

Carbon dioxide emissions using the coefficient in Table 6.4 were 52 kg CO_2/ha or 63.3 kg CO_2/tonne MS.

Potassium

Potassium was found by Wells (2001) to be applied at a rate of 56.0 kg/ha. Using the energy coefficient of 10 MJ/kg energy, embodied energy in potassium is 560 MJ/ha (684 MJ/tonne MS).

Carbon dioxide emissions using the coefficient in Table 6.4 were 34 kg CO_2/ha or 41.0 kg CO_2/tonne MS.

Sulphur

Sulphur is applied to NZ dairy pastures at a similar rate as phosphorous and potassium, being 62.4 kg/ha. Using the energy coefficient of 5 MJ/kg energy, embodied energy in sulphur is 312 MJ/ha (381 MJ/tonne MS).

Carbon dioxide emissions using the coefficient in Table 6.4 were 19 kg CO_2/ha or 22.9 kg CO_2/tonne MS.

Lime

Lime is extensively used in NZ. Wells (2001) found that it was applied at a rate of 289 kg/ha. Using the energy coefficient of 0.6 MJ/kg energy, embodied energy in lime is 173 MJ/ha (212 MJ/tonne MS).

Carbon dioxide emissions using the coefficient of 0.72 kg CO_2/MJ were 135 kg CO_2/ha or 151.7 kg CO_2/tonne MS.

Agrichemicals

In the Wells (2001) study agrichemicals were broken down into pesticides, of which the predominate one was glyphosate; cleaning chemicals; animal remedies, mainly bloat oil; and all other chemicals.

Some of the energy coefficients for the various agrichemicals has changed slightly from those used by Wells (2001) and are described in Table 6.5. The carbon coefficients, in kg CO_2/MJ, remained the same as used by Wells (2001).

Pesticide use was 3.0 kg/ha of active ingredient. Given that this was predominantly glyphosate the energy coefficient was 310 MJ/kg or 930 MJ/ha (1,136 MJ/kg MS). The carbon dioxide emissions for all agrichemicals are 0.06 kg CO_2/MJ. Pesticide carbon dioxide emissions are 56 kg CO_2/ha or 68.2 kg CO_2/tonne MS.

Cleaning chemicals use 3.1 kg/ha. Wells (2001) used a low energy value of 10 MJ/kg of active ingredient based on based on the requirements of producing industrial phosphoric acid. This has been increased in this study to 120 MJ/kg ai to more accurately reflect the energy not only embodied in the chemicals but also the packaging and transport. Using the energy coefficient of 120 MJ/kg energy, embodied energy in cleaning chemicals is 375 MJ/ha (458 MJ/tonne MS). Cleaning chemicals carbon dioxide emissions are 23 kg CO_2/ha or 27.5 kg CO_2/tonne MS.

Animal remedies, mainly in the form of bloat oil, are applied at 0.5 kg/ha (Wells, 2001). Using the energy coefficient of 110 MJ/kg energy, embodied energy in animal remedies is 52 MJ/ha (64 MJ/tonne MS). Animal remedies carbon dioxide emissions are 3 kg CO_2/ha or 3.8 kg CO_2/tonne MS.

All other chemicals use 1.3 kg/ha (Wells, 2001). Using the energy coefficient of 120 MJ/kg energy, embodied energy in these chemicals is 158 MJ/ha (193 MJ/tonne MS). Other chemical carbon dioxide emissions are 10 kg CO_2/ha or 11.6 kg CO_2/tonne MS.

Concentrate

Concentrate use in NZ includes zinc/magnesium, grain, calf meal, milk powder and molasses. All these inputs were collected separately in the Wells survey and have been amalgamated into a single concentrate rate. Each component has its own energy coefficient and varies between 1 MJ/kg for molasses up to 20 MJ/kg for milk powder. The rate of carbon dioxide emissions is 0.058 kg CO_2/MJ, except for zinc which is slightly higher at 0.060 kg CO_2/MJ.

Concentrate use is 83 kg/ha (Wells, 2001). There is no single energy coefficient for concentrates, their total embodied energy use is 189 MJ/ha (231 MJ/tonne MS). Carbon dioxide emissions are 11 kg CO_2/ha or 13.5 kg CO_2/tonne MS.

Fodder and Regrassing

Fodder and regrassing use in NZ includes grass seed, maize silage, hay, straw, and baleage. All these inputs were collected separately in the Wells survey and have been amalgamated into a single fodder rate. Each component has its own energy coefficient and varies between 0.87 MJ/kg of baleage up to 10 MJ/kg for grass seed. The rate of carbon dioxide emissions is 0.058 kg CO_2/MJ, except for grass seed which is slightly higher at 0.060 kg CO_2/MJ. Fodder use is 389 kg/ha (Wells, 2001). There is no single energy coefficient for fodder and their total embodied energy use is 542 MJ/ha (662 MJ/tonne MS). Carbon dioxide emissions are 31 kg CO_2/ha or 38.5 kg CO_2/tonne MS.

Capital Inputs

Buildings

On NZ dairy farms there are two main types of buildings. The dairy shed and general storage sheds for implements and hay or fodder.

Dairy Shed

The dairy shed contains the milking plant, vat and general storage including the hot water cylinder.

Wells (2001) calculated that the energy embodied in the dairy shed was closely correlated to the number of cups and determined the embodied energy as 36,000 MJ/cup (36 GJ/cup). Wells (2001) found the average shed size was 22 cups. Based on a shed life of 20 years this is 1,800 MJ/cup/yr. Total embodied energy in the dairy shed is 431 MJ/ha (527 MJ/tonne MS).

Wells (2001) assigned a carbon dioxide emissions value for all buildings of 0.1 kg CO_2/MJ. Carbon dioxide emissions are 43 kg CO_2/ha or 52.7 kg CO_2/tonne MS.

Storage Sheds

Wells (2001) calculated that the energy embodied in storage sheds was closely correlated to area and determined the embodied energy as 590 MJ/m^2. Based on a shed life of 20 years this is 29.5 MJ/m^2. Wells found the average total storage shed size on a farm was 468 m^2. Total embodied energy in the storage sheds is 151 MJ/ha (185 MJ/tonne MS).

Based on a carbon dioxide emissions value of 0.1 kg CO_2/MJ sheds contribute 15 kg CO_2/ha or 18.5 kg CO_2/tonne MS.

Fences

Total fence length was the amalgamation of internal fences, which tend to be lower input electrified fences, and boundary fences, which are often 7 wire post and batten.

Wells (1998) presented a detailed analysis of the capital energy costs of fencing, which he later simplified. Boundary fences have an embodied energy coefficient of 20 MJ/m length. Internal fences have an energy coefficient of 4.5 MJ/m length. The carbon dioxide emission factor is 0.09 kg CO_2/MJ and working life were assumed to be 25 years for boundary fences and 15 years for internal fences.

The length of the fences was calculated from the area, number of paddocks and internal race length. Wells found that the average boundary length was 8,990m while internal fences were 18,000 meters. Based on the energy and carbon coefficients described above the total embodied energy in fences is 138 MJ/ha (169 MJ/tonne MS).

Carbon dioxide emissions contribute 13 kg CO_2/ha or 17.0 kg CO_2/tonne MS.

Races

The energy embodied in the construction of new farm races is 75 MJ/m (Wells, 2001). Races were assumed to have a working life of 30 years.
Race length was calculated by Wells (2001) using the following formula:

$$R = 0.0494A\left(\frac{N}{A}\right)^{0.58}$$

where:

R = length of races (km)
A = farm area (ha)
N = number of paddocks

The average race length was 3,290 m. The total embodied energy in races is 90 MJ/ha (110 MJ/tonne MS). Carbon dioxide emissions based on a rate of 0.0687 kg CO_2/MJ (Wells, 2001) contribute 6 kg CO_2/ha or 7.6 kg CO_2/tonne MS.

Irrigation

There are many types of irrigation systems used in NZ dairy production. These include border strip, travelling irrigators, centre pivots, long line laterals, big guns, side rolls, and hand shift.

The energy embodied in these systems was based on the irrigated area. Most had an energy value of 12,500 MJ/ha, with border strip at 25,000 and travelling irrigators at 13,500 MJ/ha. All irrigators had a life of 30 years. The carbon dioxide emissions for all were 0.057 kg CO_2/MJ.

Most dairy farms in NZ are not irrigated. The average irrigated area over all NZ dairy farms is 16 ha. The average embodied energy of all the different systems is 98 MJ/ha (120 MJ/tonne MS). Carbon dioxide emissions contribute 3 kg CO_2/ha or 3.7 kg CO_2/tonne MS.

Water Supply

All NZ dairy farms use reticulated water to troughs. The embodied energy in a water supply is 2,100 MJ/ha with a carbon dioxide emission of 0.07 kg CO_2/MJ and a working life of 30 years.

Based on an average farm size of 91 ha the embodied energy in the water supply system is 70 MJ/ha (85 MJ/tonne MS). Carbon dioxide emissions contribute 6 kg CO_2/ha or 7.1 kg CO_2/tonne MS.

Effluent

There are many types of effluent disposal systems used in NZ dairy production. These are mainly twin ponds (anaerobic and aerobic) and spray irrigation although there are still some ditch systems

Wells found the average embodied energy of all the different systems is 100 MJ/ha (123 MJ/tonne MS). Carbon dioxide emissions contribute 6 kg CO_2/ha or 7.7 kg CO_2/tonne MS.

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.

Outputs

The average yield for dairy herds which is used in this study is 6665 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).

Direct Inputs

Fuel, Electricity and Oil

Data on fuel and electricity use and especially the breakdown of this into the components was not readily available. Colman et al. (2004) did not separate out fuel and electricity use at all from other generic inputs and Nix (2004) provided information on fuel, electricity and oil combined at £65 per hectare, implying £38 per cow. The Farm Management Survey report for Yorkshire on dairying however provides information on fuel and oil use of £46 per hectare or £27 per cow. Thus, using the Nix estimate of £38 per cow for fuel, electricity and oil use, electricity use would be approximately £11 per cow. This is the same as that reported in Carpenter (1989) of £11 per cow per year and is further verified by data from the more recent North East Farm Business Survey of £10 per cow, (pers comm). There is also a fuel component which is included in contracting costs, additional to the fuel/oil cost quoted above. These contracting costs are derived from Farrar and Franks (1998) including both elements from his forage variable costs of £52 per hectare but also his reported £8 per hectare for other contracting costs, giving a total of £60 per cow.

Fuel/Oil Use

First, calculations will be made for the fuel/oil costs. Unfortunately there is no way to separate these into the two individual components, therefore a diesel equivalent approximation will be used. This will be based on a price of diesel of 24p per litre, which was sourced from the Department of Trade and Industry (2005a) and is the figure for August 2004 (approximately the time the Nix (2004) figures were compiled). This is for 'red diesel' (gas oil), which is only available to farmers and has very small rates of excise duty attached. The price of consumer diesel at the same time was 82p.

As discussed above, £27 per cow has been allocated for these fuel costs. In order to obtain the energy use and CO_2 emissions from fuel, and oil, this price per cow is first divided by the price of diesel to give a fuel usage of 112.5 litres. The primary energy coefficient of diesel from Table 6.1 (41.2 MJ/L) is then applied to this value to give the primary energy usage:

112.5*41.2 = 4,635.0 MJ
This value is the divided by the yield of milk solids (MS) per cow (563 kg) and multiplied by 1,000 to give the energy usage per tonne of MS from fuel and oil use:

4,635.0/563*1,000 = 8,234 MJ per tonne MS

In order to obtain the CO_2 emissions associated with fuel use in the dairy sector, the CO_2 emission rate from Table 6.3 (65.1g/MJ) is applied to this value of energy per tonne of MS:

8,234*65.1/1,000 = 536.0 kg of CO_2 per tonne MS

The contracting fuel must also be added to these values of energy and CO_2 emissions, which is assumed to amount to 12 per cent of the contracting costs (see Chapter 6, Contracting Fuel Use for an explanation of this) (£60 per cow). This means that 0.12*60 = £7.20 of fuel is used, which again is converted into a diesel equivalent based on a price of 24p per litre.

In order to derive the amount of diesel used per cow, this price of fuel must be divided by the price per litre of diesel (24p as discussed previously), which comes to 7.20/0.24 = 30.0 litres of diesel per cow. Again multiplying this value by the coefficient for primary energy for diesel, obtained from Table 6.3, gives the primary energy value of:

30.0*41.2 = 1,236.0 MJ

This value is then divided by the MS per cow and multiplied by 1,000 to give the energy use per tonne of MS:

1,236.0/563*1,000 = 2,196 MJ per tonne MS

CO_2 emissions are obtained by multiplying this value of MJ per tonne of MS by the CO_2 emission rate from Table 6.3:

2,196*65.1/1,000 = 142.9 kg of CO_2 per tonne MS

Totalling the farm and contracting fuel gives an equivalent diesel usage of 245 litres per hectare, while the energy used is 10,429 MJ per tonne MS and 679.0 kg CO_2 per tonne MS is emitted.

Electricity Use

Secondly, the farm electricity usage will be analysed. Assuming a price of UK electricity of 5p per kilowatt hour (kWh) and the total cost of electricity of £11 per cow, this gives 1,100 pence at 5p/kWh = 220 kWh/cow. This compares to the NZ average for dairy shed electricity use of 160 kWh/cow.

Applying the primary energy coefficient on UK electricity from Table 6.3 of 10.37 MJ/kWh, the total energy use is:

10.37*220 = 2,281.4 MJ per cow, or 2,281.4/563*1,000 = 4,053 MJ per tonne MS

The corresponding CO_2 emissions, obtained by applying the emission coefficient for electricity, also from Table 6.3 are:

4,053*41.5/1,000 = 168.2 kg CO_2 per tonne MS

Indirect Inputs

Fertiliser

The level of fertiliser use was also not readily available by dairy farm. Nix (2004) reports that for a stocking rate of 2 cows per hectare (higher that that used in the study) the level of nitrogen is 220 kg per hectare. Colman et al. (2004) report however a rate of 149 kg per hectare, which will be used in this study. However, it is unlikely that dairy farms just apply nitrogen and therefore using data from *The British Survey of Fertiliser Practice* (Chalmers et al., 2001), the average application rate on pasture under 5 years was very similar to that reported in Colman et al. (2004) at 147 kg per hectare. According to this source the corresponding amounts of phosphorous and potassium were 14 and 38 kg per hectare respectively (after making appropriate transformations to separate out the raw amount of these chemicals from the stated P_2O_5 and K_2O figures), therefore these rates have been used in this study. A rate of lime application has also been derived, of 175 kg per hectare.

Nitrogen

Applying the energy use coefficient from Table 6.4 to the nitrogen application rate, gives the total energy use of:

65*149 = 9,685 MJ per hectare

This is then divided by the milk yield per hectare of 968 kg MS (= yield per cow*stocking rate) and multiplied to provide the energy use per tonne of milk solids:

9,685/968*1,000 = 10,003 MJ per tonne MS

In order to obtain the CO_2 emissions from nitrogen fertiliser use, the energy use per tonne of MS is multiplied by the emission coefficient for N fertiliser from Table 6.4. This provides the amount of CO_2 associated with each kg of MS from N fertiliser application:

10,003*0.05 = 500.1 kg CO_2 per tonne MS

Phosphorus

Similarly, the energy use of phosphorus is obtained by applying the energy use coefficient from Table 6.4 to the rate of Phosphorus fertiliser applied per hectare. This gives the energy associated with the application of phosphorus, per hectare:

14*31 = 203 MJ per hectare

Dividing the energy use by the milk yield per hectare and multiplying by 1,000 gives the energy used per tonne of MS produced:
203/968*1,000 = 209 MJ per tonne MS

This value per tonne of MS can then be multiplied by the emission coefficient from Table 6.4 (0.06) to provide the kg CO_2 associated with the application of Phosphorus fertiliser, per tonne of MS:

209*0.06 = 12.6 kg CO_2 per tonne MS

Potassium

As described above, 38 kg of potassium fertiliser are assumed to be applied per hectare. The energy use involved in this application is obtained by applying the energy use coefficient for potassium from Table 6.4 to this application rate:

10*38 = 382 MJ per hectare. Dividing this energy use per hectare by the milk yield per hectare and multiplying by 1,000 gives the energy used per tonne of MS:

382/968*1,000 = 394 MJ per tonne MS

The CO_2 emissions are then obtained by applying the emission rate coefficient for Potassium from Table 6.4 (0.06) to the energy use per tonne of MS:

394*0.06 = 23.7 kg CO_2 per tonne MS.

Lime

Lime is assumed to be applied at a rate of 175 kg per hectare. The energy use of Lime is again obtained through multiplying this application rate by the energy use coefficient for lime from Table 6.4:

0.6*175 = 105.2 MJ, and then dividing this energy use per hectare by the kg of MS per hectare and multiplying by 1,000 to obtain the energy use per tonne of MS:

105.2/968*1,000 = 109 MJ per tonne MS

This value per tonne MS is then multiplied by the CO_2 emission rate for lime from Table 6.4 (0.72) in order to obtain the CO_2 emissions associated with lime application:

109*0.72 = 78.2 kg CO_2 per tonne MS.

Agrichemicals

Only one type of agrichemical is assumed to be applied to fields – herbicide. As will be discussed later in the section on fodder, the costs allocated for agrichemical sprays are £5 per cow, or around £9 per hectare at the assumed stocking rate (1.72 cows per hectare).

Nix (2004) lists the herbicide MCPA as an agrichemical used on grass in the UK, such as that used for grazing cattle, at a cost of £5-9 per hectare. Agrichem International Limited, which

supplies one variety of MCPA called HY-MCPA containing 500g of the active ingredient per litre of the product, suggest an application rate of 3.5 litres per hectare (Agrichem International, 2005). Therefore this is equivalent to 1.75 kg of MCPA per application. Since the assumed cost per hectare and the cost per application fall in the same range, only one application per year will be assumed in this study.
For the energy and emission calculations, the coefficients from Table 6.5 for Herbicide – General will be used i.e. 310 MJ and 0.06 kg CO_2 per MJ.

The energy input per hectare for the herbicide is derived by multiplying the application rate of MCPA of 1.75kg by the energy coefficient obtained from Table 6.5:

310*1.75 = 542.5 MJ per hectare

This value of energy per hectare is then divided by the milk yield per hectare and multiplied by 1,000 to obtain the energy usage per tonne of MS:

542.5/968*1,000 = 560 MJ per tonne MS

CO_2 emissions per tonne of MS are then derived using the emission rate coefficient for this herbicide in Table 6.5 (0.06) and multiplying it by the energy per tonne of MS:

560*0.06 = 33.6 kg CO_2 per tonne MS

Concentrate

Concentrate usage is an important input into the UK dairy farming system and one which is a significant difference to NZ dairy production systems. The composition of concentrates varies considerably but generally has a grain base supplemented with other sources of protein and minerals. For the purposes of this study it is assumed that concentrates have the same energy profile as barley. Whilst this is likely to be an underestimate of the energy in the concentrate mixed, in the absence of detailed data on the ingredients of the concentrate mix it is the best approximation.

The concentrate use on dairy farms is estimated to be 2 tonnes per cow (Colman et al., 2004). This is similar to that reported in Nix (2004) of 1.95 tonnes per cow. However, this is assuming there are no replacements for the herd, and thus to be compatible with NZ data the costs of rearing replacements should be included. According to Nix, for each dairy cow a third of replacement unit is required. This allows for the four year milking life per cow and losses in the rearing of replacements. Thus one calf, one yearling and one heifer for every three dairy cows should be allowed for, Nix (2004). The cost of concentrates to raise a replacement is estimated at 714 tonnes of concentrates over the three years, so per cow this would be 0.238, Nix (2004). Thus total concentrate use per year per dairy cow is the sum of 2 and 0.238 tonnes i.e. 2.238 tonnes.

The energy and CO_2 emissions coefficients per kg of barley are taken from Table 6.8 (see Chapter 6 for detailed derivations of these figures).

For each cow the energy embodied in the concentrate which they (and the replacements attributed to them) consume is calculated by multiplying the concentrate use per tonne, as derived above (2.238 tonnes) by the coefficient for MJ per tonne of barley (3,361):

3,361*2.238 = 7,521.7 MJ

The amount of energy per tonne of MS is calculated by dividing this energy per cow by the milk yield per cow and multiplying by 1,000:

7,521.7/563*1,000 = 13,362 MJ per tonne MS

Similarly, the amount of CO_2 emitted is found by multiplying the quantity of concentrate used by the CO_2 emission coefficient for the production of barley (206.9) from Table 6.8:

206.9*2.238 = 463.0 kg CO_2

This is 463.0/563*1,000 = 822.6 kg CO_2 per tonne MS.

Fodder and Animal Bedding

The other important input into dairying is forage, bulk fodder and bedding. Colman et al. (2004) provide a figure of £151 per cow per year. In addition to this is the cost of bulk feed for replacements for the dairy herd. This is estimated from Nix (2004) as 15 per cent of the total forage costs. Therefore the total forage variable costs are assumed to be £174 per cow. Not all these forage costs are relevant to this study and care has to be taken to avoid double counting. However, a detailed breakdown is not available in the 2004 Colman report, but there is a breakdown in an earlier report (Farrar and Franks, 1998) and this is used to allocate the costs. On this basis 30 per cent of the forage variable costs are contracting (£52 – a proportion of this is included in the fuel, electricity and oil section) and sprays are 3 per cent of costs, giving £5 per cow (included in agrichemical section).

The estimates for bulk feeds and, bedding in Colman et al (2004) are £62 per cow which when accounting for replacement is £72 per cow. These are reported by the authors as being made up of bought-in fodder and other inputs such as brewers grains and vegetable by products. Given the difficulty in knowing the proportions of these, it is assumed that these are bought-in fodder.

However the whole £72 of costs for the three types will be assumed to be silage, for either feed or bedding. This is likely to underestimate the energy component because whilst silage and straw have same value in the UK other components of fodders do not such as brewers grain. Nix (2004) claims that silage costs £25 per tonne (similar to straw at between £20 and 25 per tonne), giving an estimate of 72/25 = 2.88 tonnes per cow.

In order to obtain the energy per cow involved in fodder and animal bedding, the energy coefficient from Table 6.9 is applied to this value of 2.88 tonnes of silage per cow:

1.5*2,880 = 4,320 MJ per cow

This value can then be divided by the milk yield per cow and multiplied by 1,000 to obtain the energy involved per tonne of MS from animal fodder and bedding:
4,320/563*1,000 = 7,674 MJ per tonne MS

This value is then multiplied by the emission rate of 0.058 kg CO_2 from Table 6.9 in order to obtain the CO_2 emissions associated with this category:

The emissions therefore from silage come to 7,674*0.058 = 445.1 kg CO_2 per tonne MS.

Cleaning Chemicals

Cleaning chemicals (acids and alkali rinses used to clean dairy milking equipment – Wells, 2001) will be assumed to be applied at the same rate as for New Zealand dairy – that is, at 3.1 kg per hectare. These chemicals have an energy coefficient of 120 MJ per kg and an emission coefficient of 0.06 kg CO_2 per MJ, which will be employed in the calculations below. Initially, the rate of application of 3.1 kg is multiplied by the energy coefficient of 120 MJ, to give the MJ per hectare:

120*3.1 = 372 MJ per hectare

This amount is then divided by the milk yield per hectare and multiplied by 1,000 to give the energy per tonne of MS:

372/968*1,000 = 384 MJ per tonne MS

CO_2 emissions are then derived by multiplying the energy per tonne of MS by the emission coefficient of 0.06 kg CO2 per MJ:

384*0.06 = 23.1 kg CO_2 per tonne MS

Other Chemicals

‘Other chemicals’ include animal health remedies, and as with the cleaning chemicals will be applied at the same rate as New Zealand – 1.6 kg per hectare. These chemicals have an energy coefficient of 110 MJ per kg and an emission coefficient of 0.06 kg CO_2 per MJ, which will be used in the calculations below. The application rate of 1.6 kg per hectare is multiplied by the energy coefficient of 110 to give the energy per hectare associated with ‘Other chemicals’:

110*1.6 = 176 MJ per hectare

This rate is then divided by the milk yield per hectare and multiplied by 1,000 to give the energy per tonne of MS:

176/968*1,000 = 182 MJ per tonne MS

CO_2 emissions are then calculated by multiplying this energy per tonne of MS by the emission coefficient of 0.06 kg CO_2 per MJ:

182*0.06 = 10.9 kg CO_2 per tonne MS

Capital Inputs

Buildings

Buildings are one of the key capital inputs on a dairy farm. Nix (2004) lists a set farm buildings for such an operation. Three of these are able to be used for the purposes of this energy/emission analysis (since areas rather than just costs are specified):

a. Covered strawed yard with 4.0 m^2 per head floor area

b. Covered collection yard with 1.1 m^2 per cow

c. Milking parlour building: 5.5*11.5 = 63.25 m^2 total

For dairy farming buildings in the UK the basic energy and emission coefficients are taken from Table 6.12, but are scaled up by a rate of 1.5. This is to reflect the fact that in the UK these buildings are of a higher standard than in New Zealand, using for example more metal. The new coefficients are therefore 885 MJ per/m^2 and 0.15 kg CO_2 per MJ. However the assumed working life of the buildings remains at 20 years.

Covered Strawed Yard

Energy per cow associated with a covered straw yard is calculated by multiplying the energy per square metre by the metres per head of floor area:

Energy per cow: 885*4 = 3,540 MJ

The energy per year is calculated by dividing the energy per cow by the working life of the building:

3,540/20 = 177 MJ per year

In order to derive the energy per tonne of MS, this energy per year is divided by the annual yield per cow and multiplied by 1,000:

177/563*1,000 = 314 MJ per tonne MS

The CO_2 emissions are calculated by multiplying the energy per tonne of MS by the emission coefficient of 0.15 kg CO_2 per MJ of energy:

314*0.15 = 47.2 kg CO_2 per tonne MS.

Covered Collection Yard

Energy per cow associated with a covered collection yard is calculated by multiplying the energy per square metre by the metres per head of floor area:

Energy per cow: 885*1.1 = 974 MJ

The energy per year is calculated by dividing the energy per cow by the working life of the building:

974/20 = 48.7 MJ per year

The energy per tonne of MS is calculated by dividing the energy per year by the annual yield per cow and multiplying by 1,000:

This comes to 48.7/563*1,000 = 86 MJ per tonne MS
CO_2 emissions are then calculated by multiplying the energy per tonne of MS by the CO_2 emission coefficient:

86*0.15 = 13.0 kg CO_2 per tonne MS

Milking Parlour Building

Total energy embodied in the building is calculated by multiplying the energy per square metre by the total area of the building:

885*63.25 = 55,976 MJ

Dividing this energy by the working life of the building (20 years) gives the energy per year:

2,799 MJ per year

Since there are 86.5 cows on an average UK dairy farm (from above), the energy per cow is calculated by dividing the energy per year by the average cows per farm:

2,799/86.5 = 32.4 MJ per cow

The energy per tonne MS is found by dividing the energy per cow by the annual yield per cow and multiplying by 1,000:

32.4/563*1,000 = 57 MJ per tonne MS

CO_2 emissions are again calculated by multiplying the energy per tonne of MS by the emission coefficient for CO_2:

These emissions are: 57*0.15 = 8.6 kg CO_2 per tonne MS.

Dairy Shed

To estimate the energy embodied in Dairy shed in the UK information from Nix on farm buildings is supplemented with the Wells (2001) model for calculating energy reported in Chapter 6. In the absence of more detailed information the energy and emission rates for the UK will be the same as those assumed for New Zealand, which are summarised in Table 6.12:

Capital Energy (GJ) = 24.2 C + 293, where C is the number of sets of milking cups

Although there is no specific information on the average number of cups used in British dairy sheds, it is well-known that these sheds are much smaller than ones which are typical in New Zealand, and have fewer cups. Due to this, the average number of cups has been assumed to be 10 in the UK.

The energy embodied in a dairy shed per year, based on a 20 year working life, is therefore calculated by multiplying the average number of cups by 24.2, adding 293 and dividing this result by 20:

Energy = 24.2*10 +293 = 535 GJ or 26.75 GJ per year (dividing the total energy by 20)
Since there are 86.5 cows on an average dairy farm, the energy per cow associated with dairy sheds is calculated by dividing this energy per year by the number of cows:

26,750/86.5 = 309.2 MJ per cow

The energy per tonne of MS can then be calculated by dividing the energy per cow by the annual yield per cow and multiplying by 1,000:

309.2/563*1,000 = 549 MJ per tonne MS

CO_2 emissions associated with dairy sheds are then calculated by multiplying the CO_2 emission coefficient by the energy per tonne of MS:

549*0.1 = 54.9 kg CO_2 per tonne MS.

Races

Wells (2001) assumes for New Zealand dairy farms that for every metre of race, there are 750 kg of aggregate used. This results in an energy coefficient of 75 MJ per metre of race, and the carbon dioxide coefficient is the same as for diesel fuel. Races are budgeted to have a working life of 30 years.

Nix (2004) assumes that UK dairy farms have 20m of race. Applying the energy coefficient discussed above to the 20m of race gives:

75*20 = 1,500 MJ or 50 MJ per year based on a working life of 30 years.

This is then divided by the average number of cows on a dairy farm (86.5) to give the energy per cow:

50/86.5 = 0.578 MJ per cow
The energy per tonne of MS is calculated by dividing the energy per cow by the kg of MS and multiplying by 1,000:

0.578/563*1,000 = 1 MJ per tonne MS

The emissions are: 1*65.1/1,000 = 0.1 kg CO_2 per tonne MS.

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 7.1.

Table 7.1
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		10,429		679.0
Diesel (L) (including contracting)	56.2		2,990		205.4	
Petrol (L)	22.4		1,093		73.2	
Lubricants (L)	0.9		50		1.8	
Electricity use (kWh)	545.4	378	5,425	4,053	104.0	163.5
Direct sub total	**-**	**-**	**9,558**	**14,482**	**384.5**	**847.1**
Indirect						
Nitrogen (kg)	72.0	149	5,712	10,003	263.7	500.1
Phosphorus (kg)	57.6	14	1,055	209	63.3	12.6
Potassium (kg)	56.0	38	684	394	41.0	23.7
Sulphur (kg)	62.4		381		22.9	
Lime (kg)	288.9	175	212	109	151.7	78.2
Pesticides (kg ai)	3.0	1.75	1,136	560	68.2	33.6
Cleaning Chemicals (kg)	3.1	3.1	458	384	27.5	23.1
Animal remedies (e.g. drench, bloat aids) (kg)	0.5		64		3.8	
Other chemicals (kg)	1.3	1.6	193	182	11.6	10.9
Forage, Fodder and Bedding (kg grass silage)	389	4,954	662	7,674	38.5	445.1
Cereals/concentrate (kg of dry matter)	83	3,849	231	13,362	13.5	822.6
Grazing-off (ha)	0.2	-	413	0	24.8	0
Aggregate (kg)	1,072		131		9.0	
Indirect sub total	**-**	**-**	**11,331**	**32,877**	**739.2**	**1,949.8**
Capital						
Vehicles (kg)	4.6		368		29.4	
Implements (kg)	5.4		336		30.2	
Dairy shed (cups)	-		527	549	52.7	54.9
Other farm buildings (m^2)	0.3	-	185	458	18.5	68.8
Fences (m)	3.9	-	169		17.0	
Races (m)	1.2	0.4	110	1	7.6	0.1
Stock water supply (ha)	0.0		85		7.1	
Irrigation (ha)	0.0		120		3.7	
Effluent disposal system (m^3)			123		7.7	
Capital sub total	**-**	**-**	**2,023**	**1,009**	**173.9**	**123.8**
Total Production	**-**	**-**	**22,912**	**48,368**	**1,297.6**	**2,920.7**
Yield (kg Milk Solids)	**819**	**968**				
Shipping (NZ to UK) (17,840 km)	-	-	2,030		124.9	
Total Production Energy Input/Emissions	**-**	**-**	**24,942**	**48,368**	**1,422.5**	**2,920.7**

Table 7.1 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 7.1 and shows that the UK uses considerably more energy per tonne of milk solids produced. The UK uses 50 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.

In the UK a total of 48,368 MJ of energy is used per tonne of milk solid compared to 22,912 in NZ, over twice as much. Including shipping at 2,030 MJ per tonne milk solids still makes NZ production much more energy efficient at 24,942 at just over half 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 twice that of NZ. Thus, the UK emits 2,921 kilograms of carbon dioxide per tonne of milk solids compared to just 1,423 in NZ (including transport to the UK).

7.2 Apples

NZ Apples

Currently there is a Total Energy Use study being conducted of the pip fruit sector using the Wells (2001) methodology (per. comm. G Frater). However there are currently no results available. The data used to determine NZ's total energy and carbon dioxide emissions was from a discussion with Nelson based horticultural consultant Greg Dryden (Fruition Horticulture), MAF Policy (2005a), and the CAE Guide (1996).

Outputs

The average marketable orchard yield is 50 tonnes per hectare, of which 37 tonnes is exported. The average orchard size for the purpose of this analysis is 18 hectares.

Direct Inputs

Fuel, Electricity and Oil

Liquid fuel use for the season was determined from a list of operations as presented in Table 7.2. Each operation was given a fuel use rate in litres per hour, a work rate and the average number of passes. All tractor work, except for shelter trimming was based on a 50 hp tractor operating at 10.3 L/hr (Barber, 2004b). Work rates were attributed to each operation to determine fuel use per hectare.

Table 7.2
Fuel use in NZ apple production

Operation	Fuel Use (L/hr)	Work rate (hr/ha)	Fuel use per pass (L/ha)	Number of passes per yr	Total fuel use (L/ha)
Mulching – prunings	10.3	2.2	22.7	1.4	32
Shelter trimming	27.9	2.0	55.8	0.5	28
Fungicide sprays	10.3	0.7	7.2	17.5	126
Insecticides (combined with fungicides)				4.5	
Calcium (combined with fungicides)				12.0	
Weed spray	10.3	0.5	5.2	2.5	13
Mowing	10.3	1.1	11.3	5.0	57
Fertiliser application	10.3	1.2	12.4	1.5	19
Lime application	10.3	1.2	12.4	0.4	5
Pruning – hydra ladder					9.0
Harvest – hydro ladder					9.3
Harvest – tractor	3.4	23.3	79.2	1.0	79
Forklift	4.5	2.2	9.9	1.0	10
General					50
Total Orchard Production					**436**

Fuel use of 436 L/ha compared to an estimated fuel use of 495 L/ha in the CAE Guide (1996) for pipfruit.

Most orchards are irrigated. The quantity of electricity use was estimated at 1,180 kWh/ha. This was based on electricity use of $4,381 from the 19.3 ha in MAF Policy (2005a) ($227/ha). The cost of electricity including line charges for 3 phase power was obtained from the Genesis Energy web site for Wellington (http://www.genesisenergy.co.nz/genesis/index.cfm). Based on a line charge of $1.70/day and a variable rate of 16.45 cents/kWh total energy use was 22,860 kWh or 1,180 kWh/ha.

Based on the energy coefficient for diesel in Table 6.1, fuel use on the orchard is 23,540 MJ/ha or 380 MJ/tonne apples. Carbon dioxide emissions from all liquid fuels is 1,307 kg CO_2/ha or 26.1 kg CO_2/tonne apples.

Electricity at 1,180 kWh/ha is 9,600 MJ/ha or 192 MJ/tonne apples. Carbon dioxide emissions are 184 kg CO_2/ha or 3.7 kg CO_2/tonne apples.

Indirect Inputs

Fertiliser

Fertiliser use was based on the discussions with Dryden (per comm.). The three main fertilisers used are CAN which is 27 per cent nitrogen, urea at 46 per cent nitrogen and an orchard mix of 10:2:10. An upper and lower rate for each fertiliser was determined and broken down into kilograms per hectare of nitrogen, phosphorous and potassium. A typical rate was settled on of 80 kg/ha of nitrogen, 8 kg/ha of phosphorous and 60 kg/ha of potassium.

Lime is often applied every 2 to 3 years. We assumed an application rate of 2,500 kg/ha, or an average annual rate of 1,042 kg/ha.

Based on the energy and carbon dioxide coefficients described in Table 6.4 total embodied energy in fertiliser is 6.545 MJ/ha or 131 MJ/tonne apples. Carbon dioxide emissions are 770 kg CO_2/ha or 14.6 kg CO_2/tonne apples.

Sprays

The spray programme was based on an analysis of agrichemical use in the Hawkes Bay, conducted for MAF Policy (Holland and Rahman) in 1999 and from discussions with Dryden (per. comm.).

In 1999, when Holland and Rahman conducted their pesticide use survey, organophosphates were a major component of insecticide use. These have now virtually been removed, so we based current practice on an average of five applications, totalling 2.20 kg ai. Based on an embodied energy of 310 MJ/kg ai, insecticide use was 680 MJ/ha (0.014 MJ/kg apples). Total carbon dioxide emissions, at a rate of 0.06 kg CO_2/MJ, were 41 kg CO_2/ha (0.001 kg CO_2/kg apples).

Holland and Rahman (1999) found fungicide applications were 15.6 kg ai/ha. The embodied energy at a rate of 210 MJ/kg ai is 3,266 MJ/ha (0.065 MJ/kg apples). Total carbon dioxide emissions for fungicide is 196 kg CO_2/ha (0.004 kg CO_2/kg apples).

Holland and Rahman (1999) found herbicide was applied at a rate of 3.2 L ai/ha. There was a mix of different herbicides used, which has an embodied energy of 310 MJ/kg ai. Total herbicide energy use was 992 MJ/ha or 0.02 MJ/ kg apples. Carbon dioxide emissions were 60 kg CO_2/ha (0.001 kg CO_2/kg apples).

Holland and Rahman (1999) found growers using oil sprays at a rate of 29.1 L/ha. Based on an embodied energy of 120 MJ/kg ai, total energy use was 3,492 MJ/ha or 0.07 MJ/kg apples. Carbon dioxide emissions were 210 kg CO_2/ha (0.004 kgCO_2/ kg apples).

Total energy embodied in all sprays was 8,432 MJ/ha or 169 MJ/tonne apples. Total carbon dioxide emissions were 506 kg CO_2/ha (10.1 kg CO_2/tonne apples).

Capital Inputs

Buildings

The only buildings on an orchard are usually a storage shed. This was assumed to be a 2 bay or 36 m^2 shed for the 18 hectare orchard. At an embodied energy rate of 590 MJ/m^2 and a life of 20 years total energy was 59 MJ/ha or 1 MJ/tonne apples. Carbon dioxide emissions at a rate of 0.1 kg CO_2/MJ are 6 kg CO_2/ha (0.1 kg CO_2/tonne apples).

Vehicles

Vehicles used included two 50 hp tractors and one utility. Total weight based on the assumptions given in Chapter 6 was 5,860 kg or 326 kg/ha with an embodied energy of 1,424 MJ/ha or 28 MJ/tonne apples.

Carbon dioxide emissions at a rate of 0.094 kg CO_2/MJ are 132 kg CO_2/ha (2.6 kg CO_2/tonne apples).

Machinery

Typical machinery on an orchard includes a hydro ladder, sprayer, mulcher, mower, fork lift, and fertiliser spreader. The total weight was 5,300 kg or 294 kg/ha with an embodied energy of 855 MJ/ha or 17 MJ/tonne apples.

Carbon dioxide emissions at a rate of 0.101 kg CO_2/MJ are 85 kg CO_2/ha (1.7 kg CO_2/tonne apples).

Support Structures

Typically apples use a simple support structure of posts and 4 wires. A typical orchard with 800 trees per hectare has a row spacing of 5m and a gap within the row of 2.5m. There are 400 posts per hectare and 8,000 meters of wire. Based on the coefficients given in Chapter 6 total embodied energy is 542 MJ/ha or 11 MJ/tonne apples.

Carbon dioxide emissions at a rate of 0.07 kg CO_2/MJ for posts and 0.12 kg CO_2/MJ for wire equals 54 kg CO_2/ha (1.1 kgCO_2/tonne apples).

Irrigation

The length of irrigation pipe is calculated based on the orchard layout described in the section above on support structures with the additional assumption that the average row length is 150m.

The mainline length is assumed to be 20 per cent longer than the cropped orchard width, which is 80m/ha. The pipe is 65mm PVC at a weight of 0.74 kg/m. The embodied energy in PVC is 120 MJ/kg (Barber, 2004b). The embodied energy is 7,104 MJ/ha or over the 40 year life 178 MJ/ha/yr.

The submain is the same width as the orchard, 67m/ha. Using 50mm PVC pipe at a weight of 0.51 kg/m, the embodied energy is 4,080 MJ/ha or over the 40 year life of the pipe 102 MJ/ha/yr.

The lateral pipe is 16mm low density polyethylene (LDPE). The length is equal to the total row length of 2,000 m/ha. At a weight of 0.07 kg/m and an embodied energy of 160 MJ/kg total embodied energy is 22,400 MJ/ha. With a 30 year life the embodied energy is 747 MJ/ha/yr.

Total embodied energy in the 2,147 meters of irrigation pipe is 1,026 MJ/ha/yr, or 21 MJ tonne of apples. With a carbon dioxide emission rate of 0.073 kg CO_2/MJ for PVC and 0.045

kg CO_2/MJ for LDPE total carbon dioxide emissions are 54 kg CO_2/ha (0.0 kg CO_2/tonne apples).

UK Apples

In the case of apples a number of sources of data were used to calculate the UK production system. As in case of sheepmeat (see below) the main source of data was Nix (2004) but this was supplemented by Tanton and Williams (2004), Chalmers et al. (2001) and the UK pesticide survey, Garthwaite et al. (2001).

Outputs

Nix (2004) cites an average yield of 14 tonnes per hectare in the UK for desert apples. Other information detailed in this report which is relevant to the current analysis includes fertiliser costs of £75 per hectare and agrichemical spray costs of £400 per hectare. A more detailed breakdown of the production system is given in Table A.3 in the appendix.

Direct Inputs

Fuel, Electricity and Oil

Tanton and Williams (2004) give the average cost of fuel, oil and electricity for intensive arable – fruit as £135 per hectare in 2002/2003 from a survey over 26 farms (this is a total output per hectare of £5,728 and is similar to the £5,600 reported by Nix for apples). In 2002/03 the price of red diesel (gas oil) was lower than that in 2004, with the average of its December 2002 and January 2003 price was 17p per litre (Department of Trade and Industry, 2005a) and this is the figure which will be used to quantify the amount assumed in this publication.

As in the case of sheepmeat a breakdown of fuel electricity and oil is unavailable therefore a diesel equivalent of the fuel, oil and electricity is calculated by multiplying the cost per hectare by the price of diesel per litre, as follows:

£135/£0.17 = 794.1 litres per hectare

Therefore for production of apples an equivalent of 794.1 litres of diesel per hectare is used. Applying the UK diesel energy coefficients from Tables 6.1 the energy content of this is calculated. Thus the quantity of diesel per hectare (794.1 litres) is multiplied by the primary energy coefficient for diesel from Table 6.1 (41.2), giving total energy of 32,717.6 per hectare:

794.1*41.2 = 32,717.6 MJ

At the yield of 14 tonnes per hectare, the energy use per tonne of apples is calculated by dividing the primary energy content of diesel calculated above by the yield per hectare:

32,717.6/14 = 2,337 MJ per tonne of apples

Similarly, the CO_2 emissions from fuel involved in apple production are calculated by multiplying this energy per tonne of apples by the CO_2 emission rate per MJ of primary energy from Table 6.3:

2,337*65.1/1,000 = 152.1 kg CO_2 per tonne apples.

Indirect Inputs

Fertiliser

Information on the level and type of fertiliser used was sourced from *The British Survey of Fertiliser Practice* (Chalmers et al., 2001), for top fruit, of which apples are an important variety.

The rates which were stated are as follows: 78 kg of nitrogen, 11 kg of phosphorus, 55 kg of potassium, per hectare (after making appropriate transformations to separate out the raw amount of phosphorus and potassium from the stated P_2O_5 and K_2O figures respectively).

Nitrogen

To calculate the energy associated with nitrogen fertiliser the energy coefficient for N fertiliser taken from Table 6.4 (65MJ/kg) is multiplied by the application rate of 78 kg of nitrogen per hectare:

65*78 = 5,070 MJ

Thus energy associated with nitrogen fertiliser is 5,070 MJ per hectare. To obtain the per tonne apple equivalent, the hectare amount is then divided by the yield of apples per hectare (14 tonnes), as follows:

5,070/14 = 362 MJ per tonne of apples

This value is then multiplied by the CO_2 emission rate for N fertiliser, also from Table 6.4, of 0.05 kg CO_2/MJ to give the amount of CO_2 per tonne of apples from N fertiliser application:

362*0.05 = 18.1 kg CO_2 per tonne of apples.

Phosphorus

When the energy coefficient for phosphorus from Table 6.4 (15MJ/kg) is applied to the 11 kg of phosphorus, the following amount of energy results:

15*11 = 170 MJ

Dividing this amount of energy by the apple yield per hectare gives the energy per tonne of apples:

170/14 = 12 MJ per tonne of apples

CO_2 emissions associated with phosphorus application in the apple sector are obtained by multiplying the energy per tonne of apples by the CO_2 emission rate for phosphorus in Table 6.4 (0.06):

12*0.06 = 0.7 kg CO_2 per tonne of apples.

Potassium

The energy coefficient for potassium from Table 6.4 (10MJ/kg) is applied to the 55 kg/ha of potassium, to derive the energy associated with potassium fertiliser application per hectare:

10*55 = 548 MJ

This is again divided by the apple yield per hectare to obtain the energy per kg of apples from potassium application:

548/14 = 39 MJ per tonne of apples.

CO_2 emissions per tonne of apples are then calculated using the emission rate for potassium from Table 6.4 (0.06kg CO_2/MJ):

39*0.06 = 2.3 kg CO_2 per tonne of apples.

Sprays

Detailed data from Nix (2004) was not available on pesticide use therefore the pesticide usage survey was used, Garthwaite et al. (2001). In this pesticide usage survey report there is information for orchards and fruit stores, include data on agrichemical applications, which will be used as the basis for the analysis below.

Herbicide

Data derived from Garthwaite et al. (2001) indicate that the average application of herbicide on orchards is 1.46 kg of active ingredient (ai) per hectare. According to the survey, glyphosate is the most important herbicide which is applied to desert apples, therefore the higher energy coefficient from Table 6.5 will be used (for herbicide which includes paraquat, diquat or glyphosate).

The energy is associated with herbicide use in apple production can therefore be calculated by multiplying the kg of active ingredient by the total MJ per kg of ai (from Table 6.5):

550*1.46 = 804.2 MJ per hectare

The energy per tonne of apples can then be derived by dividing the energy per hectare by the yield per hectare (14 tonnes):

804.2/14 = 57 MJ per tonne of apples

The CO_2 emissions are then calculated by applying the CO_2 emission coefficient from Table 6.5 to the energy per tonne of apples:

57*0.06 = 3.4 kg CO_2 per tonne of apples.

Fungicide

From Garthwaite et al. (2001), the average application of fungicide on orchards is 6.21 kg ai per hectare.

The energy is therefore calculated as above for herbicide; by multiplying the ai per hectare by the total energy per kg of ai from Table 6.5:

210*6.21 = 1,303.3 MJ per hectare

Energy per tonne of apples is then calculated by dividing this energy per hectare by the yield per hectare:

1,303.3/14 = 93 MJ per tonne of apples

CO_2 emissions can be calculated by multiplying the energy per tonne of apples by the CO_2 emission coefficient from Table 6.5:

93*0.06 = 5.6 kg CO_2 per tonne of apples.

Insecticide

From Garthwaite et al. (2001), the average application of insecticide on orchards is 1.24 kg ai per hectare.
The energy is per hectare is therefore obtained by multiplying the amount of ai per hectare by the energy coefficient per kg of ai from Table 6.5:

315*1.24 = 390.5 MJ per hectare

This is then divided by the yield per hectare to obtain the energy per tonne of apples associated with insecticide use:

390.5/14 = 28 MJ per tonne of apples

CO_2 emissions are then able to be calculated by multiplying the energy per tonne of apples by the CO_2 emission coefficient from Table 6.5

28*0.06 = 1.7 kg CO_2 per tonne of apples.

Insecticide – Tar Oil

Garthwaite et al. (2001) also have some specific information on the special insecticide tar oil and an application rate of 3.51 kg ai per hectare can be derived from the report. The relevant energy and emission coefficients can be found in Table 6.5 under ‘Oil’ and these are applied below:

The energy per hectare is 120*3.51 = 421.8 MJ

This is then divided by the yield per hectare to obtain the energy per tonne of apples associated with the use of this agrichemical:

421.8/14 = 30 MJ per tonne of apples

CO_2 emissions are then able to be calculated by multiplying the energy per tonne of apples by the CO_2 emission coefficient from Table 6.5

30*0.06 = 1.8 kg CO_2 per tonne of apples.

Growth Regulator

From Garthwaite et al. (2001), the average application of growth regulator on orchards is 0.17 kg ai per hectare.

The energy per hectare of apples associated with growth regulator is therefore calculated by multiplying the ai per hectare by the energy coefficient for growth regulator from Table 6.5:

175*0.17 = 30.1 MJ per hectare

The energy per tonne of apples is then derived by dividing the energy per hectare by the yield per hectare:

30.1/14 = 2 MJ per tonne of apples

CO_2 emissions from this category are then calculated by applying the CO_2 emission coefficient from Table 6.5 to the energy per tonne of apples:

2*0.06 = 0.1 kg CO_2 per tonne of apples.

Post Production

To be able to meet same market window as NZ apples British apples are assumed to be stored for six months. For these storage periods the apples are chilled to around 2°C, in a refrigerated environment. No energy or emission coefficients are available for the UK, thus to estimate the energy associate with this storage the Wells and Scarrow (1997) cold storage of NZ kiwifruit is used, which is 169 kWh/tonne, for pre-cooling and storage over 5 months. Of this 16 kWh/t were attributed to pre-cooling and 153 kWh/t to storage. Keeping the pre-cooling the same and increasing the storage component from 5 to 6 months equates to 200 kWh/tonne. The British electricity coefficients of 10.37 MJ per kWh (Table 6.1) and 41.5 gCO_2 per MJ (Table 6.3) is applied to the energy use:.

The total energy is: 199.5 * 10.37 = 2,069 MJ per tonne of apples.

The corresponding CO_2 emissions are: 2,069*41.5/1,000 = 85.8 kg CO_2 per tonne of apples.

Comparison of NZ and UK Apple Production

The energy and carbon dioxide emission associated with apple production in NZ and the UK are summarised in Table 7.3. The table highlights the difference in energy content in production of apples for direct and indirect inputs, no data was available for the UK for capital expenditure. However, the energy embodied in capital is relatively insignificant and thus not expected to affect the conclusions although once again the UK estimates will be lower than those for NZ.

As Table 7.3 shows the direct energy in apple production in the UK is considerably higher, at 2,337 per tonne, compared to 573 in NZ. The indirect energy is also lower in apple production in the NZ compared to the UK at 300 compared to 624. When the total energy component is calculated adding the transport and storage costs still make NZ apples lower are than the UK in energy intensity at 2,980 per tonne compared to 3,271 for UK apples.

The carbon dioxide emissions per tonne of apples produced are also higher in the UK than in NZ, reflecting the higher energy use. Thus per tonne of apples in NZ delivered to the UK the emissions are 185 compared to 199 in the UK.

Table 7.3
Total energy and carbon dioxide indicators for NZ and UK apple production

Item	**Quantity/hectare**		**Energy MJ/Tonne apples**		**CO$_2$ Emissions kg CO$_2$/Tonne apples**	
	NZ	UK	NZ	UK	NZ	UK
Direct						
Fuel, Electricity and Oil – (L of Diesel equivalent)		794		2,337		152.1
Fuel use - Orchard (L of Diesel)	436		380		26.1	
Electricity Use (kWh)	1,180		192		3.7	
Direct subtotal	**-**	**-**	**573**	**2,337**	**29.8**	**152.1**
Indirect						
Nitrogen (kg)	80	78	104	362	4.8	18.1
Phosphorus (kg)	8	11	2	12	0.1	0.7
Potassium (kg)	60	55	12	39	0.7	2.3
Lime (kg)	1,042		13		9.0	
Herbicide (kg ai)	3.2	1.46	20	57	1.2	3.4
Fungicide (kg ai)	15.6	6.21	65	93	3.9	5.6
Insecticide - General (kg ai)	2.2	1.24	14	28	0.8	1.7
Insecticide – Oil (kg ai)	29.0	3.51	70	30	4.2	1.8
Plant Growth Regulator (kg ai)		0.17		2		0.1
Indirect subtotal	**-**	**-**	**300**	**624**	**24.7**	**33.8**
Capital						
Farm buildings (m^2)	2.0		1		0.1	
Tractors (kg)	248		22		2.0	
Light trucks/utilities (kg)	78		7		0.6	
Machinery (kg)	294		17		1.7	
Support Structures						
Posts (#)	400		4		0.3	
Wire (m)	8,000		7		0.8	
Irrigation (m)	2,147		21		0.0	
Capital subtotal	**-**	**-**	**78**	**-**	**5.6**	**-**
Total Production	**-**	**-**	**950**	**2,961**	**60.1**	**186.0**
Yield (tonnes)	**50**	**14**				
Post Harvest						
Cold storage (UK 6 months)	-	-		2,069		85.8
Shipping (NZ to UK) (17,840 km)	-	-	2,030		124.9	
Post Harvest subtotal	**-**	**-**	**2,030**	**2,069**	**124.9**	**85.8**
Total Energy Input/Emissions	**-**	**-**	**2,980**	**5,030**	**185.0**	**271.8**

7.3 Onions

There are some serious questions about the feasibility of the UK being able to supply the market during its winter, this is due to technical issues around storage. Therefore whilst this has been assumed possible here, as mentioned below, whether it is feasible to replace NZ imports is questionable.

The New Zealand and UK onion crop has been compared based on supplying a crop into the same window of time, June to August, during the UK winter. The only way the UK onion crop can achieve this is by using cold and controlled atmosphere (CA) storage.

New Zealand grows the onion cultivar Pukekohe Longkeeper, and as the name suggests it has excellent storage quality. The UK onion varieties simply do not store well. The Pukekohe Longkeeper can not be grown in the UK due to different climatic conditions compared to in NZ (where it was developed).

NZ Onions

The key source of information was the NZ onion industry report *Seven Case Study Farms: Total Energy & Carbon dioxide Indicators for New Zealand Arable & Outdoor Vegetable Production* (Barber, 2004a). Three vegetable operations that included onions in their crop mix were surveyed on their production inputs. Where some of the data were aggregated, particularly the carbon coefficients, we went back to the raw data for presenting in this report.

Some of the coefficients have been updated in this report in order to make them consistent across all sectors studied. These are described in more detail below.

Outputs

Most of NZ's onion are grown in Auckland and the Waikato, accounting for 68 per cent of the productive area (HortResearch, 2003), although an increasing area is going into the Hawkes Bay. No official statistics are kept on yields. While they can be up to 60 t/ha, marketable yields are more typically between 40 and 50 t/ha. In this report we have assumed that the average yield is 45 t/ha, of which 80 per cent is exported.

Direct Inputs

Fuel, Electricity and Oil

Liquid fuel use

The liquid fuel inputs were diesel, and oil lubricants. This included all on farm operations as well as road transport using the farm utility or car. All personal transport was excluded in the survey.

Diesel for field operations including cultivation, spraying and harvesting required 332 litres/ha. Based on the energy and carbon dioxide emission coefficients in Tables 6.1 and 6.3

total energy use was 14,472 MJ/ha or 322 MJ/tonne onions. Oil was a small component at 6 litres/ha or 284 MJ/ha (6 MJ/tonne onions).

Carbon dioxide emissions from all liquid fuels were 994 kg CO_2/ha or 22.3 kg CO_2/tonne onions.

Electricity Use

Electricity use for irrigation was 78 kWh/ha. The survey was taken during a wet season and normally this would be higher. However onions are often not a high irrigation priority, particularly while returns are so low and even negative in 2005. No adjustment was made to this figure. The energy and carbon dioxide indicators for electricity are 635 MJ/ha (14 MJ/tonne onions) and 12 kg CO_2/ha or 0.3 kg CO_2/tonne onions.

Indirect Inputs

Fertiliser

Fertiliser use was taken from the Barber (2004a) survey. Fertilisers were broken down into their N, P, K, S components. The energy and carbon dioxide emissions for each component were then calculated from the different coefficients described in Table 6.4.

The most significant fertiliser is nitrogen, accounting for just under 70 per cent of the fertiliser energy input.

Nitrogen

Nitrogen was found by Barber (2004a) to be applied at an average rate of 135.0 kg N/ha. Using the energy coefficient of 65 MJ/kg energy, embodied energy in nitrogen is 8,775 MJ/ha (195 MJ/tonne onions).

Carbon dioxide emissions using the coefficient in Table 6.4 were 405 kg CO_2/ha or 9.0 kg CO_2/tonne onions.

Phosphorus

Phosphorous was found by Barber (2004a) to be applied at a rate of 134 kg P/ha. Using the energy coefficient of 15 MJ/kg energy, embodied energy in phosphorous is 2,010 MJ/ha (45 MJ/tonne onions).

Carbon dioxide emissions using the coefficient in Table 6.4 were 121 kg CO_2/ha or 2.7 kg CO_2/tonne onions.

Potassium

Potassium was found by Barber (2004a) to be applied at a rate of 105 kg K/ha. Using the energy coefficient of 10 MJ/kg energy, embodied energy in potassium is 1,050 MJ/ha (23 MJ/tonne onions).

Carbon dioxide emissions using the coefficient in Table 6.4 were 63 kg CO_2/ha or 1.4 kg CO_2/tonne onions.

Sulphur

Barber (2004a) found that sulphur was applied to onions at an average rate of 77 kg S/ha. Using the energy coefficient of 5 MJ/kg energy, embodied energy in sulphur is 385 MJ/ha (9 MJ/tonne onions).

Carbon dioxide emissions using the coefficient in Table 6.4 were 23 kg CO_2/ha or 0.5 kg CO_2/tonne onions.

Lime

Lime is extensively used in NZ. Barber (2004a) found that it was applied at a rate of 977 kg/ha. Using the energy coefficient of 0.6 MJ/kg energy, embodied energy in lime is 586 MJ/ha (13 MJ/tonne onions).

Carbon dioxide emissions using the coefficient of 0.72 kg CO_2/MJ were 455 kg CO_2/ha or 9.3 kg CO_2/tonne.

Sprays

In the vegetable total energy use report (Barber, 2004a), agrichemical use was broken down into herbicide, fungicide, and insecticide. Other chemicals are used like adjuvant, but the use was considered only minor and was not included.

Herbicide

Herbicides are used quite extensively in onion production, with a range of chemicals. Herbicides are applied at a rate of 10.9 kg ai/ha. The embodied energy is a product of the glyphosate compounds at 550 MJ/kg ai and all other herbicides at 310 MJ/kg ai. Total embodied energy is 3,619 MJ/ha or 80 MJ/tonne onions.

Based on a carbon dioxide emission of 0.06 kg CO_2/MJ total emissions were 217 kg CO_2/ha (4.8 kg CO_2/tonne onions).

Fungicide

In Barber (2004a) fungicide use was found to be 35.7 kg ai/ha. It was noted that the 2002 season, which the data was collected for, was particularly wet and that typically applications would be a quarter of this. In this report we reduced to fungicide use by 75 per cent to 8.9 kg ai/ha. Based on an embodied energy of 210 MJ/kg ai, energy use was 1,874 MJ/ha or 42 MJ/tonne onions.

Carbon dioxide emissions were 112 kg CO_2/ha (2.5 kg CO_2/tonne onions).

Insecticide

Insecticide use is 3.0 kg ai/ha (Barber, 2004a). Based on an embodied energy of 310 MJ/kg ai, energy use was 930 MJ/ha or 21 MJ/tonne onions.

Carbon dioxide emissions were 56 kg CO_2/ha (1.2 kg CO_2/tonne onions).

Capital Inputs

Capital inputs were separated into buildings and all machinery. This included tractors, utilities, forklifts, and implements such as ploughs, rippers, trailers, etc. Irrigation is carried out using movable big gun irrigators and was included in machinery.

Buildings

Buildings include storage sheds both for equipment and produce. Most operations also have a packing shed. On average Barber (2004a) found a building area of 0.90 m^2/ha. At an embodied energy rate of 590 MJ/m^2 and a life of 20 years total energy was 533 MJ/ha or 12 MJ/tonne onions. Carbon dioxide emissions at a rate of 0.1 kg CO_2/MJ are 53 kg CO_2/ha (1.2 kg CO_2/tonne onions).

Vehicles and implements

The total weight of vehicles and implements was 31.3 kg/ha/yr, based on their life of 20 years. Embodied energy was the product of vehicles at 65.5 MJ/kg and implements at 51.2 MJ/kg. Total embodied energy was 1,775 MJ/ha or 39 MJ tonne onions.

Carbon dioxide emissions at a rate of 0.09 kg CO_2/MJ for vehicles and of 0.10 kg CO_2/MJ for implements was 167 kg CO_2/ha (3.7 kg CO_2/tonne onions).

Postharvest Inputs

NZ onions have a very small selling window into the UK market of about 8 to 12 weeks, between June and August. In NZ the crop is left in the paddock for the skins to harden and then they are harvested, either by hand or machine, then graded and transported to the customer.

Grading

Electricity is the predominant energy used to operate the grading machine and lights. A small amount of liquid fuel is used for forklifts but this has already been accounted for in the production fuel use.

Barber (2004a) found that 239 kWh/ha were used for onion grading and office functions. It was assumed that 90 per cent of this electricity was used in the packing shed. Based on the energy and carbon coefficients for electricity described in Tables 6.1 and 6.3, energy use was 1,751 MJ/ha or 39 MJ/tonne onions. Carbon dioxide emissions were 34 kg CO_2/ha (0.7 kg CO_2/tonne onions).

Transport

Once on a ship the onions travel 17,840 km's to the UK at a shipping rate of 0.114 MJ/t-km. Total direct energy use in shipping is 2,030 MJ/tonne onions. The carbon dioxide emissions come to 124.9 kg CO_2/tonne onions.

UK Onions

The key source of information on the production system for onions was Nix (2004) The production system for onions is reported in Table A.4 in the appendix. In addition to Nix (2004), Chalmers et al. (2001) which surveys fertiliser use in the UK, was also used.

Outputs

The average yield of onions in the UK reported in Nix is 35 tonnes per hectare.

Direct Inputs

Fuel, Electricity and Oil

As described above, £50 per hectare has been allocated to the costs of fuel, electricity and oil. No further breakdown of these costs was available and therefore, as in the case of apples and sheepmeat, a diesel equivalent quantity was calculated.

These costs are converted into a diesel equivalent by dividing the fuel cost per hectare by the cost per litre of red diesel (at 24p per litre):

£50/£0.24 = 208.3 litres of diesel per hectare

The energy from this is calculated using the UK diesel energy coefficient from Table 6.1:

41.2*208.3 = 8,583.3 MJ per hectare

In terms of the functional unit of 1 tonne of onions, this energy value per hectare is divided by the onion yield per hectare of 35 tonnes:

8,583.3/35 = 245 MJ per tonne of onions

The CO_2 emissions are then calculated by applying the CO_2 emission coefficient from Table 6.1 to the energy per tonne of onions:

245*65.1/1,000 = 16.0 kg CO_2 per tonne of onions.

This diesel usage is far lower than Barber assumes (319 litres per ha for field operations), even excluding other charges (e.g. electricity).

Indirect Inputs

Fertiliser

As in the case of apples, information on the level and type of fertiliser used was sourced from Chalmers et al. (2001), for vegetables (other), which is appropriate to use for onions.

The rates which were stated are as follows: 104 kg of nitrogen, 37 kg of phosphorus, 86 kg of potassium, per hectare (after making appropriate transformations to separate out the raw amount of phosphorus and potassium from the stated P_2O_5 and K_2O figures respectively).

Nitrogen

To calculate the energy associated with nitrogen fertiliser the energy coefficient for N fertiliser taken from Table 6.4 (65MJ/kg) is multiplied by the application rate of 104 kg of nitrogen per hectare:

65*104 = 6,760 MJ

Thus energy associated with nitrogen fertiliser is 6,760 MJ per hectare. To obtain the per tonne onion equivalent, the hectare amount is then divided by the yield of onions per hectare (35 tonnes), as follows:

6,760/35 = 193 MJ per tonne of onions

This value is then multiplied by the CO_2 emission rate for N fertiliser, also from Table 6.4, of 0.05 kg CO_2/MJ to give the amount of CO_2 per tonne of onions from N fertiliser application:

193*0.05 = 9.7 kg CO_2 per tonne of onions.

Phosphorus

When the energy coefficient for phosphorus from Table 6.4 (15MJ/kg) is applied to the 37 kg of phosphorus, the following amount of energy results:

15*37 = 562 MJ

Dividing this amount of energy by the onion yield per hectare gives the energy per tonne of onions:

562/35 = 16 MJ per tonne of onions

CO_2 emissions associated with phosphorus application in the onion sector are obtained by multiplying the energy per tonne of onions by the CO_2 emission rate for phosphorus in Table 6.4 (0.06):

16*0.06 = 1.0 kg CO_2 per tonne of onions.

Potassium

The energy coefficient for potassium from Table 6.4 (10MJ/kg) is applied to the 86 kg/ha of potassium, to derive the energy associated with potassium fertiliser application per hectare:

10*86 = 863 MJ

This is again divided by the onion yield per hectare to obtain the energy per tonne of onions from potassium application:

863/35 = 25 MJ per tonne of onions.

CO_2 emissions per tonne of onions are then calculated using the emission rate for potassium from Table 6.4 (0.06kg CO_2/MJ):

25*0.06 = 1.5 kg CO_2 per tonne of onions.

Sprays

Garthwaite et al. (2004) in their pesticide usage survey report for outdoor vegetable crops, include data on agrichemical applications which will be used as the basis for the analysis below.

Herbicide

Data derived from Garthwaite et al. (2004) indicate that the average application of herbicide on onions and leeks is 8.17 kg of active ingredient (ai) per hectare. The energy and emission coefficients from the standard herbicide (i.e. Herbicide - General) in Table 6.5 are applied to this amount of ai per hectare to obtain the energy per hectare of onions:

The energy is: 310*8.17 = 2,533.1 MJ per hectare

This amount is then divided by the onion yield to obtain the energy per tonne of onions:

2,533.1/35 = 72 MJ per tonne of onions

CO_2 emissions are the obtained by applying the CO_2 emission coefficient from Table 6.5:

72*0.06 = 4.3 kg CO_2 per tonne of onions.

Fungicide

Again from Garthwaite et al. (2004), the average application of fungicide on onions and leeks is 9.04 kg ai per hectare.

The energy is therefore obtained by multiplying the kgs of ai per hectare by the energy coefficient for fungicide from Table 6.5:

210*9.04 = 1,899.4 MJ per hectare

The energy per tonne of onions is obtained by dividing the energy per hectare by the onion yield:

1,899.4/35 = 54 MJ per tonne of onions

CO_2 emissions are calculated by multiplying the energy per tonne of onions by the CO_2 emission coefficient for fungicide from Table 6.5:

54*0.06 = 3.3 kg CO_2 per tonne of onions

Insecticide

From Garthwaite et al. (2004), the average application of insecticide on onions and leeks is 0.40 kg ai per hectare.

The energy associated with insecticide use on onions is therefore calculated by multiplying the amount of ai per hectare by the energy coefficient from Table 6.5:

315*0.40 = 125.6 MJ per hectare

The energy per tonne of onions is obtained through dividing the energy per hectare by the onion yield of 35 tonnes:

125.6/35 = 4 MJ per tonne of onions

CO_2 emissions are calculated through the application of the CO_2 emission rate from Table 6.5 on the energy per tonne of onions:

4*0.06 = 0.2 kg CO_2 per tonne of onions

Growth Regulator

From Garthwaite et al. (2004), the average application of growth regulator on onions and leeks is 0.52 kg ai per hectare.

The energy per hectare of onions in this category is calculated by applying the energy coefficient from Table 6.5 for growth regulator to the amount of ai per hectare:

175*0.52 = 91.7 MJ per hectare

Energy per tonne of onions is obtained by dividing this energy per hectare by the onion yield per hectare:

91.7/35 = 3 MJ per tonne of onions

CO_2 emissions are then able to be calculated by using the CO_2 emission coefficient for growth regulator from Table 6.5 and multiplying the energy per tonne of onions by this value:

3*0.06 = 0.2 kg CO_2 per tonne of onions

Seeds

These will not be factored into the calculations for energy use and CO_2 emissions as the New Zealand figures did not include seeds.

Post Production

Cold and Controlled Atmosphere Storage

British onions are assumed to be stored for a minimum of nine months using a mixture of cold and controlled atmosphere environment. The onions used for storage are harvested in August and stored through to July.

The best data that was available for evaluating the energy cost of storage was the study conducted by Wells and Scarrow (1997) on the storage of kiwifruit. This is likely to underestimate the energy cost as the kiwifruit stores an ever decreasing volume of kiwifruit, hence decreasing energy load, over the 5 months that the stores are typically operated for. By contrast the volume of stored UK onions will remain the same over the 9 months required to get them into the same customer window in July.

Wells and Scarrow (1997) found that it took 0.614 kWh/tray, or 169 kWh/tonne, for pre-cooling and storage over 5 months. Of this 16 kWh/t were attributed to pre-cooling and 153 kWh/t to storage. Keeping the pre-cooling the same and increasing the storage component from 5 to 9 months equates to 291 kWh/tonne.

Based on the energy and carbon dioxide emission coefficients in Tables 6.1 and 6.3 total energy use was 3,020 MJ/tonne onions. Carbon dioxide emissions were 125 kg CO_2/tonne.

Comparison of NZ and UK Onion Production

The energy and carbon dioxide emission associated with onion production in NZ and the UK are summarised in Table 7.4. The table highlights the difference in energy content in production of onions for direct and indirect inputs, as yet no data is available for the UK for capital expenditure.

As Table 7.4 shows the direct energy in onions for NZ is higher than that in the UK at 342 MJ per tonne compared to 245 MJ in the UK. The energy in indirect inputs is also higher in NZ at 427 MJ per tonne compared to 367 MJ per tonne in the UK. Thus the energy associated with onion production is higher at 821 MJ per tonne in NZ compared with 678 MJ in the UK. When shipping costs are included, the NZ total rises to 2,889 MJ per tonne. However, when storage is included for the UK so they can supply the same window in market as NZ, the UK energy costs rise to 3,760MJ per tonne, higher than those in NZ.

In case of emissions the UK has a lower carbon dioxide emission rate per tonne of onions produced compared to NZ, at 170 kg emissions compared to 185 kg emissions in NZ per tonne onions produced. The apparent anomaly of NZ having lower energy but higher CO_2 emissions is due to the different mix of energy sources.

Table 7.4
Total energy and carbon indicators for NZ and UK onion production

Item	**Quantity/hectare**		**Energy MJ/Tonne onions**		**CO_2 Emissions kg CO_2/Tonne onions**	
	NZ	UK	NZ	UK	NZ	UK
Direct						
Fuel, Electricity and Oil (L of Diesel equivalent)		208		245		16.0
Diesel Use (L)	332		322		22.1	
Lubricants (L Oil)	6		6		0.2	
Electricity Use (kWh)	78		14		0.3	
Direct subtotal	**-**	**-**	**342**	**245**	**22.6**	**16.0**
Indirect						
Nitrogen (kg)	135	104	195	193	9.0	9.7
Phosphorus (kg)	134	37	45	16	2.7	1.0
Potassium (kg)	105	86	23	25	1.4	1.5
Sulphur (kg)	77		9		0.5	
Lime (kg)	977		13		9.3	
Herbicide (kg)	10.9	8.17	80	72	4.8	4.3
Fungicide (kg)	8.9	9.04	42	54	2.5	3.3
Insecticide (kg)	3.0	0.40	21	4	1.2	0.2
Plant Growth Regulator (kg)		0.52		3		0.2
Indirect subtotal	**-**	**-**	**427**	**367**	**31.5**	**20.1**
Capital						
Farm buildings (m^2)	0.9	0.9	12	15	1.2	1.5
Tractors and implements (kg)	31.3	31.3	39	51	3.7	4.7
Capital subtotal	**-**	**-**	**51**	**66**	**4.9**	**6.2**
Total Production	**-**	**-**	**821**	**678**	**58.9**	**42.3**
Yield (tonnes)	**45**	**35**				
Post harvest						
Grading	215	215	39	62	0.7	2.6
CA Storage (UK 9 months)	-	-		3,020		125.2
Shipping (NZ to UK) (17,840 km)	-	-	2,030		124.9	
Post harvest subtotal	-	-	**2,069**	**3,082**	**125.6**	**127.8**
Total Energy Input/Emissions	**-**	**-**	**2,889**	**3,760**	**184.6**	**170.0**

7.4 Lamb

NZ Lamb

Most of the lamb information was gathered from a database developed by Andrew Barber as part of the ARGOS Project (www.argos.org.nz) during 2004/05. The analysis of this database has not yet been presented in a report. The data for this report is based upon seven conventional farms which had a mix of sheep, beef and cropping.

In mixed output farms (sheep and beef meat, wool and crops), a way of allocating energy use and carbon dioxide emissions is needed. Two common methods is to either allocate as a proportion of output weight or on the share of revenue. In this study sheep production has been allocated according to its contribution to revenue, which was 47 per cent.

All outputs are either per hectare or tonne of carcass weight. In order to estimate the carcass weight it was assumed that each lamb and ewe sold weighted 55 kg and that the dressing-out percentage, the percentage of carcass weight to live weight, was 42 per cent (Burtt 2004). The seven farms surveyed were on average 359 ha and sold an average of 2,947 lambs and ewes.

Total on-farm energy input was 1,630 MJ/ha or 8.6 MJ/kg carcass (8,588 MJ/tonne carcass). This is 38 per cent lower than McChesney et al. (1981/82) found at 13.8 MJ/kg carcass. It is not clear in the paper how McChesney determined this figure.

Direct Inputs

Fuel, Electricity and Oil

The quantity of all direct inputs were taken from the ARGOS database, or MAF Policy (2005c). The coefficients used to derive the energy content and carbon dioxide emissions are described in Chapter 6.

Liquid Fuel Use

All the liquid fuel inputs were diesel and included all on farm operations as well as road transport using the farm utility or car. All personal transport was excluded.

Fuel use was 33.3 litres/ha, of which 15.5 L/ha was allocated to sheep production. Based on the energy and carbon dioxide emission coefficients described in Chapter 6, total energy use was 677 MJ/ha or 3,565 MJ/tonne carcass.

Carbon dioxide emissions were 46.5 kg CO_2/ha or 244.9 kg CO_2/tonne carcass.

Electricity Use

Electricity is only a small input in sheep production (7 per cent). The ARGOS electricity data is incomplete so electricity use was based on the MAF Farm Monitoring (2004) budget figure of $3,851 for a 660 ha, 5,014 stock unit sheep and beef farm. The cost of electricity including line charges for 3 phase power was obtained from the Genesis Energy web site for Wellington (http://www.genesisenergy.co.nz/genesis/index.cfm). Based on a line charge of $1.70/day and a variable rate of 16.45 cents/kWh total energy use was estimated at 30 kWh/ha, of which 14 kWh/ha were allocated to sheep. This is 113 MJ/ha or 594 MJ/tonne carcass.

Carbon dioxide emissions are 2.2 kg CO_2/ha or 11.4 kgCO_2/tonne carcass.

Indirect Inputs

Fertiliser

Fertiliser use was taken from the ARGOS database. Fertilisers were broken down into their N, P, K, and S components. The energy and carbon dioxide emissions for each component was then calculated from the coefficients described in Chapter 6.

The most significant fertiliser is nitrogen, accounting for 58 per cent of the fertiliser energy input.

Nitrogen

Nitrogen was applied across the whole farm at a rate of 12.3 kg/ha, 5.7 kg/ha of this was allocated to sheep. Using the energy coefficient of 65 MJ/kg, embodied energy in nitrogen is 371 MJ/ha (1,953 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient in Table 6.4 were 17.1 kg CO_2/ha or 90.1 kg CO_2/tonne carcass.

Phosphorus

Phosphorous was applied at a rate of 26.8 kg/ha, 12.5 kg/ha was allocated to sheep. Using the energy coefficient of 15 MJ/kg energy, embodied energy in phosphorous is 187 MJ/ha (985 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient in Table 6.4 were 11.2 kg CO_2/ha or 59.1 kg CO_2/tonne carcass.

Potassium

Potassium was applied at a rate of 1.2 kg/ha, 0.5 kg/ha was allocated to sheep. Using the energy coefficient of 10 MJ/kg energy, embodied energy in potassium is 5 MJ/ha (29 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient in Table 6.4 were 0.3 kg CO_2/ha or 1.7 kg CO_2/tonne carcass.

Sulphur

Sulphur is applied at a similar rate to phosphorous, being 26.4 kg/ha, of which 12.3 kg/ha was allocated to sheep. Using the energy coefficient of 5 MJ/kg energy, embodied energy in sulphur is 61 MJ/ha (323 MJ/tonne carcass).
Carbon dioxide emissions using the coefficient in Table 6.4 were 3.7 kg CO_2/ha or 19.4 kg CO_2/tonne carcass.

Lime

The ARGOS database showed lime was applied at a rate of 48 kg/ha, 22.3 kg/ha was allocated to sheep. Using the energy coefficient of 0.6 MJ/kg energy, embodied energy in lime is 13 MJ/ha (71 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient of 0.72 kg CO_2/MJ were 9.6 kg CO_2/ha or 50.6 kg CO_2/tonne carcass.

Agrichemicals

The ARGOS database has agrichemical use broken down into bloat oil, animal remedies, herbicides, fungicides, insecticides and other chemicals. The energy and carbon dioxide emissions associated with each of these are the same as these described in Section 7.1 NZ Dairy.

Total agrichemical use was 1.2 L ai/ha, 0.6 L ai/ha was allocated to sheep. Embodied energy was 64 MJ/ha (338 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient of 0.06 kg CO_2/MJ were 3.9 kg CO_2/ha or 20.3 kg CO_2/tonne carcass.

Capital Inputs

Vehicles

Vehicles used mainly include tractors and utilities. Total weight was 1.7 kg/ha, of which 0.8 is allocated to sheep. Based on a coefficient of 65.5 MJ/kg the embodied energy is 52 MJ/ha or 273 MJ/tonne carcass.

Carbon dioxide emissions at a rate of 0.094 kg CO_2/MJ are 4.8 kg CO_2/ha (25.4 kg CO_2/tonne carcass).

Buildings

On NZ sheep and beef farms there are two main types of buildings. The wool shed and general storage sheds for implements and hay or fodder.

Based on a life of 20 years sheds are just 0.14 m^2/ha/yr, 0.06 m^2/ha/yr being allocated to sheep. Based on a coefficient of 590 MJ/m^2, embodied energy is 38 MJ/ha (198 MJ/tonne carcass).

Carbon dioxide emissions using the coefficient of 0.1 kg CO_2/MJ were 3.8 kg CO_2/ha or 19.8 kg CO_2/tonne carcass.

Fences

The length of fences was calculated using Wells (2001) method as described in Section 7.1 NZ Dairy. This is based on the area, number of paddocks and internal race length. The ARGOS database found total fence length was 4.1 m/ha/yr, 1.9 m/ha/yr was allocated to sheep.

The length of each type of fence was then based on the farmer's estimate of the percentage of 7 wire post and batten, electrified fences, and deer fences. Post and batten have an embodied energy coefficient of 20 MJ/m length, electrified fences have an energy coefficient of 4.5 MJ/m length (Wells, 2001) and deer fences are 30 MJ/m. The carbon dioxide emission factor is 0.09 kg CO_2/MJ and the working life is 25 years for post and batten, and deer fences and 15 years for electrified fences. Based on these energy and carbon coefficients total embodied energy in fences is 37 MJ/ha (194 MJ/tonne carcass).

Carbon dioxide emissions contribute 3.3 kg CO_2/ha or 17.5 kg CO_2/tonne carcass.

Water Supply

NZ sheep and beef farms use a combination of reticulated water to troughs and access to natural water ways. The ARGOS database includes the type of pipe, its diameter and length. From this the embodied energy in a water supply attributable to sheep was 12 MJ/ha (66 MJ/tonne carcass) with a carbon dioxide emission of 0.6 kg CO_2/ha or 3.0 kg CO_2/tonne carcass.

UK Lamb

In the case of sheepmeat production finding sources of data on farm production systems was difficult given the fact there are few specialist sheep farms in the UK which do not have other stock or crops. Therefore the production system data for sheepmeat relied on Nix Farm Management Pocketbook data (Nix, 2004). There are also a number of sheepmeat production systems in the UK ranging from hill and upland to lowland farms. However, as typically it is the lowland farms where sheep are finished for meat, this is used as the system in the current report.

As for dairy, to assess the energy and emission levels per unit of output, in this case tonnes of meat carcass, the level of output has to be obtained and then the inputs. The average stocking rate and output from a lowland spring lambing operation, is 11 ewes per forage hectare with 1.45 lambs are reared per ewe, Nix (2004). The average lamb carcass in the UK weighed 19.3kg in 2004, Defra (2005c). Therefore, the output of meat per ewe is the number of lambs produced at 1.45 multiplied by the average weight of lamb carcass produced, at 19.3 kg, giving 28 kg of meat per ewe, (1.45*19.3 = 28.0 kg). This is equivalent (assuming a stocking rate of 11 ewes per hectare) to 308 kg of meat per hectare.

The next section calculates the energy and emissions associated with sheepmeat production. However, when calculating energy and emissions from sheepmeat, the rates calculated need to be discounted further to allow for the fact that not just meat is being produced but also co-products in the system (e.g. wool), Keedwell et al. (2002). These authors allocated the products from sheep production according to their contribution to revenue. Therefore in this study the energy consumed by the various elements will also be attributed according to revenue (as will CO_2 emissions). The level of revenue per ewe is £55.10 for lamb sales, £1.80 for wool and £5.80 for culling of ewes and rams, which comes to a total of £62.70, Nix (2004). Lamb sales are therefore 87.9 per cent of revenue and therefore it will be assumed that 87.9 per cent of energy and emissions will be attributed to meat production. This will henceforth be referred to as the "co-product discount rate", and will be used to adjust all the calculations below.

Direct Inputs

Fuel, Electricity and Oil

Nix (2004) allocates £35 per hectare for the fuel, electricity and oil expenses incurred in a predominantly sheep/cattle, lowland operation. However a further breakdown of this into its three components is not available, therefore a diesel equivalent total (which represents the components) will be derived, based on the price of diesel used in the dairy section above (24p).

The diesel equivalent of this fuel, electricity and oil cost is calculated by dividing the total cost per hectare by the price of diesel per hectare:

£35/0.24 = 145.8 litres per hectare of which 128 litres per hectare is attributed to lamb production.

Applying the energy coefficient on diesel from Table 6.3 and the co-product discount rate (discussed above) gives the following energy usage per hectare:

41.2*145.8*0.879 = 5,281.3 MJ

This energy use per hectare is then divided by the weight of lamb carcass per hectare, as derived above (308kg), and is multiplied by 1,000 to give the energy per tonne of carcass:

5,281.3/308*1,000 = 17,156 MJ per tonne of carcass

In order to derive the CO_2 emissions arising from fuel associated with lamb production, this value is then multiplied by the emission rate for diesel in Table 6.3:

17,156*65.1/1,000 = 1,116.9 kg CO_2 per tonne of lamb carcass

Indirect Inputs

Fertiliser

For the lowland spring lambing operation being assessed in this section, the fertiliser application rates were sourced from *The British Survey of Fertiliser Practice* (Chalmers et al., 2001), for grass 5 years and over. These rates are 87 kg of nitrogen, 8 kg of phosphorus, 17 kg of potassium, and 99 kg of lime, per hectare (after making appropriate transformations to separate out the raw amount of phosphorus and potassium from the stated P_2O_5 and K_2O figures respectively). Of these fertiliser inputs 76 kg of nitrogen, 7kg of phosphorous, 15kg of potassium and 87 kg of lime are attributed to lamb production.

Nitrogen

To calculate the energy associated with nitrogen fertiliser the energy coefficient for N fertiliser taken from Table 6.4 (65 MJ/kg) is multiplied by the application rate of 87 kg of nitrogen per hectare. This is then adjusted by the co-product discount rate (0.879), as follows:

65*87*0.879 = 4,970.7 MJ

Thus energy associated with nitrogen fertiliser is 4,971 MJ per hectare. To obtain the per tonne meat equivalent, the hectare amount is then divided by the weight of lamb carcass per hectare (308) and is multiplied by 1,000, as follows:

4,970.7/308*1,000 = 16,147 MJ per tonne of carcass

This value is the multiplied by the CO_2 emission rate for N fertiliser, also from Table 6.4, of 0.05 kg CO_2/MJ to give the amount of CO_2 per tonne of lamb carcass from N fertiliser application:

16,147*0.05 = 807.4 kg CO_2 per tonne of lamb carcass.

Phosphorus

When the energy coefficient for phosphorus from Table 6.4 (15 MJ/kg) and the co-product discount rate (0.879) are applied to the 8 kg of phosphorus, the following amount of energy results:

15*8*0.879 = 103.5 MJ

Dividing this amount of energy by the amount of carcass per hectare and multiplying by 1,000 gives the energy per tonne of carcass:

103.5/308*1,000 = 336 MJ per tonne of carcass

CO_2 emissions associated with phosphorus application in the lamb sector are obtained by multiplying the energy per tonne of carcass by the CO_2 emission rate for phosphorus in Table 6.4 (0.06):

336*0.06 = 20.2 kg CO_2 per tonne of lamb carcass .

Potassium

The energy coefficient for potassium from Table 6.4 (10 MJ/kg) and the co-product discount rate (0.879) are applied to the 17 kg/ha of potassium, to derive the energy associated with Potassium fertiliser application per hectare:

10*17*0.879 = 153.2 MJ

This is again divided by the amount of carcass per hectare and multiplied by 1,000 to obtain the energy per tonne of carcass from potassium application in the lamb sector:

163.2/308*1,000 = 498 MJ per tonne of carcass

CO_2 emissions per tonne of lamb carcass are then calculated using the emission rate for potassium from Table 6.4 (0.06 kg CO_2/MJ):

498*0.06 = 29.9 kg CO_2 per tonne of lamb carcass.

Lime

Following the same process as for the other fertilisers described above, the energy per hectare associated with the application of lime is calculated by applying the energy coefficient for lime from Table 6.4 (0.6) and the co-product discount rate (0.879) to the 99 kg of lime:

0.6*99*0.879 = 52.5 MJ

This energy value is then divided by the amount of carcass per hectare and multiplied by 1,000 to obtain the energy from lime application in the lamb sector per tonne of carcass:

52.5/308*1,000 = 170 MJ per tonne of carcass

This is converted to CO_2 emissions per tonne of lamb carcass arising from lime application by multiplying the above value by the CO_2 emission rate for lime in Table 6.4 (0.72 kg CO_2/MJ)):

170*0.72 = 122.7 kg CO_2 per tonne of lamb carcass.

Agrichemicals

As with dairy farming, only one type of agrichemical is assumed to be applied to fields – herbicide (MCPA), at the same application rate: 1.75 kg per hectare (see agrichemical section on dairy for details). Of this 1.54kg is attributed to lamb production.

For the energy and emission calculations, the coefficients from Table 6.5 for Herbicide – General will be used i.e. 310 MJ and 0.06 kg CO_2 per MJ. In addition to this the co-product discount rate will be applied (0.879).

The energy input per hectare for the herbicide is derived by multiplying the application rate of MCPA of 1.75kg by the energy coefficient obtained from Table 6.5, by the co-product discount rate (0.879) :

310*1.75*0.879 = 476.9 MJ per hectare

This value of energy per hectare is then divided by the carcass weight per hectare and multiplied by 1,000 to obtain the energy usage per tonne of carcass:

476.9/308*1,000 = 1,549 MJ per tonne of carcass

CO_2 emissions per tonne of carcass are then derived using the emission rate coefficient for this herbicide in Table 6.5 (0.06) and multiplying it by the energy per tonne of carcass:

1,549*0.06 = 92.9 kg CO_2 per tonne carcass

Concentrate

For lowland spring lambing operations Nix (2004) states that 53 kg of concentrate is fed to each ewe and 12 kg to each lamb. As with the dairy section above, this will be assumed to be barley, and the energy and emission coefficients of this are detailed in Table 6.8.

Since each ewe is assumed to have 1.45 lambs (which survive), the amount of concentrate which will be consumed per ewe is calculated by multiplying the number of lambs per ewe (1.45) by the amount of concentrate per lamb (12kg) and adding the amount of concentrate per ewe (53kg):

53 + 1.45*12 = 70.4 kg, of which 61.9kg is attributed to lamb production.

Applying the energy use coefficient from Table 6.8 (per tonne of concentrate) and the co-product discount rate gives the following energy use per ewe:

3,361*70.4/1,000*0.879 = 208.0 MJ

Dividing this energy use from concentrate by the average carcass weight (28kg) and multiplying by 1,000 gives the energy per tonne of carcass:

208.0/28.0*1,000 = 7,432 MJ per tonne of carcass

CO_2 emissions can be calculated by multiplying the weight of concentrates consumed by each ewe (and her 1.45 lambs) (70kg) by the co-product discount rate and by the CO_2 emission coefficient from Table 6.8 (per tonne of concentrate):

206.9*70.4/1,000*0.879 = 12.80 kg CO_2

This value can then be divided by the average carcass weight and multiplied by 1,000 to give the CO_2 emissions per tonne of carcass:

12,80/28.0*1,000 = 457.5 kg CO_2 per tonne of carcass.

Fodder/Forage

Nix (2004) allows £7.70 per hectare for forage variable costs, and as with the fodder and animal bedding for dairy farming, this will all be assumed to be grass silage at a price of £25 per tonne. Therefore the quantity used is: 7.7/25*1,000 = 308 kg per hectare, of which 271 kg is attributed to lamb production.

The energy used to produce this amount of fodder is calculated by multiplying the quantity of fodder per hectare (308 tonnes), the co-product discount rate, and the energy coefficient for this category from Table 6.9 (1.5) together:

1.5*308*0.879 = 406.1 MJ

The energy per tonne of lamb carcass is obtained by dividing the energy calculated above by the carcass weight per hectare, multiplied by 1,000:

406.1/308*1,000 = 1,319 MJ per tonne of lamb carcass

CO_2 emissions per kg of lamb carcass arising from fodder and forage are then calculated by multiplying this value per tonne of lamb carcass by the CO_2 coefficient from Table 6.9:

1,319*0.058 = 76.5 kg CO_2 per tonne of carcass.

Capital Inputs

Buildings

Sheep Shed

Nix (2004) makes provision for a sheep shed, with 1.35m^2 of pen space per ewe, of which 1.19 m^2 is attributed to lamb production.. The energy and emission coefficients (as well as the assumed working life – 20 years) will be taken from Table 6.12.

The energy used is calculated by multiplying the pen space per ewe by the energy use coefficient (590 MJ/m^2). This is then divided by the working life of the shed (20 years) to obtain the energy per ewe per year associated with a sheep shed:

(590*1.35)/20 = 39.8 MJ per ewe per year

This amount is then multiplied by the co-product discount rate, divided by the average carcass weight of 28kg and multiplied by 1,000 to give the energy per tonne of lamb carcass:

0.879*39.8/28.0*1,000 = 1,251 MJ per tonne of lamb carcass

CO_2 emissions per tonne of lamb carcass are calculated by multiplying the above energy value by the CO_2 emission rate of 0.1 kg CO_2 per MJ:

1,251*0.1 = 125.1 kg CO_2 per tonne of carcass.

Table 7.5
Total energy and carbon dioxide indicators for NZ and UK lamb production

Item	Quantity/hectare		Energy MJ/Tonne carcass		CO_2 Emissions kg CO_2/Tonne carcass	
	NZ	UK	NZ	UK	NZ	UK
Direct						
Fuel, Electricity and Oil (L of Diesel Equiv.)		128		17,156		1,116.9
Fuel use (L of Diesel) (including contracting)	15.5		3,565		244.9	
Electricity use (kWh)	13.8		594		11.4	
Direct sub total	**-**	**-**	**4,158**	**17,156**	**256.3**	**1,116.9**
Indirect						
Nitrogen (kg)	5.7	76	1,953	16,147	90.1	807.4
Phosphorus (kg)	12.5	7	985	336	59.1	20.2
Potassium (kg)	0.5	15	29	498	1.7	29.9
Sulphur (kg)	12.3		323		19.4	
Lime (kg)	22.3	87	71	170	50.6	122.7
Agri-chemicals (L ai)	0.6	1.5	338	1,549	20.3	92.9
Concentrate (kg of dry matter)		681		7,432		457.5
Forage, fodder and bedding (kg grass silage)		271		1,319		76.5
Indirect sub total	**-**	**-**	**3,698**	**27,452**	**241.3**	**1,607.1**
Capital						
Vehicles and machinery (kg)	0.8		273		25.4	
Farm buildings (m^2)	0.1	13.1	198	1,251	19.8	125.1
Fences (m)	1.9		194		17.5	
Stock water supply	-		66		3.0	
Capital sub total	**-**	**-**	**731**	**1,251**	**65.6**	**125.1**
Total Production	**-**	**-**	**8,588**	**45,859**	**563.2**	**2,849.1**
Yield (kg lamb carcass)	**190**	**308**				
Post Production						
Shipping NZ to UK (17,840 km)	-	-	2,030	-	124.9	-
Total Production Energy Input/Emissions	**-**	**-**	**10,618**	**45,859**	**688.0**	**2,849.1**

Comparison of NZ and UK Lamb Production

Table 7.7 compares the production, energy and carbon dioxide emissions for lamb production in the UK and NZ. This shows that NZ has considerably lower direct energy inputs per tonne of carcass at 4,158 MJ compared to 17,156 MJ in the UK. In case of indirect energy use the energy input in NZ are also significantly lower at 3,698 MJ per tonne of carcass weight compared to 27,452MJ in the UK. When the energy embodied in capital is included, NZ energy inputs are lower still with total energy associated with production 8,588 MJ in NZ compared with 45,859 MJ in the UK. Including transport to the UK market increases the energy used in NZ production but just to 10,618 MJ which is under a quarter of that in the UK. This reflects the extensive production system in NZ compared with the UK.

In the case of emissions NZ carbon dioxide emissions are lower at 688 kg CO_2/Tonne carcass compared to 2,849 in the UK.

Chapter 8
Conclusions

Food miles is a very simplistic concept relating to the distance food travels as a measure of its impact on the environment. As a concept food miles has gained some traction with the popular press and certain groups overseas. However, this debate which only includes the distance food travels is spurious as it does not consider total energy use especially in the production of the product. This report has attempted to address some of these factors by comparing the energy use and CO_2 emissions associated with a production system in NZ and that in an EU country. Included in the analysis is the cost of transport to the UK border.

This report has shown that in the case of dairy and sheepmeat production NZ is by far more energy efficient even including the transport cost than the UK, twice as efficient in the case of dairy, and four times as efficient in case of sheepmeat. In the case of apples NZ is more energy efficient even though the energy embodied in capital items and other inputs data was not available for the UK. 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.

A number of caveats should be raised when interpreting these results. The most important of these was the lack of comparable data between the countries and more importantly the lack of data in particular for the EU countries on production systems and their energy use. A second important caveat is that the analysis assumes that the EU would be able to meet the shortage of supply if NZ did not supply the EU market. It also assumes that this can be done using the same levels of inputs currently used. This may well not be the case especially for important products where NZ supplies significant parts of the market especially out of season. To supply these would mean that land would have to be diverted from other uses and this land is unlikely to be of the same quality as existing land producing the product and therefore may well require greater inputs. Moreover, in some products such as onions it is doubtful that the technology exists to be able to store the product to match the same window of supply as NZ produce can. Finally the report has also assumed that the products to replace NZ imports are of similar quality and type, this is clearly not always the case.

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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	£38 per cow
Vet. and Med.	£23 per cow
A.I. and Bull Hire	£12 per cow
Recording,	£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)

Table A.2: Sheep Production system for the UK

Item	**Cost**	**Physical Level**
Stocking rate		11 ewes (with lambs) per forage hectare
Lambs reared		1.45 per ewe (put to ram)
Fuel, Electricity and Oil	£35 per hectare	
Concentrate		53 kg per ewe and 12 kg per lamb
Vet. and Med.	£5.50 per ewe	
Miscellaneous and Transport	£6 per ewe	
Forage Cost	£7.70 per ewe	
Tractor Usage		1.25 hours per ewe
Machinery Depreciation	£70 per hectare	
Machinery Repairs	£40 per hectare	
Contract	£40 per hectare	
Vehicle tax and insurance	£10 per hectare	
Rent/Rental Value	£115 per hectare	
General Overhead expenses	£125 per hectare	
Buildings	553 pounds per cow	Covered strawed yard with 4.0 m^2 per head floor area Covered collection yard with 1.1 m^2 per cow Milking parlour building: 63.25 m^2 total

Source: Nix (2004)

Table A.3: Dessert Apples Production system for the UK

Item	Cost	Level
Yield		14 tonnes per hectare
Fuel, Electricity and Oil	£135 per hectare	
Fertiliser	£75 per hectare	
Sprays	£400 per hectare	
Packaging	£450 per hectare	
Casual Labour (picking)	£1,450 per hectare	
Regular Labour		185 hours per hectare
Regular Labour (paid)	£701 per hectare	
Regular Labour (unpaid)	£329 per hectare	
Machinery Depreciation	£214 per hectare	
Mach. Repairs, Vehicle taxes and Insurance	£173 per hectare	
Rent and Rates	£369 per hectare	
General Overhead Costs	£351 per hectare	

Source: Nix (2004)

Table A.4: Onion Production system for the UK

Item	Cost	Level
Yield		35 tonnes per hectare
Fuel, Electricity and Oil	£50 per hectare	
Seed	£325 per hectare	
Fertiliser	£125 per hectare	
Sprays	£375 per hectare	
Other (including casual labour and packaging etc)	£1,450 per hectare	
Regular Labour		40-60 hours per hectare
Machinery Depreciation	£90 per hectare	
Machinery Repairs	£55 per hectare	
Contract	£62.50 per hectare	
Vehicle tax and insurance	£12.50 per hectare	
Rent/Rental Value	£160 per hectare	
General Overhead expenses	£85 per hectare	

Source: Nix (2004)