Energy use, "food miles" and greenhouse gas emissions from New Zealand dairying – how efficient are we?

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Abstract

Assessment of energy use and greenhouse gas emissions associated with dairy products needs to account for the whole life cycle of the products, particularly with the debate about "food miles"(the transportation of product from producer to consumer). A life cycle assessment (LCA) of an average NZ dairy farm for 2005 showed that total energy use per kg milk from the "cradle-to-milk-in-the-vat" was 45-65% of that from EU farms. The greenhouse gas (GHG) emissions or carbon footprint showed similar relative trends although differences were smaller due, at least in part, to lower methane efficiency from lower-producing NZ cows. Energy use associated with shipping dairy product (e.g. cheese) from NZ to UK is equivalent to about one-quarter of the on-farm use. Even when added together, the energy use from the NZ farm and from shipping would still be less than on-farm energy use for the EU farms. However, this is affected by intensification and the Dexcel Resource Efficient Dairying trial showed that increasing maize silage use, and nitrogen fertiliser use in particular, increased the energy use and GHG emissions per kg milk by up to 190% and 23%, respectively. Thus, the trend for intensification on NZ dairy farms means that our comparative advantage with EU farms is diminishing. A focus on improved farm system practices and integration of mitigation options is required to reverse this trend.

Keywords: food miles, greenhouse gases, energy, life cycle assessment, milk, New Zealand, efficiency

Introduction

Most NZ food products are exported worldwide and have to be transported over long distances to reach their markets. The concept of "food miles" (defined as the distance food travels from producer to consumer; Paxton 1994) has become popular in the UK and potentially threatens market access of NZ food products to distant markets. The purpose of this study was to analyse the relevance (or not) of "food miles" in the debate over sustainability and export of NZ dairy products. Dairy products were selected because of the importance of the dairy industry to the NZ economy. In 2004, 660 000 tonnes of whole-milk powder and 296 000 tonnes of cheese were exported from NZ (Ministry of Agriculture and Forestry 2005). Cheese exported to the UK was selected as a case study because the UK is one of the furthest export destinations for NZ products and there is a high level of awareness about "food miles" in this country. A life cycle assessment (LCA; e.g. Cederberg & Mattsson 2000; McGregor *et al*. 2004) was performed for all inputs relating to farm production from the "cradle-to-milk-in-the-vat" (i.e. including all aspects of resource use from extraction of resources such as phosphate rock in Africa, its manufacturing and use on farm) for an average NZ dairy farm. This was compared with an LCA for EU dairy farm systems. The contribution from transportation to a UK market was determined and implications of intensification of NZ dairying were also studied. Information relating to total energy use and greenhouse gas (GHG) emissions is presented.

Materials and Methods

Dairy farm system LCA

An LCA (Basset-Mens *et al*. 2007) was prepared covering all aspects of resource use and potential environmental impacts for an average NZ dairy farm for 2004/2005 (only energy use and GHG emissions are presented here). It used data from LIC (2006), Dexcel ProfitWatch and surveys, and was based on a 115 ha dairy farm with 2.8 cows/ha, producing 862 kg milksolids/ha, using 114 kg fertiliser-N/ha/yr and purchasing supplementary feed equivalent to 1100 kg DM/ha/yr. It also accounted for resource use associated with land for grazing replacement animals and land producing the supplementary feed which was assumed to be maize and annual ryegrass silage (see Ledgard *et al*. 2003).

Dairy product LCA

Cheese processed in the Waikato was used as a case product and was assumed to be distributed to the UK by shipping (Fig. 1). The most recent data available for energy used in dairy manufacturing was from Lovell-Smith and Baldwin (1988) but this was similar to more recent data from Denmark (LCAFood 2003). It was assumed that the cheese was refrigerated for all transportation stages and during storage at the retail distribution centre and at home. Specific industry data were used for transportation from farm to factories and

Figure 1 Life cycle of cheese in the study (distances are one-way).

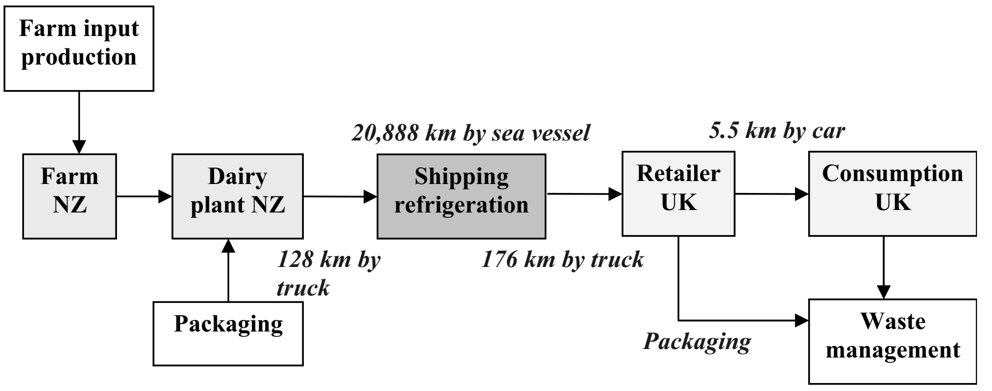
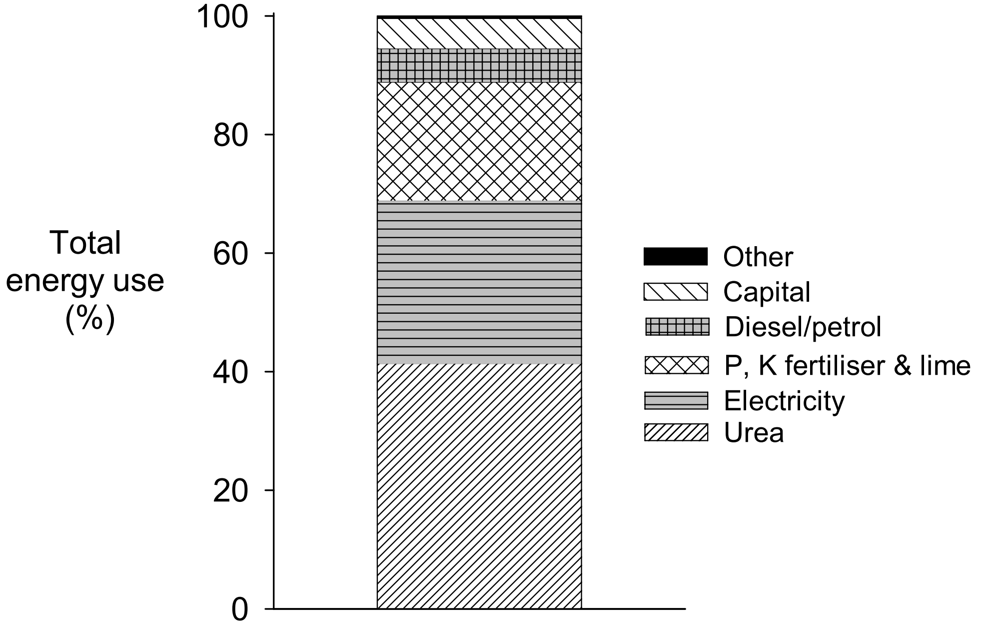


Figure 2 Contribution of different sources to total energy use for the average 2005 NZ dairy farm to the stage of milk-in-the-vat.



from factories to NZ port. Transportation distance by ship was obtained from maritimeChain (2006) and data for onward transport to retailer and to the home were from Smith *et al*. (2005).

Evaluation of effects of dairy intensification

The average NZ farm for 2004/2005 was compared with that for an average 1997/1998 farm using data from LIC (2006) and fertiliser companies.

The Dexcel Resource Efficient Dairying (RED) trial (Jensen *et al*. 2005) was used to examine effects of intensification by comparing results for the following four farmlets:

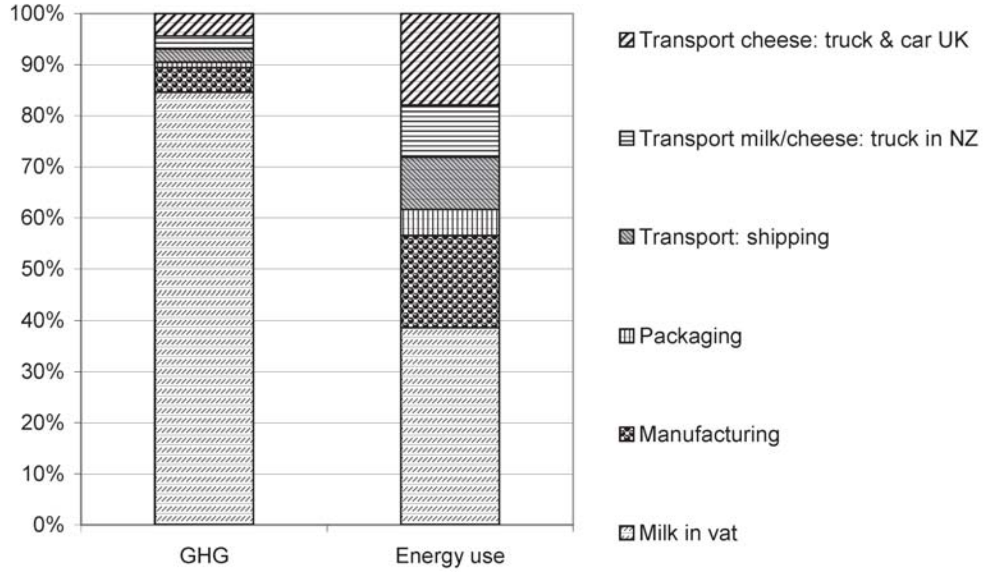
1. Nil-N-fertiliser, 2.3 cows/ha, replacements grazed on.
2. 170 kg fertiliser-N/ha/yr, 3.0 cows/ha, replacements off.
3. Maize silage (10 t DM/ha/yr-equivalent), 170 kg fertiliser-N/ha/yr, 5.2 cows/ha, replacements off.
4. High supplements (20 t maize-DM/ha and 3 t soybean-DM/ha), 170 kg fertiliser-N/ha/yr, 7.0 cows/ha, replacements off.

The LCA again incorporated all components of resource use, transportation and emissions for the whole-systems including that from all cropped land (maize in NZ and soybean in South America).

Quantification of greenhouse gases and energy use

The LCA methodology was used to quantify GHGs and energy use, and these are expressed per kg of milk. GHG

Figure 3 Contribution analysis of GHG and energy use for NZ cheese.



emissions were calculated according to the standard NZ-IPCC method in kg CO_2-equivalents as CO_2 x 1, N_2O x 310 and methane x 21. Energy use, and CO_2 emissions from it, refers to direct energy use (such as electricity on the farm) and indirect energy use to extract, produce and deliver the inputs of production such as fertilisers, capital, oil and electricity. Energy use and GHG emissions were allocated between the co-products milk and meat (85:15) according to a biological causality.

Results and Discussion

Average NZ farm LCA

A breakdown of the main contributors to total energy use from the "cradle-to-milk-in-the-vat" (Fig. 2) for the average NZ dairy farm in 2004/2005 shows that N fertiliser (based on urea and including manufacturing and use) contributed 41%, electricity 28% and fuel use 6%. Of this total energy use, 87% was from the dairy farm and 13% from the areas used for grazing replacement animals and producing brought-in feed.

Total GHG emissions of 0.94 kg CO_2-equivalent/kg milk were calculated to be 57% methane, 33% nitrous oxide and 10% CO_2. The latter is largely from the total energy use.

Dairy product LCA

A full LCA of cheese from the "cradle to UK consumer" (Fig. 3) shows that the on-farm production component was the greatest contributor, ranging from 39% for energy to 85% for GHG. Dairy manufacturing was a significant contributor to total energy use at 18%. All transportation stages together (truck, ship, car) contributed from 9.5% (GHG) to 38% (energy). Ship transportation constituted 27% of all transportation stages and overall it contributed only 2.6% to total GHG and 10% to total energy use for the cheese life cycle.

Comparison with EU dairy farms

The estimated total energy use from the "cradle-to-milk-in-the-vat" for EU farms was higher than that for the average NZ farm by between 53% for the UK farm and 220% for the conventional Dutch farm (Fig. 4; Cederberg & Mattsson 2000; Thomassen *et al*. 2007; Williams *et al*. 2006). This can be attributed to a number of factors including higher N fertiliser use, winter housing and greater use of supplementary feed/concentrates (with associated energy use in growing, harvesting, transporting and feeding) for the EU farms. The 53% higher energy use per kg milk from the UK farm relative to the NZ farm is less than the corresponding 110% value for the UK versus NZ dairy case study of Saunders *et al*. (2006). However, the latter study did not use a whole-system LCA methodology and was based on the early NZ dairy data of Wells (2001) with lower farm inputs than for the current average NZ farm (see next section on effects of intensification).

If the energy use associated with the extra food miles (i.e. the shipping and transportation component from NZ factory to UK port) were added onto the NZ farm energy use, the estimates for the EU farms were 15 to 140%. This indicates that NZ dairy farms have a relatively high energy use efficiency compared with EU farms, even accounting for food miles. There is a similar relativity for GHG (Fig. 5), although the variation between countries is less than that for energy use. The latter can be attributed, at least in part, to the smaller difference in

Figure 4 Total energy use per kg milk to the stage of milk-in-the-vat for dairy farms in different countries, including conventional (Conv.) and organic (Org.) farms for Sweden and the Netherlands. The hatched bar above the NZ farm represents energy use associated with food miles to the UK.

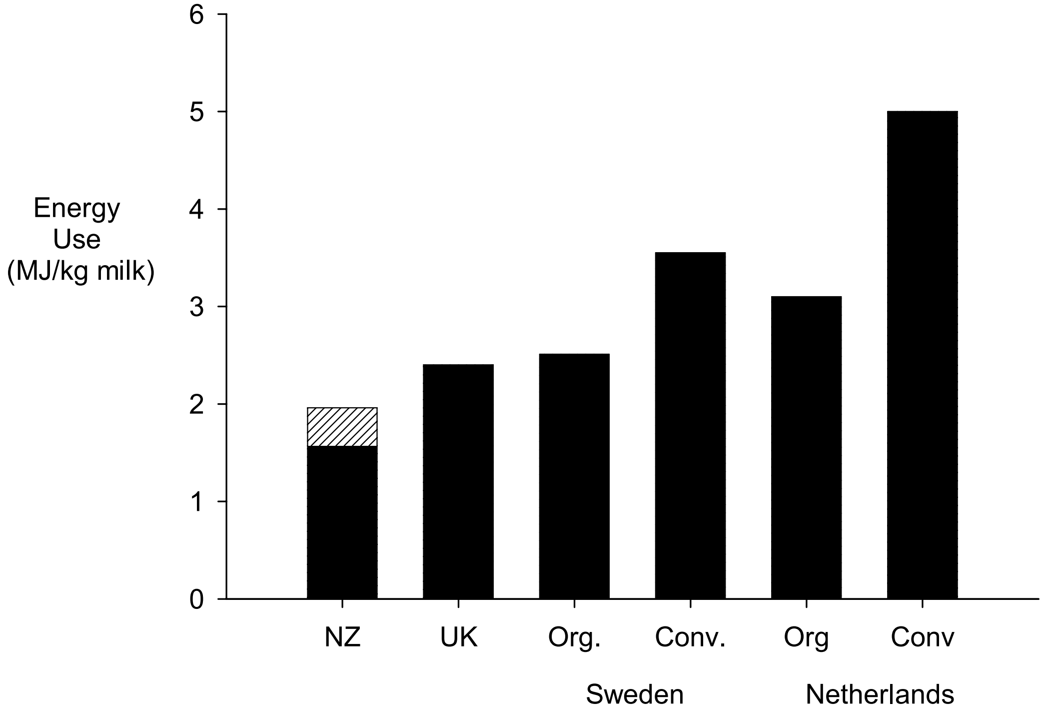


Figure 5 Total greenhouse gas emissions per kg milk to the stage of milk-in-the-vat for dairy farms in different countries, including conventional (Conv.) and organic (Org.) farms for Sweden and the Netherlands. The hatched bar above the NZ farm represents emissions associated with food miles to the UK.

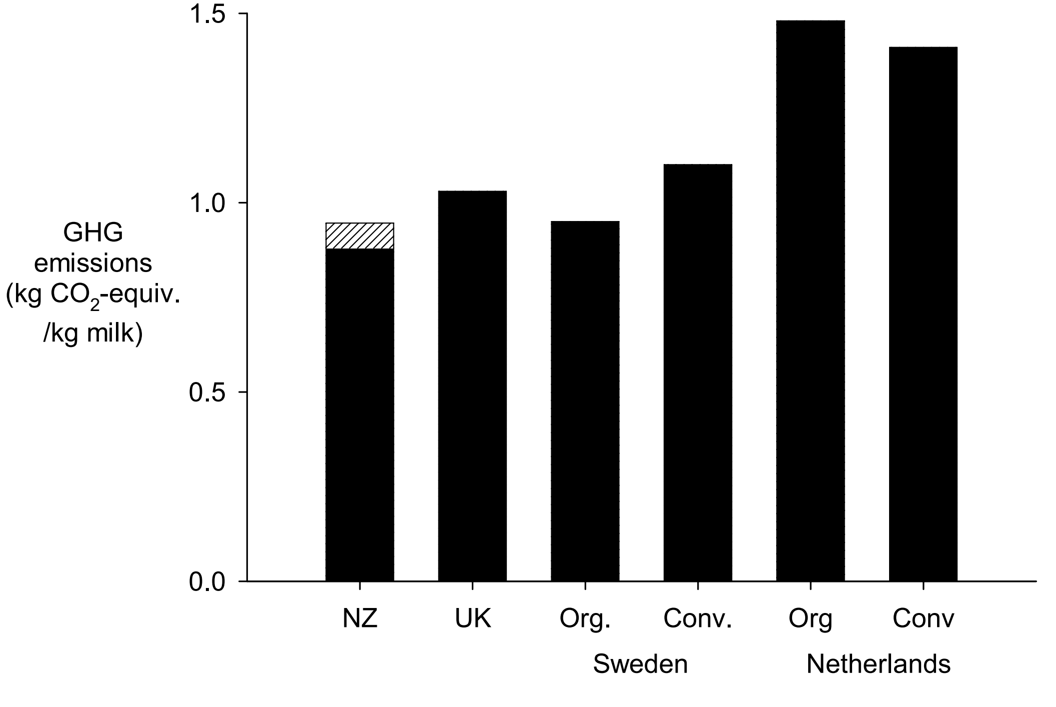


Table 1 Changes in energy use efficiency and GHG per kg milk produced associated with intensification in the RED trial farmlets.

	nil-N	170-N	+maize	+high suppl.
Energy use (MJ/kg milk)	0.55	1.13	1.55	1.75
GHG (kg CO_2-equiv./kg milk)	0.65	0.76	0.75	0.78
Milksolids (kg/ha/yr)*	987	1162	2215	2867

* Jensen *et al.* (2005); data applies to dairying land only and excludes cropping land

methane emissions per kg milk due to the higher per-cow milk production and relatively lower cow maintenance component on EU farms.

It should be noted that estimates are based on initial comparison between results from four separate studies at national level. Big variability across EU studies can be noted, probably due both to country specificities (climate, farm practices) and to small differences in methodologies. In particular in the UK study; (a) a quite different approach was used to model the UK dairying system, including a weighting of different types of production and (b) different methodological assumptions were made which make it difficult to compare directly with our results. A comparative study with harmonised methodology is needed to validate this analysis and is planned.

Evaluation of effects of dairy intensification

The average NZ farm for 2004/2005 showed 13% greater energy use per kg milk compared with that for the average 1997/1998 farm. This reduced energy efficiency was largely due to the increase in N fertiliser use on farms. In contrast, the calculated GHG emissions per kg milk were 2% lower for the 2004/2005 farm because of higher per-cow milk production.

The RED trial had a range of intensification practices resulting in a three-fold range in milksolids/ha production (Jensen *et al*. 2005). On a per kg milk production basis, the most energy-efficient farmlet was the self-contained nil-N-fertiliser farmlet, by at least two-fold relative to the other farmlets (Table 1). This can be attributed to the high energy requirement associated with manufacturing urea (c. 30 MJ/kg urea; Wells 2001). The use of maize silage for intensification was calculated to have a greater energy use efficiency than N fertiliser, as evident from a 37% increase in energy use for a 90% gain in milksolids per on-farm hectare for maize compared to a 105% increase in energy use for an 18% production gain for N fertiliser (based on a comparison of +maize versus 170-N, and 170-N versus nil-N, respectively). Nevertheless, maize silage use was still associated with a decrease in energy efficiency, even with a 30 t DM/ha crop (data not presented). The +maize farmlet also had a higher GHG efficiency than the 170-N farmlet, with a marginal GHG emission for the maize supplementation component (0.74 kg CO_2-equivalent/ kg milk) not much higher than the nil-N farmlet. The lower maize system emissions were associated with reduced nitrous oxide emissions (from low N excretion), countering the increased energy-related CO_2 emissions. Our study did not account for CO_2 emissions from maize cultivated soil, although if maize was part of a pasture rotation the net long-term effect may be minimal. The high energy use and GHG emissions with the high supplement farmlet system was due in part to the imported soybeans (protein source) from South America.

It should be noted that this paper refers only to energy use and GHG emissions. Application of the LCA methodology results in a wide range in estimates of resource use and environmental emissions, and the relative effects of intensification on these other indices vary (Basset-Mens *et al*. 2007). For example, the eutrophication index focuses on N and P losses to waterways and a dairy system with an optimally managed maize silage component can potentially reduce N leaching per kg milksolids (Williams *et al*. 2007).

Conclusions

The average NZ dairy farm showed greater energy use efficiency and GHG efficiency than the three EU farm systems against which it was compared, although methodology differences mean there is some uncertainty about the magnitude of this difference. Energy use associated with shipping (the largest part of the food miles distance) from NZ to UK represented a small component (c. 10%) of total energy use for the life cycle from cradle to consumer. Even when added to on-farm energy use, it did not negate the comparative advantage of the NZ farm system relative to the EU farm systems. This also applied to the GHG or carbon footprint (from total CO_2-equivalent emissions), although there was a smaller difference between the various farm systems than in the energy used. The RED trial revealed that intensification of dairy farms, through increased use of maize silage and by increased N fertiliser use in particular, reduced the energy use efficiency. Thus, the trend for intensification on NZ dairy farms means that our comparative advantage with EU farms is diminishing. A focus on improved farm system practices and integration of mitigation options is required to reverse this trend.

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