The Carbon Footprints of Beef and Lamb

A Lifecycle Approach to Measuring the Sustainability of New Zealand's Primary Produce

by

Amélie Goldberg

Thesis

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Abstract

Carbon footprints show the carbon impacts of food products. They are argued here to reflect these impacts more accurately than 'food miles'. New Zealand research has shown that our major primary sectors are more efficient in terms of carbon dioxide emissions than their British equivalents over the farming and shipping stages of the lifecycle. However, little research has examined other stages, such as road and rail freight and meat processing *within* New Zealand. Furthermore, the agro-food sector only has partial knowledge about its greenhouse gas (GHG) emissions from 'farm gate to plate' and is not yet fully prepared to implement GHG mitigation strategies. The aims of this study are to 1) calculate the carbon footprints of beef and lamb produced and consumed in New Zealand using a lifecycle approach (including all GHGs), and 2) evaluate, through key stakeholder interviews, the applicability of the carbon footprint concept to New Zealand for addressing consumer environmental concerns. The calculations show that the GHG footprints (all GHGs) of beef and lamb are comprised, for the most part, of on-farm methane and nitrous oxide emissions. Domestic and international freight contribute less than 5% to these footprints, and data from a case study of two meat processing plants suggest that meat processing emissions contributes even less than freight emissions. When leaving aside on-farm methane and nitrous oxide emissions, meat processing and freight contribute less than half to the carbon dioxide (CO₂) footprints. Interviews conducted for this study show that key stakeholder attitudes to these issues are varied. Responses from government representatives centred on the need to support the agro-food sector in responding to foreign market demands; the response from industry was mixed but suggests that it is prepared to account for its GHG emissions, showing a preference for carbon footprints over food miles. Environmental NGOs warned that there are risks to New Zealand if it continues to rely on a 'clean green' image mostly due to its natural comparative advantage, and fails to account for its emissions.

Keywords

Lifecycle assessment, carbon footprints, food miles, sustainable food systems, New Zealand's agro-food sector.

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1

INTRODUCTION

Today's food system is experiencing unprecedented changes in how food is produced, distributed, and consumed. Food systems are highly dependent on fossil fuels, emit large quantities of greenhouse gases (GHGs), and significantly contribute to some serious environmental problems (Steinfeld *et al.*, 2006). The sustainability of the world's food systems will be affected by a changing climate, an increasingly carbon-constrained world, rising energy costs (Greene *et al.*, 2006; Hirsch, 2007; MED, 2007c), as well as a raft of other issues. These concerns are also increasingly influencing the purchasing decisions of consumers, who are looking to reduce their environmental impact including their contribution to climate change.

1.1 New Zealand's Strategic Management

The drivers of change discussed above present potential risks and opportunities to New Zealand and therefore have implications for the strategic management of our economy. New Zealand could pursue a 'laissez-faire' strategy, continuing to let the market deal with energy scarcity and the Emissions Trading Scheme (ETS) with carbon emissions; or, it could pursue a strategy that positions New Zealand's economy to better manage risk and take advantage of opportunities arising from energy independence, carbon abatement and related consumer concerns. The government has a role to provide strategic direction and better manage these risks and opportunities, but needs industry cooperation and good information to work with.

The risk posed by 'food miles', a concept which measures environmental impacts in terms of the distance food travels from producer to consumer, has received particular attention in recent years. The concept gives environmentally conscious consumers the ability to base

purchasing decisions on the distance food has travelled and therefore to preferentially purchase products with a smaller apparent environmental impact from food transport. Food miles has potentially significant implications for New Zealand due to the large distance our exports travel to their markets, particularly the 15% and 13% sold to European and US consumers respectively (Statistics NZ, 2007). Carbon footprints, which measure the GHGs emitted throughout the lifecycle of a product (from production through to consumption, and in some cases disposal), have been mooted as a more meaningful response to the environmental concerns of overseas consumers, because footprint calculations constitute a more comprehensive approach to demonstrating environmental performance.

The idea of 'food miles' has become popular in the United Kingdom media, perhaps because it provides an easy to grasp rule-of-thumb for consumers wishing to exercise their ecological citizenship. British media have often suggested that New Zealand products should be avoided because of their large food miles relative to domestic or European products (Finch & Vidal, 2007; Lawrence, 2005; Oram, 2007a; Shepard, 2007). Moreover, British food retailers have taken opportunities to use food miles for marketing purposes (Figure 1).

Figure 1 Advertisement for British Butter

A synthesis of New Zealand media reports and politicians' speeches from mid-2006 to the end of 2007 reveals that New Zealand has a well-formulated political response to these claims. The report by Saunders *et al.* (2006) commissioned by the Ministry of Agriculture and Forestry (MAF) (further discussed in Chapters Four and Six below) has received a lot of media attention including in the *Dominion Post* (Davey & Laurence, 2007; Gibson, 2007; Goff, 2007; Luke, 2007; The Dominion Post, 2007), *The Press* (Eaton, 2007), *The Listener* (Price, 2007), *Radio New Zealand National* (Oram, 2007a), and by several New Zealand Government Ministers (Clark, 2007; Mallard, 2007; New Zealand Government, 2007). For example, Trade Minister Hon Phil Goff criticised the use of the food miles in the United Kingdom as “simply another thinly disguised protection mechanism” (Luke, 2007: C8).

Early articles and statements focused on addressing the risk posed by food miles by affirming the efficiency of the New Zealand agro-food sector's *modus operandi*. However, more recently, government and industry are recognising the significant opportunities that can be gained from consumer environmental concerns. The opportunity to demonstrate New Zealand's 'clean green' image (CGI) has been widely acknowledged as New Zealand products compete not only on price but also on perceptions of how the product is produced, its traceability, and its environmental and animal welfare credentials. Prime Minister Hon Helen Clark recently affirmed how critical New Zealand's 'clean green' reputation is and explained that, although food miles has limitations, this type of consumer concern “is a warning to us that we must constantly strive to have the best possible environmental credentials in everything we do, if we are to retain and grow our markets” (Clark, 2007). Former Economic Development Minister Hon Trevor Mallard also commented:

Crucial sectors of our economy are already under pressure from international customers. Presenting impeccable environmental credentials is hugely important to be able to continue to sell our products. The simplistic and erroneous food miles argument is just one example why such credentials are necessary.

(Mallard, 2007)

In partnership with research organisations, the agro-food industry is beginning to see the opportunities in transparently auditing, managing and mitigating GHG emissions. The Government's sustainability 'six-pack' (MfE, 2007b), in particular Eco-Verification (Cabinet, 2007), the forthcoming ETS and the GHG Footprinting Strategy (MAF, 2007)

should help to encourage the agro-food sector to demonstrate (and improve) its environmental performance. In November 2007, some months after research for this thesis began, Minister of Agriculture and Forestry Hon Jim Anderton announced that Government and industry groups were signing contracts for GHG footprinting projects that include around 65% of all land-based primary exports, and which would employ the lifecycle approach, encompassing the farm through to the destination port, and in some cases through to the point of retail in foreign markets.

By July next year, we will have three sectors already completed: dairy, wine, and kiwifruit. Two others will be well on the way – forestry and lamb, with on-farm beef and venison also being done.

(Anderton, 2007)

Current and proposed government and industry auditing efforts indicate opportunities are being taken. However, there are risks from only demonstrating current performance versus demonstrating that performance is being improved. For example, under current conditions New Zealand's extensive production systems enjoy a natural comparative advantage. This results in products with apparently lower carbon footprints relative to products from intensive housed production systems. However, methane capture technologies may prove to be easier and more effective for housed livestock systems with contained animal waste. The United States, Australia and the United Kingdom (but not New Zealand) are working towards such projects through their membership in the 'Methane to Markets' initiative, which identifies methane recovery and uses opportunities in animal waste management (Methane to Markets, 2006).

1.2 Aims and Objectives

The aims of this study are to 1) calculate the carbon footprints of New Zealand beef and lamb, and 2) evaluate the relevance of the carbon footprint concept to New Zealand for addressing consumer environmental concerns.

The objectives of the research are to:

- 1 Identify the relevant trends in thinking about agro-food systems, and consumer trends towards ecologically-aware food consumption (Chapter Three).
- 2 Compile baseline information on the overall GHG emissions associated with beef and lamb production, processing and transport in order to identify stages

in the lifecycle of beef and lamb where a reduction in emissions might be achieved (Chapter Five). Chapter Four prefaces this with a review of New Zealand-specific literature on this topic.

- 3 Investigate stakeholder views on the potential of carbon footprints for addressing consumer environmental concerns (Chapter Six). Specifically, investigation will focus on:
 - a Whether food miles concerns threaten New Zealand primary food exports, and whether the carbon footprint concept is useful for responding to food miles concerns
 - b The preparedness of industry to account for GHG emissions
 - c Identifying the important issues associated with New Zealand's 'clean green' image (CGI), if seen to be important
 - d The opportunities for reducing the carbon footprints of New Zealand food.

1.3 Research Purpose and Scope

Individual foods can have substantially different environmental impacts depending on how they are produced, processed, packaged and transported (Brodt, 2007). Lifecycle analyses (LCAs) of different foods quantify and clarify environmental impacts holistically by assessing all effects from production through to consumption (and sometimes through to disposal). LCAs generally include a set of impact categories such as water pollution, ecotoxicity, ozone depletion, and emissions to air. However, because of the recent emphasis on climate change, this research uses GHG emissions, expressed in terms of global warming potential (GWP), as a key indicator of environmental impact. This provides a lens to focus on a critical element of the sustainability of one of New Zealand's primary industries. Fossil energy dependence is not explicitly discussed. Energy use calculations in this study are a means to obtain GHG emissions. An analysis of energy use would complement this study's context in terms of New Zealand's strategic management of energy scarcity dependence.

Beef and lamb were chosen in this study because they generally have the greatest share of merchandise exports by value after dairy (Meat and Wool NZ, 2006; Statistics NZ, 2007), and cause serious environmental impacts (Steinfeld *et al.*, 2006). Other sectors such as

dairy, wine, and fruit also require investigation for comparison, but are beyond the scope of this study.

An exploration of the ongoing debate on the costs and benefits of international trade and local food is also outside the scope of this thesis.

2

METHODOLOGY

This chapter describes the methodology employed to address the aims of this study. The philosophical assumptions inherent in the research are presented first, followed by an outline of the research design. Finally, the specific methods used to address each of the objectives are explored.

2.1 Philosophical Assumptions

2.1.1 Positionality

My positionality in this research is based on my perceptions of the environment-economy interaction. Generally I see myself as having elements of the ‘bioenvironmentalist’ worldview as described by Clapp and Dauvergne (2005). Bioenvironmentalists stress the biological limits of the earth to support life and reject the neoclassical assumption of infinite economic growth, which, in my view, is a key cause of today’s global environmental crisis. I focus principally on environmental sustainability, and believe one of the largest barriers to achieving sustainability is the disjunct between producers and consumers. Enabling better understanding between producers and consumers about aspects of production and consumption that are not reflected in prices is an essential part of mainstreaming sustainability goals, and a prerequisite for progressing sustainable development.

2.1.2 Postpositivism and Pragmatism Paradigms

This research is based on a combination of postpositivist and pragmatic paradigms for making claims about knowledge. Elements of the postpositivist paradigm described by Creswell (2007) employed include aspects of the scientific approach such as logic, empirical

data collection, and an orientation to cause-and-effect relationships. However, among the several elements of postpositivism that I do not adopt, are its reductionist elements.

Focus on the outcomes of the research, the actions, situations and consequences of inquiry (rather than antecedent conditions as in postpositivism) (Creswell, 2007) are elements of the largely pragmatic approach employed in this study. With pragmatism, instead of a focus on methods, the important aspect of research is the problem being studied, the questions asked and the solutions to the problem (Creswell, 2007). The pragmatic epistemology is critical of any notion of absolutes in knowledge (Parker, 1996) and is not committed to any one system of philosophy or reality (Creswell, 2007). According to Rosenthal & Buchholz (1996: 41), referring to solutions to problematic situations, pragmatism allows for diverse perspectives to grasp the “richness of reality in different ways but [which] must be judged in terms of workability”. Workability requires “growth, resolution of conflicts in terms of enlargement of context which can adjust or adjudicate the conflicting perspectival claims” (*ibid*). Individual researchers are free to choose methods, techniques and procedures that best meet their needs and purposes (Creswell, 2007). This research employs mixed methods, and collects and analyses different types of data.

2.1.3 Methodological Assumptions

This study uses published research material from a wide range of disciplines, and both quantitative and qualitative data. I believe this material will allow a balanced and robust platform upon which to discuss the topic. The assumptions of each method are explored in their relevant sections.

2.2 Research Design

This study uses both quantitative and qualitative methods. Data collection is based on the assumption that environmental problems may be complex and often require interdisciplinary and multiple ways of analysing and synthesising them. The methodology and procedures followed in this study employ an inductive logic: the research uses a bottom-up approach and looks at particulars and details before generalisations.

The mixed methods used are summarised in Table 1.

Table 1 Summary of Mixed Methods

Data Source	Type of Analysis	Description of Specific Method and Outcome	To Meet Objective
Literature Review	N/A	Review of academic literature about current thinking about agro-food systems, and trends to more ecologically aware consumption.	One
Literature Review	Quantitative	Use published sources to determine energy and GHG emissions for on-farm stage.	Two
Industry Participant Data Records	Quantitative	Obtain business records from beef and lamb processing plants to determine GHG emissions for freight and meat processing.	Two
Interviews	Qualitative	Semi-structured face-to-face interviews with key stakeholders to explore perceptions about food miles and carbon footprints. Coding employed to aid analysis.	Three

These methods are detailed below.

2.3 Objective One: Literature Review

For Objective One, a wide body of literature was reviewed to identify trends in current thinking about agro-food systems, the environmental externalities of food, ecological citizenship and New Zealand analytical approaches to agro-food system research.

2.4 Objective Two: LCA and the Case Study

A case study with two meat processing plants was employed to address Objective Two. Case study research traditionally involves the exploration of an issue through one or more cases within a bounded system (e.g., a setting, a context, a process, an activity) (Creswell, 2007). The study of a single unit or a smaller number of units (the cases) has the purpose of understanding a larger class of similar units (a populations of cases) (Gerring, 2007). This case study is ‘exploratory’ according to Yin (2003), and ‘instrumental’ according to Creswell (2007), as I focus on an issue or concern and then select one bounded case to illustrate this issue.

Case studies may be more useful than cross-case studies when a subject is being encountered for the first time or is being considered in a new way (Gerring, 2007). Conducting LCAs of agricultural products in New Zealand is practically a new exercise (see Chapters Three and Four).

Data collection involves multiple sources of information – typically using both quantitative and qualitative approaches to case study development (Creswell, 2007; Yin, 2003). Here, I have drawn on published documents from research institutes, government records and peer-reviewed journal articles, and empirical quantitative data gathered at two processing plants.

2.4.1 Lifecycle Assessment Framework

Carbon footprint calculations are based on the LCA methodology developed by the International Standards Organisation (ISO). LCA is built on the principles of explicit scope and goal definition, comparative assertion¹, transparency, data quality, and uncertainty and sensitivity analyses (ISO, 2006a).

The ISO 14040 and 14044 LCA Framework (ISO, 2006a, 2006b), conceptualised in Figure 2, guides this study's carbon footprint construction.

Figure 2 The ISO 14040 Lifecycle Assessment Framework

Drawing on ISO guidelines, the **goal and scope definition** of the LCA in this thesis is to obtain the GHG emissions of New Zealand beef and lamb in order to identify and compare the magnitude of the different lifecycle stage impacts. The **functional unit** is kg of meat

¹ An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function. LCAs are used for product comparative assertions (Audsley *et al.*, 1997; Curran, 2001; ISO, 2006a).

(beef or lamb measured in carcass weight (CW)). The applied LCA of beef and lamb is diagrammed in Figure 3 and accounts for direct and indirect major greenhouse gases carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). This study's **system boundaries** are shaded (both primary and secondary research) in Figure 3. The on-farm and shipping stages are based on secondary research, while the domestic freight and processing stages involve primary research.

Figure 3 represents the LCA specific to this study, adapted from ISO (2006a), Patterson (1984) and Wells (2001).

Figure 3 LCA Applied Conceptual Framework for Beef and Lamb

Stages excluded from the research are:

- Consumption (household transport and preparation) and disposal, such as packaging to landfill, because the study is targeted at supply chain performance.

- Freight between rearing farms and fattening farms² (see Figure 3). In reality, farms may either be rearing farms, fattening farms, or both. This means that there are additional trips between farms, sometimes through sale yards, which will increase overall freight distances. Trip distances to sale yards and between farms are likely to be considerable (pers. comm. beef and sheep farmer, 2007).
- Domestic retail. It is assumed that, as most of the production is exported (90% for lamb and 82% for beef (Meat and Wool NZ, 2006)), domestic freight to port applies equally as to freight to domestic retail outlets. This assumption is unlikely to significantly affect the results as most domestic consumption generally occurs in population hubs that are also seaports, although there is likely to be some additional transport involved in retail distribution systems.
- Storage in warehouses or coldstores, due to lack of data.

For the **inventory analysis**, direct emissions such as arising from diesel and electricity use, and indirect emissions such as arising from fertiliser use were collected in the secondary sources. For the primary research (processing and freight stages), data consisted of freight distances, destinations and loads, processing plants' energy types and annual consumption, and annual product and co-product quantities. Only direct emissions sources are taken into account; energy embodied in machinery and emissions from packaging and cleaning products are not included, in accordance with the Carbon Trust's (2007) methodology. The **impact assessment category** is the global warming potential (GWP)³. Impacts are analysed as kilograms of carbon dioxide equivalents per kilogram of carcass weight (kg CO₂-e/kg CW). The **interpretation** phase identifies the strong and weak points of the footprints, and a sensitivity analysis evaluates whether assumptions or uncertainties change the results.

Readers should note that changing system boundaries might change the magnitude of the impacts and the end results. In an ideal situation, a true 'cradle to grave' approach would be taken. Furthermore, only one impact category (GWP) has been chosen. If other categories such as soil quality, biodiversity, land use etc. were to be included, the environmental impact might be greater. For example analysis of shipping would capture other negative costs such as sulphur and soot; and analysis of agriculture would capture large water and land use and/or degradation.

² A rearing farm breeds and sells animals as juveniles to fattening farms, who raise them until they are mature for processing.

³ Global warming potential (GWP) is the effect of GHGs in the atmosphere measured in carbon dioxide equivalents (CO₂-e) and over a 100 year period (Baede, 2007).

2.4.2 Uncertainty and Assumptions

Because the LCA methodology is a set of guidelines with substantial scope to choose different system boundaries and approaches, many decisions need to be made as to what to include or exclude and which approach to take. Estimates and assumptions are sometimes required to overcome data gaps. The nature of the investigation in some of the more complex stages, such as freight, involved structural uncertainties⁴ (detailed in s5.1.2).

Where estimations could not be based on knowledge of specific situations or processes a non-conservative approach (leading to an underestimation of emissions) was used, whereby lower bounds of emissions were obtained based on available data. This approach is similar to the 'bounds approach' employed by Saunders *et al.* (2006). The sensitivity analysis will include assumptions about uncertain or unknown data to determine their relative importance.

2.4.3 Sampling Strategy

'Purposeful' and 'opportunistic' sampling was chosen (Bradshaw & Stratford, 2005; Creswell, 2007). In purposeful sampling, an ordinary or typical case is selected to calculate the carbon footprint. Because of the commercially sensitive nature of the meat industry, it was relatively difficult to conduct an environmental studies research project; therefore opportunistic sampling was also appropriate.

2.5 Objective Three: Interviews

To address Objective Three, interviews explored the perceptions of key stakeholders.

2.5.1 Sampling strategy

An amalgam of critical case sampling and politically significant sampling was chosen for the interviews. Critical case sampling permits logical generalisation and politically significant sampling attracts desired attention from a wider range of stakeholders (Creswell, 2007).

⁴ There are different types of uncertainty, which can be either statistical or structural (Manning *et al.*, 2004). In this case, we are dealing with structural uncertainty where it is not clear that all relevant variables and functional relationships are known. Quantifying structural uncertainty is done using different plausible alternative formulations or relationships that are not well known (Manning *et al.*, 2004).

2.5.2 Technique

A semi-structured interview technique was adopted, as it enables a flexible approach, both in terms how issues are addressed, and in terms of allowing interviewees to put forward issues that are relevant to them but may not included in the 'themes' (Creswell, 2007). Semi-structured interviewing works well for dealing with managers, bureaucrats and elite members of a community because it demonstrates the researcher is competent and prepared but not trying to exercise excessive control over the respondent (Bernard, 2000). The self-reporting issues (response, deference and accuracy effects) characteristic of the interviewing method is recognised (*ibid*).

2.5.3 Interview protocol

Interviewees were contacted via email and phone. Interviews lasted approximately one hour. Face-to-face interviews were conducted at the participants' workplace, and were audio-recorded, transcribed and sent back to the participants for correction. The interview format consisted of a combination of open-ended questions, one-word answer questions or questions that required interviewees to rank different issues or concepts (see Appendix One). Interviewees were given the option of remaining confidential or being identified by name, as approved by the Victoria University of Wellington Ethics Committee (Appendix Two).

The interviews were conducted with major political, industry and environmental stakeholders. A focus on government officials and industry stakeholders was taken to reflect their ability to influence and shape the development and use of carbon footprints. Several environmental NGOs were also interviewed because of their specific involvement in the agro-food sector's impact on climate change. Research institutions, such as Crown Research Institutes (CRIs) or universities, were not included because of the difficulty in obtaining commercially-sensitive information on their research, and because focus was not on what researchers believed, but on non-academic stakeholder perceptions of carbon footprints and their applicability and relevance to the New Zealand context.

2.5.4 Coding

Coding, a technique commonly used in qualitative research (Coffey & Atkinson, 1996), was employed whereby the data were condensed into analysable units. Codes are thematic

or theoretic labels (Willis *et al.*, 2007), which enable the researcher to identify meaningful data and draw out emerging themes and concepts (Coffey & Atkinson, 1996).

The findings of the literature review (Objective One) can be found in the following Chapter.

3

TOWARDS SUSTAINABLE FOOD SYSTEMS

This chapter is broadly concerned with sustainable food systems. It identifies the relevant trends in thinking about agro-food systems, consumer trends towards ecologically-aware food consumption, and the contexts created by producers within which ecological consumers and citizens act. In particular, it analyses the relative merits of food miles and carbon footprints in terms of assisting in ecological citizenship.

A food system includes the production, processing, distribution, sales, purchasing, preparation, consumption, and waste disposal pathways of food (Pirog *et al.*, 2001). When using the word ‘sustainable’, I refer to strong sustainability (Turner, 1997), which sees the economy as a subset of the environment, posits environmental limits to its growth, and sees little if any scope for substitution of human-made capital for natural capital (Daly & Farley, 2004). The transition towards a more sustainable food system requires decoupling (OECD, 2002) the economic benefits of agro-food production and consumption from their negative environmental effects; and recognition that the food system is a sub-system fully dependent on a larger system – the ecosphere (Wackernagel & Rees, 1996).

This research is embedded in the theoretical concepts of ecological economics and environmental economics. One of the major concepts discussed among theorists of these fields is externalities – or effects not borne by parties to a transaction – and how to minimise or internalise external costs (Daly & Farley, 2004; Harris, 2002; Tietenberg, 2000). The purpose of a carbon footprint in this research is to evaluate the externalities from beef and lamb production and consumption and enable the progression towards internalising these costs.

This chapter first distils some of the major environmental impacts of food production and consumption and their possible causes, then describes the tools, particularly LCA and carbon footprints, for assessing negative externalities. Thirdly, it highlights how people can use information based on these assessment tools to express their ecological citizenship. Finally, the importance of producer preparedness to adopt environmental practices is discussed in the context of the transition towards sustainable food systems.

3.1 Environmental Impacts of Food Production and Consumption

3.1.1 Underlying Processes

The ‘Green Revolution’, economic globalisation and trade liberalisation have led to significant changes in the way food is produced and consumed. Because the dominant food system is now globalised, and societies are increasingly urbanised and industrialised, it can no longer be understood simply as a way of moving basic goods from farm to plate. Instead, food today is largely produced by commercial growers, operating through long and technically sophisticated supply chains, and often transported large distances from producer to consumer (Jones, 2002; Maxwell & Slater, 2003; Mont & Bleischwitz, 2007). Arising out of the Green Revolution and the accompanying expansion in trade, global food markets have become widespread: overall food supply has increased, as well the range of foods supplied in supermarkets, with price reductions occurring as a result of ever-increasing technical and allocative efficiency and productivity (Conner, 2002; Kriflik, 2006; Raijnders & Soret, 2003). Industrial agriculture has achieved its objectives in terms of food security through increases in productivity and lower prices⁵ (Conner, 2002).

Globalised industrialised food systems can be further characterised by monocropping, large-scale commercially operated farms, reduction in the diversity of crops grown (Conner, 2002), dependence on the large-scale use of external energy sources (Fluck, 1984; Goodman, 2002), lengthening supply chains (Jones, 2002), market concentration to only

⁵ Organisations such as the World Bank, the United Nations Food and Agriculture Organisation (FAO), the World Food Council, and the International Food Policy Research Institute, were part of concerted efforts to ensure food security, increase food supply, reduce prices, stabilise terms of trade for raw commodity producers, improve nutrition and combat world hunger (Clapp & Dauvergne, 2005; Maxwell & Slater, 2003). Subsidies that rewarded productivity and increased yields also supported these objectives. Examples can be seen through the initial goals of the European Union’s Common Agricultural Policy (CAP), and the US Farm Bills passed every few years for over two dozen commodities (USDA, 2002).

several very large food retailers (Hendrickson & Heffernan, 2002; Konefal *et al.*, 2005), and changing consumer food preferences, especially a greater demand for livestock products (Raijnders & Soret, 2003; Steinfeld *et al.*, 2006) and a full range of all-year supply of fruit, vegetables and other foods (Smith *et al.*, 2005).

Despite the significant benefits and efficiency gains of modern, globalised food systems, an increasing body of literature is identifying the adverse effects of these systems. Means to gain competitive advantage include producers shifting external costs onto others, specialisation, homogenisation and concentration of resources to fewer crops, and the application of more intensive inputs for higher productivity and economic returns (Clapp & Dauvergne, 2005; Costanza *et al.*, 1995; Daly & Farley, 2004; Gale, 2000; Hodges, 2005; Salmon, 2002). These unsustainable producers are then able to expand at the expense of sustainable producers and become more dominant in the marketplace (Salmon, 2002). Another central problem is that the increasing distance between producers and consumers and the global supply chain structure make it possible to blur and mask these externalities, referred to by Sundkvist *et al.* (2005), as feedback signals from unhealthy ecosystems (Mont & Bleischwitz, 2007; Seyfang, 2006; Sundkvist *et al.*, 2005). Thus, with these feedback signals masked, the consumer fails to see and understand the negative impact of his/her consumption on ecosystems, and corrective actions to reduce these impacts are not taken by consumers.

3.1.2 Stocktake of Major Environmental Impacts

Because food systems are complex, systematic assessments of the environmental impacts of agriculture remain sparse (Brodt, 2007; Gerbens-Leenes *et al.*, 2003). However, a number of studies that have attempted to assess the sustainability, or calculate the external costs, of agro-food systems have found the negative environmental effects arising out of food production, processing, packaging, transport, consumption, and waste disposal are significant (Andersson, 2000; Dutlih & Kramer, 2000; EEA, n.d; IEEP & GHK Consulting, 2005; Jones, 2002; Jungsbluth *et al.*, 2000; Pearce, 1999; Pimental & Pimental, 2003; Pirog, 2003; Pretty *et al.*, 2005; Raijnders & Soret, 2003; Smith *et al.*, 2005; Steinfeld *et al.*, 2006; Tukker & Jansen, 2006; Watson & Zakri, 2005). The *Millennium Ecosystem Assessment* (Watson & Zakri, 2005) has shown that agriculture has contributed substantially to the depletion and pollution of the environment in many countries through water and air pollution, eutrophication, deforestation, biodiversity loss, damage and depletion of

ecosystems, depletion of soil quality, effects of agrichemical use (such as discharges to waterways and residues in food), and GHG emissions. Furthermore, these impacts are increasing (*ibid*).

While it is not possible to review all the environmental impacts associated with food systems, some of the notable findings relating broadly to the food system are summarised below. Food consumption is the single largest contributor to households' total environmental impact (Tukker & Jansen, 2006), responsible for approximately one third of households' total impact, based on lifecycle analyses that include the indirect effects of consumption (Andersson, 2000; EEA, 2005). According to Jungsbluth *et al.* (2000), about two-thirds of total energy use arises during production and distribution to retail, one-fourth of energy use takes places at the consumption phase, and the remainder from waste disposal. Pretty *et al.* (2005) assessed the external costs of twelve commodities consumed in the UK. The real cost of the weekly per capita food basket (£24.79) was calculated to be £2.91 more per person per week (11.8%) if externalities and subsidies are included, with farm externalities (£0.81), domestic road transport (£0.76), government subsidies (£0.93) and shopping transport (£0.41) contributing the most (*ibid*). Transport of food from the retail outlet to the home is significant, contributing 28% of all vehicle-kilometres that all food consumed in the UK travels (Smith *et al.*, 2005), and is estimated to impose £1.28 billion per year in external costs (Pretty *et al.*, 2005). Post-retail transport is said to be the least efficient of all transport stages, since cars are rarely loaded to maximum capacity (Brodt, 2007). However the consumption stage has been studied very little (Andersson, 2000). A study of the effect of the structural changes in food retailing on shopping habits suggests that mapping the environmental trade-offs in consumer shopping can be very complex (Svensson & Haraldsson, 2002). Supermarket home-delivery schemes, once they become more widespread, may help to reduce transport's direct and external costs.

Agricultural production is the stage in the lifecycle of food with the highest impact, with the external cost of UK agriculture up to the farm gate estimated to be £1.51 billion per year (Jungsbluth *et al.*, 2000; Pretty *et al.*, 2005). Use of direct energy, non-energy related emissions such as methane and nitrous oxide, and synthetic fertilisers and pesticides contribute significantly to agriculture impacts (Andersson, 2000; Richardson *et al.*, 2005). However, agricultural impacts vary between geographic locales. The geographic or 'natural comparative advantage' of an area is determined by biophysical variables such as mild climate, abundance of surface water, topography, soil richness and structure (Andersson,

2000). The biophysical elements of different geographic locations are crucial variables when comparing agricultural food products (see s4.5 below).

For vegetable production, heated greenhouses and air transportation cause the highest single environmental impacts (Carlsson-Kanyama *et al.*, 2003; Dutlih & Kramer, 2000; Jungsbluth *et al.*, 2000).

Meat and dairy products are the most environmentally detrimental foods (Pretty *et al.*, 2005; Tukker & Jansen, 2006), although their impacts vary by country/region. In fact, the livestock sector is one of the top two or three most significant contributors to the most serious environmental problems, including climate change (Carlsson-Kanyama *et al.*, 2003; Dutlih & Kramer, 2000; Steinfeld *et al.*, 2006). This is because livestock production produces the additional GHGs methane (CH₄) and nitrous oxide (N₂O), accounting for 80% and 20% respectively of all livestock production emissions according to a European study (Monteny *et al.*, 2006), or two-thirds CH₄, one-third N₂O, according to a New Zealand study (Terry, 2007). Methane emissions are highly variable and are affected by soil type, manure management, diet and animal type, size and age (Monteny *et al.*, 2006; Monteny *et al.*, 2001). Methane emissions from beef cattle enteric fermentation, which are responsible for approximately 80% of total on-farm CH₄, are highly variable. Emissions range between 87 and 102 kg CH₄ (or 1827 to 2142 kg CO₂-e) per animal per year (Monteny *et al.*, 2001). For *New Zealand's Greenhouse Gas Emissions Inventory 1990-2005* (MfE, 2007a), the uncertainty in annual CH₄ emissions in 2005 was $\pm 53\%$ and is attributed mostly to natural variation from animal to animal.

Diet affects enteric methane emissions. Under a high grain diet, cattle produce less CH₄ when fed corn than when fed barley (Beauchemin & McGinn, 2005). Emissions were in both of those cases less than when cattle are fed a low-grain diet (Johnson *et al.*, 2007; Schils *et al.*, 2007). The net benefits of substituting different feeds however need to be assessed in terms of effects or opportunity costs of additional land use, as well as emissions in the production and transport of the feed.

For N₂O emissions, the relative scarcity of data and the inconsistency in how data are reported makes it difficult to assess overall impacts of crop and soil management on N₂O

emission rates (Johnson *et al.*, 2007). However, matching nitrogen fertiliser application rates to crop uptake reduces N₂O emissions and water degradation (Monteny *et al.*, 2001).

The GHG emissions trade-offs from different management systems and practices that affect net GWP are yet to be determined across a wide range of agricultural systems (Johnson *et al.*, 2007). Mitigation strategies include changes in tillage, fertiliser application, feed and manure management, and substitution from fossil fuels to energy produced in agricultural systems. However, there is no universally applicable list of measures because mitigation measures are site-specific and need to be evaluated for individual agricultural systems based on climate, soil, social and historical land use and management patterns (Smith *et al.*, 2007)

In spite of the sometimes conflicting studies and the difficulty in comparing studies for methodological reasons, it is likely that the greatest climate change impacts from food occur at the on-farm production and household shopping stages, and from meat consumption (particularly ruminants), air transport and heated greenhouses. Impacts that do not show up as having great magnitude are outdoor (seasonal) vegetable production, shipping, and rail freight.

3.2 Lifecycle Assessment as an Environmental Assessment Tool

To achieve more sustainable food systems, tools to evaluate the effect of human activity on the environment are required. Lifecycle assessment (LCA) is one such tool⁶. LCA, introduced in Chapter Two, is a systematic tool for assessing environmental impact, whereby all the steps in a production and consumption chain are considered (EEA, 2005; Mont & Bleischwitz, 2007). It is used in this study as both a central part of the study's conceptual framework and as a methodology based on the International Standards Organization (ISO) Standards (ISO, 2006a, 2006b).

The purpose of agricultural LCAs is to determine the differences in environmental impacts among different systems with equivalent functions (Audsley *et al.*, 1997). LCA has not traditionally been used for food products and has largely focused on engineering products, building materials and chemical industries (Andersson, 2000; Audsley *et al.*, 1997;

⁶ Other environmental assessment tools similar to LCA include input-output analysis, process analysis, material flow analysis, and index decomposition analysis (see Ang & Zhang, 2000; Greening *et al.*, 1997; Heijungs & Suh, 2006) but are not covered in this study.

Handfield *et al.*, 2005; Kellenberger, 2007; Núñez *et al.*, 2005). Recently though, analysts and managers have come to realise the relevance of LCA to almost any product and its supply chain (Handfield *et al.*, 2005). At the same time, the food system has increasingly become the concern of consumers and community groups (Hawken, 2007; Jones, 2002).

3.2.1 LCA as a Systems Approach

An important step towards sustainable business practices is a systems-based assessment tool providing information on the sustainability of a product that reflects the practices of all companies involved (Gerbens-Leenes *et al.*, 2003). LCA is one such ‘whole systems’ holistic approach (*ibid*), reflecting the theories of ecological complexity (Capra, 1997; Folke *et al.*, 2002; Klein, 2004; Winterton, 2003), and arguing that complex environmental problems cannot be solved with simple or ‘quick-fix’ solutions.

The holistic approach of LCA connects consumption with production towards positive environmental outcomes in a systematic and integrative way (ISO, 2006a; Mont & Bleischwitz, 2007). Because LCA takes account of the cumulative environmental impacts across a product’s lifecycle, it often includes impacts not considered in more traditional analyses, such as raw material extraction, material transportation and ultimate disposal, or in single-company assessments (Environmental management systems (EMS)). LCA therefore provides a more accurate and comprehensive picture of the environmental impact of a product and helps to avoid shifting environmental problems from one place to another (Curran, 2006; Mont & Bleischwitz, 2007), or from one company to another or to consumers (Gerbens-Leenes *et al.*, 2003). EMSs of individual companies can promote cooperation among actors along the supply chain for engagement in LCA (Darnall *et al.*, 2006) can therefore be complementary to LCAs.

3.2.2 Methodological Issues

Harmonisation of LCAs has been highlighted as a research priority, suggesting that the numerous differences in methodological approaches are a problem for product comparisons (Audsley *et al.*, 1997; Brodt, 2007; Núñez *et al.*, 2005; Tukker & Jansen, 2006). Because LCA practitioners are free to choose the scope, goal and system boundaries of an LCA, different studies arrive at conclusions that may be contradictory (Jones, 2002). Aspects most commonly excluded are capital goods, packaging, waste, transport from the retailer to the consumer, energy use in the retail industry, carbon sequestered in crops, and

transport of inputs to the farm (Brodt, 2007). Practitioners may also use a sub-optimal approach, not to identify the most environmentally benign option, but so that the impact of *their* existing system is seen to have less of an impact than another. Another problem highlighted by Audsley *et al.* (1997) is the allocation of environmental effects to the different functions delivered by a multi-functional system. Núñez *et al.* (2005) suggest that results of LCAs should be submitted for an evaluation of the assumptions and the decisions taken throughout the study as there is little experience of applying LCA to food systems. In Europe, efforts have been made to standardise lifecycle inventory databases in order to mitigate methodological inconsistencies (Kellenberger, 2007).

3.2.3 Research Gaps

The literature on food and energy/GHG LCAs reviewed for this chapter suggests that the majority of studies to date have concentrated on energy use and/or GHGs within specific sectors of the food system. These studies are useful in identifying ways to improve key parts of individual sectors of the food system but are not useful to consumers where decisions about which foods to purchase cut across multiple sectors at once (Brodt, 2007). LCAs of food products, which take account of cross-sectoral impacts, have largely emerged in the last ten to 15 years. This research needs to be consolidated and furthered, including between the very specific LCA studies for single food products and the simplified research required for the comparison of a range of food products (Jungsbluth *et al.*, 2000).

LCA lays the groundwork for a number of tools such as lifecycle costing, eco-efficiency indicators, eco-labelling, supply chain management, EMSs, integrated product policy and carbon footprints (Darnall *et al.*, 2006; European Commission, 2001; Jollands & Patterson, 2004; Mont & Bleischwitz, 2007; Steen, 2005). In the context of this study, LCA is considered to be the analytical process for calculating the carbon footprint of a product (s3.3), and forms the basis for communicating environmental-related information to consumers wishing to exercise their ecological citizenship (s3.5), for instance, with the help of carbon labelling schemes (s3.5.2).

3.3 Carbon Footprints

A carbon footprint is the total amount of CO₂ and other greenhouse gases emitted over the lifecycle of a product or service (Wiedmann & Minx, 2007). Because of the relatively

newness of the term, and despite its widespread use in the media in recent years, there is a dearth of peer-reviewed academic definition and literature on what carbon footprints for goods and services are (Hammond, 2007; Wiedmann & Minx, 2007)⁷.

Despite the absence of an academic definition, other institutions have provided their own definitions. I adopt the Carbon Trust's definition⁸:

A methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its lifecycle from the production of raw materials used in its manufacture, to disposal of the finished product (excluding in-use emissions).

(...)

A technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product.

(Carbon Trust, 2007: 4)

The carbon footprints of many products or services may not have a non-CO₂ component. However, this thesis deals with agricultural products, for which non-CO₂ gases are a significant part of the overall footprint and are therefore included.

There is also as yet no widely agreed method for carrying out a carbon footprint. Carbon footprint calculations range from simplified online calculations to comprehensive LCAs (Wiedmann & Minx, 2007). Whether carbon footprints should include indirect emissions and emissions embodied in capital is also central to the decisions made about the footprinting methodology.

Several organisations have developed GHG accounting methodologies in order to establish a common understanding of carbon footprints and streamline, consolidate and standardise methodologies for accounting and managing GHGs. In the UK, the Department of Environment, Food and Rural Affairs (DEFRA), the Carbon Trust and the BSI British Standards are developing together a Publicly Available Specification (PAS) for the measurement of the embodied GHGs in products and services (Carbon Trust, 2007). The

⁷ Carbon footprints may also refer to the emissions for which an individual is responsible, similar to the ecological footprint concept, first developed by Wackernagel and Rees (1996). Goods and services footprints appear to have evolved from this personal footprint.

⁸ The Carbon Trust, whose role is to help the UK move to a low carbon economy, is an independent company funded by the UK Government and is leading research on carbon footprints.

Environmental Change Institute of Oxford University is developing a carbon labelling scheme (Fawcett *et al.*, 2002), and the World Resources Institute (WRI) in partnership with the World Business Council for Sustainable Development has developed the GHG Protocol Initiative (Ranganathan *et al.*, 2004). The GHG Protocol Initiative is designed to guide GHG management systems for individual businesses such as Landcare Research's CarboNZero programme in New Zealand.

3.4 Carbon Footprints versus Food Miles

Carbon footprints, as indicators of sustainability of food, are considered to be superior to food miles because their system boundaries are broader in that, rather than taking only the transport component of food, they include all stages of a product's lifecycle.

The food miles concept has been criticised for several reasons. Firstly, the environmental impact of transport is not only a matter of distance, but of a number of variables including the number of kilometres travelled, the modes of transport, and the efficiency of transport loads. The most robust food miles indicator would take into account all three variables, as it would be able to represent the GHGs emitted from food transport per unit weight of product.

The efficiency of different transport modes varies considerably. Although the relative efficiencies of different studies vary somewhat (see Table 2), shipping is the most efficient (two to six times more than rail; 40 to 90 times more than air); followed by rail (three to four times more than road), and road (five to six times more than air).

Table 2 Primary Energy⁹ Use for Different Modes of Freight Transport (MJ/tonne-km)

Source	Shipping	Rail	Road	Air
Pirog <i>et al.</i> (2001: 31)	0.423	0.677	2.890	15.839
Gerbens-Leenes <i>et al.</i> (2003: 235)	0.100	0.600	1.700	9.000
Saunders <i>et al.</i> (2006: 44)	0.114	-	0.419	-

Marintek *et al.* (2000) quote shipping contributes 1.8% of global CO₂ emissions (in 1996 based on UNEP figures in Global Environmental Outlook 2000); however a report by the United Nations International Maritime Organization not yet officially released has quoted

⁹ Primary energy refers to direct energy consumption plus the energy involved in extraction, distribution and processing to deliver the consumer energy.

4.5% according to *The Guardian* (Vidal, 2008). If the higher figure is correct, it would outweigh global airfreight emissions by almost two-fold. However, shipping is undeniably less detrimental when measured per unit of product.

Different loads also affect the efficiency of food transport per kg of product. In practice, just because a product has travelled less does not necessarily mean that its GHG emissions are correspondingly lower. For example, large heavy goods vehicles travelling longer distances may be more fuel efficient than smaller vehicles or vehicles carrying smaller loads, as is typical under a local sourcing system (Smith *et al.*, 2005).

Most importantly in the current context, food miles fails to consider other significant environmental externalities of food production and consumption. While the intention of purchasing based on food miles is to reduce the environmental impacts of consumer food choices, several studies have shown that food that travels long distances does not necessarily create the greatest environmental harm in terms of carbon emissions. For example, tomatoes grown in Spain and road freighted to the UK are more energy efficient than tomatoes grown in glasshouses locally in the UK (Smith *et al.*, 2005). This result appears consistent with generally higher energy requirement of vegetables grown in a greenhouse (26.2 MJ/kg) compared with those grown in open air (0.7 MJ/kg) (Gerbens-Leenes *et al.*, 2003). This illustrates that differences among production methods and transportation modes, as well as distance, influence the environmental pressure of a final food product (Gerbens-Leenes *et al.*, 2003).

Nevertheless, food transport has significant and growing impacts (EECA, n.d; IEEP & GHK Consulting, 2005; Pirog *et al.*, 2001; Smith *et al.*, 2005), pointing to the need not to replace food miles with measures of the externalities of farm production systems, but to include food miles calculations into carbon footprints.

While the argument against food miles presented here is outside of the debate on the costs and benefits involved in international trade and local food, it is important to note this polemic. Because local food travels less distance than food from established supermarket distribution systems, food miles campaigners, which are increasing in prominence (Hawken, 2007: 239), are associated with local foods movements. However, the demand for local food is not only linked to efforts to reduce food miles. Instead local food sourcing shortens the links between producers and consumers and therefore has potential to support

local economies, increase job satisfaction, create greater trust about food safety, traceability and quality, rebuild interdependence among members of the community, and reduce environmental impacts (Bellows & Hamm, 2001; Feenstra, 2002; Halweil, 2003; Hodges, 2005; Hoekstra, 2006; Norberg-Hodge, n.d-a, n.d-b; Norberg-Hodge & Gorelick, 2002; Roep & Wiskerke, 2006; Sustain, 2001, 2002; Szmigin *et al.*, 2003).

Now that the case for carbon footprints over food miles has been made, the following section explores how LCA and carbon footprints may be used by people wishing to express their ecological citizenship.

3.5 Exercising Ecological Citizenship

The environmental effects of food are ultimately driven by consumption, via the impacts of production, use and waste (Tukker & Jansen, 2006). Changes in consumer food choices have the potential to reduce the overall environmental impact of food systems. How inclined are consumers to make environmentally considered purchases? A wide body of literature suggests that consumer awareness of the environment is growing (Laestadius & Karlson, 2001; Stancu & Smith, 2007; Vermeulen & Ras, 2006), as is the demand for environmentally preferable products in Europe (EEA, 2001; Gerbens-Leenes *et al.*, 2003; Núñez *et al.*, 2005). For example organic food is one of the fastest growing areas within food and drink sales in Europe as a whole (EEA, 2005) and corporate environmental management approaches are seeking to satisfy these wants (Laestadius & Karlson, 2001), with supermarkets making efforts to supply environmentally preferable products (Baker & Shadow, 2004; Finch & Vidal, 2007). ‘Ecological citizenship’ is a shared personal commitment to sustainability in which citizens take action in their daily lives to reduce unjust impacts on others and the environment by considering the implications of their purchasing decisions and changing behaviour accordingly (Seyfang, 2006). It challenges the theoretical dualisms between private and public interests and activity: ecological citizenship “explicitly defines consumer behaviour as political and a space for collective action for the common good” (Seyfang, 2006: 387).

The complexity of food systems and their wide-ranging costs and benefits pose a dilemma for ecological citizens who wish to purchase the ‘most sustainable’ food products. Currently, consumers may base the exercise of their ecological citizenship on a number of

criteria (Jungsbluth *et al.*, 2000; Kriflik, 2006), including their perceptions of what is most damaging to human and environmental health. For example, ecological citizens may choose local, organic, seasonal, or low-carbon products; domestically produced goods, vegetarian or vegan goods; or avoid products from a particular country or those that are genetically modified. Choosing products based on one or a combination of these criteria may not result in the most environmentally benign outcome because of the complex trade-offs and pollution-shifting inherent in food systems. In order to make the best choices, consumers can benefit from guidelines based on a systematic analysis, such as LCA (Brodt, 2007).

Consumers exercising ecological citizenship and wanting to reduce their contribution to climate change may well choose to buy products with lower carbon footprints. The next two sections address information asymmetries (s3.5.1) by issuing a carbon label to food products (s3.5.2), thus communicating the carbon cost of individual products.

3.5.1 Reducing Information Asymmetries

Reducing information asymmetries by providing environmental information to consumers helps ecological citizens to express preferences based on more than price or ingredients. In economic theory, an information asymmetry is a situation where one party to a transaction has more or better information than the other party (Harris, 2002). Here, the food industry has more information about how a good is produced than consumers do. Eco-labelling, a mechanism used by producers to communicate environmental information about certain characteristics of their product, is one of the most common means of correcting information asymmetries (Gallastegui, 2002) and may contribute to more sustainable production across the economy (EEA, 2005; Woodward-Clyde, 1999)¹⁰.

Reduction of information asymmetries for inducing ecological citizenship is based on the assumption that information will stimulate pro-environmental behaviour. However,

¹⁰ Labelling currently has mixed support amongst economists, policymakers and academics. While it is not possible to delve into the complexities of the effects of labelling on economies, trade and environment in depth, labelling can have substantial impacts on the international movement of goods and services (Nilsson *et al.*, 2004). Labelling provides international markets with a way of communicating information that otherwise would not be given under WTO rules. If states develop standards, they need to be compatible with WTO norms, and may be considered by the WTO to be Technical Barriers to Trade (TBT). However third parties, such as certification or accreditation organisations, are not subject to the WTO's rules because the WTO does not deal directly with non-member country agents. Voluntary labelling schemes not set up by governments can therefore communicate information not given under WTO rules, and many companies may de facto adopt these standards (Gueye, 2007).

increasing evidence suggests a number of other factors influence the degree to which environmental considerations influence purchasing decisions, and information is but one of the many factors such as values, attitudes, social norms, self-esteem, personality, socio-economic status, culture, and personal benefits at play (Conner, 2002; Darnton *et al.*, 2006; EEA, 2005; Forstater *et al.*, 2006; Gardner & Stern, 2002; Jackson, 2004, 2006; Jackson & Michaelis, 2003; Kollmuss & Agyemen, 2002; Mont & Bleischwitz, 2007). Therefore a label in itself may not be sufficient to change patterns of production and consumption and their consequent emissions, but it facilitates other policies and personal action towards these goals (EEA, 2005; Fawcett *et al.*, 2002). Furthermore, although these other factors are important, information remains valued; in fact, increasing evidence shows that consumers want more environmental information than currently appears on labels, in product information, and in advertising (Gallastegui, 2002).

3.5.2 Carbon Labelling

Quite often, much of the information represented by the range of eco-labels does not reflect a lifecycle approach and therefore consumers cannot relate overall GHG emissions to the goods they purchase (Stancu & Smith, 2007). Therefore an LCA-based eco-labelling scheme would meet the requirements for communicating environmental information holistically (Harris, 2007).

Because carbon footprints are a relatively new concept, there has not yet been any major introduction of carbon labelling of food. However, the British supermarket chain Tesco, announced in January 2007 the introduction of carbon labelling for all its products:

We will therefore begin the search for a universally accepted and commonly understood measure of the carbon footprint of every product we sell – looking at its complete lifecycle from production, through to distribution and consumption.

(Chief Executive of Tesco, Sir Terry Leahy, 2007).

Supermarkets abroad have also risen to the environmental challenge, each proposing different schemes (Finch & Vidal, 2007; UNEP, 2005). New Zealand labelling initiatives (further explored in Appendix Three) are not well developed in comparison and nothing yet approaches a comprehensive retailer-led carbon label.

3.6 Industry Preparedness

While consumers ultimately drive consumption and therefore the way in which food is produced, pro-environmental consumer behaviour is not the only determinant of sustainable consumption. Producers also have a role in terms of their leadership or preparedness to improve their environmental performance, and thus to enter into schemes such as LCAs, carbon footprints and eco-labelling.

Jackson & Michaelis (2003) and Sanne (2002), among others, propose that the assumptions of conventional economic theory, whereby rational consumers exert individual and deliberate choice, are far from realistic. Instead, consumers may be ‘locked in’ to unsustainable patterns of consumption by societal and institutional contexts, which are “often deliberately created by producer and business interests” (Sanne, 2002: 286). Producers and businesses “construct the field of consumption to satisfy their interests” (Sanne, 2002: 273) by cooperating with or pressuring governments to create conducive conditions for increasing consumption (Sanne, 2002).

Powerful sectoral lobbies often have the ability to heavily influence national policy development and can potentially restrict people’s opportunities to act as ecological citizens. In the New Zealand context, because agriculture plays a central role in the economy’s commodity exports, the agro-food sector has such an influence. An example is the 2004 Memorandum of Understanding¹¹ between the agricultural sector and government, whereby the government agreed to shield agriculture from Kyoto Protocol-related costs that the sector could otherwise incur from a growth in non-CO₂ emissions. With the agro-food sector having an influence powerful enough to shape major environmental policies and outcomes, it is argued that the onus of sustainable consumption is on producers as well as consumers. ‘Industry preparedness’, or the willingness/readiness of industry to improve its environmental performance in order to satisfy the demand of ecological citizens is argued here to be central in moving towards more sustainable food systems. A central determinant of industry preparedness is private sector leadership.

It is beyond the scope of this thesis to explore leadership in depth, but I touch here on one conceptual framework for private sector leadership, the theory of transformational

¹¹ Available on the Ministry of Agriculture and Forestry website: <http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/climate/memorandum-of-understanding/>

leadership. Transformational leaders bring about change in organisations, “possess charisma and provide intellectual stimulation, individualized consideration and inspirational motivation to followers” (Beugré *et al.*, 2006: 54). Transformational leaders experiment with new ways of working, seek opportunities in the face of risk and may react effectively to changes in the external environment or anticipate them.

Changes in markets, societies and technologies are forcing companies to learn new ways of operating, and are creating new challenges in organisational structures, practices and leadership. Organisations may be quicker to mobilise resources when faced with threats than when they attempt to exploit new opportunities (Beugré *et al.*, 2006). The research for this thesis embeds the theory of transformational leadership as it examines whether the agro-food industry is showing leadership with regard to the risks and opportunities arising out of both external market trends such as food miles and internal industry environmental performance such as the carbon footprints of their products. Industry leadership along with other determinants of New Zealand agro-food sector’s preparedness is explored through interviews in Chapter Six.

3.7 Summary

The negative externalities associated with agro-food systems have raised increasing concerns amongst academics, ecological citizens and society at large. For food systems to become more ecologically sustainable, it is important to minimise external impacts and avoid the transfer of environmental impacts from one stage in a food supply chain to another. LCA is a tool that can be used to ensure environmental impacts are accounted for in a comprehensive and systematic manner, although methodological freedom inherent in LCA can hinder comparability. As a tool for assessing the environmental effects of food products, carbon footprints (based on LCA) are superior to food miles as they account for a full range of related environmental impacts rather than transport alone. However, arguments against food miles presented here are set aside the wider debate on the benefits and costs of either international trade or local food. Carbon footprints and carbon labelling are steps that can be taken towards internalising GHG externalities as they ensure information about the carbon involved in a product is made available at all stages of a good’s production and consumption, thus reducing information asymmetries. This in turn facilitates consumers to act as ecological citizens. In order for carbon footprints and labels

to be widely available to consumers, producers must show leadership, and be prepared to account for their GHGs and satisfy this demand, therefore ‘un-locking’ consumers’ unsustainable patterns of food consumption.

Figure 4 shows the interrelationships between the major concepts and theories that have informed the research conducted to satisfy Objective One.

Figure 4 Conceptual Framework

The following chapter focuses on reviewing New Zealand-specific studies relating to the carbon footprints of agricultural products, with an emphasis on beef and lamb. It also examines perceptions of producer knowledge, responsibility and preparedness *vis-à-vis* carbon footprints.

4

NEW ZEALAND ANALYTICAL APPROACHES

Research on the energy use of the agro-food sector was stimulated by the New Zealand Energy Research and Development Committee (NZERDC), established in response to the oil crisis of 1972, and reflects concerns for energy scarcity, rising oil prices and agriculture's dependence on non-renewable energy sources (Patterson, 1984) rather than environmental or climate change concerns. For almost a decade, little research took place after the disestablishment of NZERDC in 1986 (Isaacs, 2003). Recently though, related research has resurged, responding to climate change concerns, and geared towards more holistic thinking.

This chapter reviews the research largely conducted in New Zealand, with several studies comparing New Zealand products with those of other countries, and focuses on all or parts (s4.1 to s4.5) of the energy used and/or GHGs emitted in the food system. It also includes a review of the qualitative research, which surveys the perceptions of the agro-food sector's environmental and climate change impacts (s4.6).

4.1 On-farm

For research concerned strictly with beef and sheep meat on-farm emissions, little data exists on a per kg of product basis (LCAs by Saunders *et al.* (2006) and Barber *et al.* (2007) are covered in s4.5). On a total national energy basis, the beef and sheep sector is the

largest agricultural user of energy, representing 41.2% or 5.86 PJ/year out of the total 14.23 PJ/year (Barber & Pellow, 2005). Dairy and heated greenhouse vegetable production are second and third, with 3.30 PJ/year (23.2%) and 2.50 PJ/year (17.6%) respectively. These figures contrast to those reported by Sims *et al.* (2004 in Barber & Pellow, 2005); for example the beef and sheep sector consumed the lesser 1.8 PJ/year figure and promotes dairy as the largest user. These conflicting figures reflect the absence of standardised statistics.

New Zealand's Greenhouse Gas Inventory 1990-2005 (MfE, 2007a) consolidates the information on GHG emissions from on-farm beef and sheep sources. Implied emission factors for enteric fermentation have been increasing per animal since 1990, with emissions in 2005 implied to be 11.0 kg CH₄ (or 23.1 kg CO₂-e)/animal/year and 57.5 kg CH₄ (or 1207.5 kg CO₂-e)/animal/year for sheep and beef respectively (*ibid*). For methane manure management, methane emission factors are 0.701 kg CH₄ (or 14.721 kg CO₂-e)/animal/year for beef and 0.109 kg CH₄ (or 2.289 kg CO₂-e)/animal/year for sheep (*ibid*). N₂O emissions from agricultural soils have New Zealand-specific emission factor of 0.01 kg N₂O-N/kg N (or 3.1 kg CO₂-e/kg N).

The uncertainties in annual emissions from enteric CH₄ ($\pm 53\%$) and N₂O in agricultural soils ($-50\%/+100\%$, IPCC default values) and CH₄ in manure management (0.33-6.21 kg CH₄/m²/year) are large; in fact they are largest uncertainties of all IPCC source categories contributing to the uncertainty in New Zealand's total emissions (MfE, 2007a).

Several studies have analysed the energy requirements of on-farm dairy production, which provide some indications for meat production. A study of dairy production found that 'all-grass' dairying systems in New Zealand require less energy to produce milk, up to the farm gate, than partial or zero grazing systems used in Europe and North America (McChesney *et al.*, 1981/1982; Sims *et al.*, 1996 in Wells, 2001; Wells, 2001). However Wells (2001) noted that further processing and transport could outweigh these energy savings. Wells (2001) appears to be the first in the New Zealand agricultural academic community to emphasise that international comparisons of different agricultural products need to involve an LCA that includes all energy and carbon costs of production, processing and transport.

Dairy studies have been updated by Barber & Pellow (2005), Flemmer *et al.* (2005) and Basset-Mens *et al.* (2005). Notable, per kg of milk, European conventional systems had two

times higher energy use and 50% to 80% greater GWP than New Zealand products, although the difference is smaller when European organic systems are compared (Basset-Mens *et al.*, 2005). In the average New Zealand system, 57% of GWP was CH₄, 34% was N₂O and less than 10% was CO₂ (*ibid*).

4.2 Processing

Patterson (1984), updated by Earle (1996), conducted studies of energy use in the food-processing sector. Energy sources in the food processing sector were dominated by fossil fuels, with 33% coal, 34% gas, 10% diesel and petrol, and 21% electricity in 1994/95. The dairy and meat processing industries accounted for 45% and 21% of direct energy consumed by the sector.

Energy audits from nine meat processing plants were conducted in order to understand energy use and sectoral energy savings potential in the context of a carbon tax (Veritas, 2005). The results of an analysis are shown in Table 3 and Figure 5. Energy use per mass of product was not given.

Table 3 Annual Energy Consumption by Type in Beef and Sheep Plants

Site	Type of Operation	Electricity GJ	Gas GJ	Coal GJ	Total GJ
A	Lamb and sheep	38.9	0	95.56	135.46
B	Lamb, sheep and beef	22.5	0	78.11	100.61
C	Lamb, sheep and beef	25.3	0	71.32	96.62
E	Beef	50.51	39.97	15.38	105.86
F	Lamb and mutton	83.78	34.54	0	118.32
G	Beef	27.98	0	5.35	33.33
H	Bobby veal, lamb/mutton	13.43	4.35	0	17.78
I	Beef and calves	18.2	31.92	0	50.12
J	Beef, lamb, calves, sheep and pelt	19.11	45.42	0	64.53
%		41	22	37	100
Mean		33.30	17.36	29.52	80.29

(Source: Veritas, 2005: 15)

Figure 5 Annual Energy Use by Type in Beef and Sheep Plants

(Source: Veritas, 2005).

Plants appear to use either gas or coal as well as electricity; both gas and coal were only used in one of the nine plants (site E, Figure 5). Coal contributes a large amount to the nine-plant energy consumption average, with 37%, only slightly less than the 41% electricity but polluting considerably more. Veritas (2005) noted that processing demands, and therefore low utilisation of plant resources, are often slower in low-season, making for inefficient resource use (Veritas, 2005).

Barber *et al.* (2007) compiled a GHG emissions and energy intensity inventory of beef and lamb for on-farm, livestock freight and processing. Primary research was conducted for on-farm emissions based on ten farms, livestock freight distances were assumed to be 100 km, and processing emissions were based on secondary and somewhat dated sources (Lovatt & Chadderton, 1996). Their findings for on-farm emissions based on primary research will be used to calculate the carbon footprint in this research in Chapter Five (Table 4).

Table 4 Energy Use and GHGs of Beef and Lamb

Stage	Primary Energy (MJ/kg CW)	GHGs (kg CO ₂ - e/kg)
Farming - lamb	13.3	15.1
Farming - beef	9.9	7.2
Meat Processing (in a non-rendering plant)	2.9 (or 1.71 consumer energy)	Not calculated
Transport to Plant	0.3	Not calculated
Total (av. sheep/cattle)	14.6	-

(Source: Barber *et al.*, 2007)

4.3 Domestic Freight

Overall, New Zealand's transport sector consumes more energy than any other sector, representing 44.6% of total energy use, and 17% of total GHG emissions in 2005 (MfE, 2007a). Since deregulation in 1986, the proportion of road freight has increased rapidly (Cavana *et al.*, 1997). Transport is also the fastest growing sector in terms of energy use, with its growth often outstripping the growth rate of Gross Domestic Product and export and import volumes (Cavana *et al.*, 1997; EECA, n.d).

Freight movements in New Zealand are highly complex and the freight industry operates with a high degree of commercial sensitivity (Friedlander, research participant (RP)¹²). This means it is difficult to obtain large amounts of data at a national level. There are also various inconsistencies between different types of data that report freight movements (Lambert *et al.*, 2001). The patterns and complexities of freight in New Zealand are not well understood: for example, Saunders *et al.* (2006) were not able to include domestic transport costs because of "data amiability" (Saunders *et al.*, 2006: 21). In the UK however, Smith *et al.* (2005) have documented these movements.

New Zealand appears to have little research since that of Patterson (1984) on the environmental impacts of food transport (both freight and post-retail transport). However, in the economic context of freight efficiency and logistics, freight has been subject to some investigation. Analysis of the supply chain capabilities and competencies of Australian and New Zealand logistic firms suggests that the majority of these firms still focus their efforts on internal logistics integration issues (within an individual company), compared with

¹² Research participant and CE of the Road Transport Forum New Zealand

external integration issues (between companies in a supply chain) (Mollenkopf & Dapiran, 2005). A comparison of industry groups showed that there is much improvement possible in the food and primary industry sectors.

Freight movements by commodity are particularly difficult to track in the absence of official statistics (see Bolland *et al.*, 2005; Cavana *et al.*, 1997). An estimated 1.2 million tonnes of meat were transported by road in 2002 (Mueller & Baas, 2004). Bolland *et al.* (2005) reviewed freight movements within New Zealand by commodity, tonnage and origin-destination, and is the first attempt to construct freight matrices. One of its limitations relates to the fact that the primary product groups in particular proved very difficult to research, having little or no input from industry. The study was therefore unable to produce conclusive results with respect to commodity groups because of commercial confidentiality and low participation. However, milk and livestock were thought to account for a significant share of total freight movements.

Another relevant finding was that, of the three main modes of transport (road, rail and shipping), road conveys most freight within New Zealand, with approximately 83% share of tonnage, and 67% share of tonne-km. Rail has approximately 13% of tonnage, and 15% of tonne-km. Coastal shipping has 4% of tonnage and 15% of tonne-km. Road has the shortest average haul of the three main modes, while coastal shipping has the longest.

Research is underway to increase the modal share of rail; for example the Ministry of Transport's (MoT) *National Rail Strategy* (MoT, 2005); yet efforts appear sluggish, are subject to controversy (Friedlander, RP), and appear to conflict with other Ministry research. According to the Fuels & Energy Management Group (2000) at the Ministry, the current *status quo* in road freight patterns, and the balance between other bulk freight modes, is at its optimum commercial equilibrium in New Zealand. The only significant shift available in the tonnes/vehicle-kilometres factor would come through an increase in the maximum truck gross vehicle weight (GVW) limit (up to 60 tonnes being mooted) (*ibid*). The Road Transport Forum New Zealand (RTFNZ) advocates this proposal (Friedlander, RP). However, commercial optimality does not mean economic nor environmental optimality, and the pricing of CO₂ in the future is likely to mean some shift towards more CO₂-economical modes. More generally, rising energy prices may stimulate a shift towards less energy-intensive modes such as shipping and rail.

4.4 Retail and Shopping-Related Transport

There does not appear to be any research related specifically to energy use or GHG emissions in the food retail sector, except its inclusion by Patterson (1984) (see 4.5 below).

For the emissions generated during transport to shopping outlets, the New Zealand Household Travel Survey, conducted annually by MoT (n.d), appears to be the only major study that investigates this. The survey has calculated that New Zealanders drive 3,028 million km per year in total to go shopping. However, this survey does not differentiate between food shopping and other types of shopping, or the average shopping loads, making it difficult to establish the environmental effects of household food transport. For many households, food shopping would comprise a significant proportion of total shopping travel.

Although household food preparation is thought to be significant, it is not included in this review because of the highly variable and complex behavioural, structural and technological variables involved, and is a stage beyond the influence of agro-food industries.

4.5 Lifecycle Assessments of Food Systems

Several studies analyse the energy use and/or GHG emissions over the lifecycle of beef and/or lamb in New Zealand. Early lifecycle studies recognised that both New Zealand's natural comparative advantage, and distance from markets has been an important variable to the economy:

While New Zealand may enjoy a comparative energy advantage in production, it has a comparative disadvantage in marketing because of the long distances involved in transporting produce.

(McChesney *et al.*, 1981/1982: 149-150)

This early study noted that, while New Zealand agriculture had relatively low energy inputs because of favourable climate, the limited use of nitrogenous fertilisers, and open pasture as opposed to grain-fed livestock methods, energy demand was heavier in on-farm transport due to the large size of farm properties relative to European farms, a geographically elongated landmass and centralised processing facilities (*ibid*). It was

thought that energy use in processing and transport before delivery to the final consumer may have been several times higher than the on-farm energy input since the authors found that the energy required to process and transport lamb to the UK was about 150% higher than on-farm inputs (*ibid*).

Patterson (1984) conducted the only energy-related LCA of the food system whose system boundaries extend to wholesale distribution, shopping and household consumption. The inventory was based on the gross energy requirement (GER, defined in terms of total amount of primary energy required) of each sector at a national scale and included indirect energy¹³. The total GER of the food system was estimated to represent 30% of the primary energy consumption of the New Zealand economy. This GER was further divided into sectors: processing required the largest percentage (31.3%), followed by production (28.5%), household preparation (21.6%) and shopping (10.6%). Wholesale distribution was a small part of the GER (5.5%), and retail had the smallest contribution (2.5%). The beef and sheep production sector comprised 56% of the agricultural sector's GER or 15.6% of the total GER. The beef and sheep processing sector comprised 27% of the processing sector GER, or 8.5% of the total GER.

While Patterson's (1984) study is dated (with improved energy efficiency and changes in the quantities and proportions of foods being produced since then), some interesting patterns emerge. The dominance of the processing GER appears to be caused by its large share of oil and gas (61%), with only 8% being attributed to electricity. The main indirect energy use is packaging (15%) and a comparatively minor amount of energy is embodied in the construction and maintenance of processing factories and plant equipment (3%). When divided by food product, the large export industries required the most energy, with dairy factories consuming 40% of the GER, and export meat plants 27%. Wholesale distribution, which refers to domestic freight and storage, is only a minor component of the food systems' GER, with indirect energy primarily from the construction and maintenance of transport networks having the greatest energy requirement. Post-retail sectors together had a significant energy requirement (32.2% of the GER) because of private automobile use and its associated infrastructure and food preparation.

¹³ Indirect energy refers to energy requirements of capital or inputs of production (e.g. fertilisers), rather than direct energy, which refers to energy directly consumed.

In an environmentally extended input-output analysis¹⁴ of New Zealand's food and fibre industries, the sheep and beef sector used a relatively small amount of energy to produce its outputs in contrast to land and water use (Andrew *et al.*, 2005). Forty percent of livestock and cropping CO₂ emissions (excluding CH₄ and N₂O) were caused by direct sources, and major indirect sources were appropriated by road transport (~9%), wholesale trade sectors (~8%), services to agriculture (~5%) and petroleum and chemical manufacturing (~5%). However, the study does not clarify which stage processing emissions fit under. The industry was found to have a large environmental impact, primarily the result of large water and land use rather than energy use. However, the study intends to include all GHGs in the future, which will alter the GWP impact significantly.

Saunders *et al.* (2006)'s LCA of the energy and carbon dioxide intensity of New Zealand apples, dairy, lamb and onions, commissioned by MAF, is the only LCA of lamb in New Zealand which analyses emissions a per unit mass of product. It is therefore one of the most significant studies for the present research and enables a direct comparison of results. The report concluded that food miles is not a good indicator of climate change impact. Indeed, like previous agricultural studies, Saunders *et al.* (2006) showed that New Zealand has greater production efficiency in agricultural commodities than the UK, despite the long distances New Zealand products travel to reach international markets. Reasons were again attributed to New Zealand's natural comparative advantage (extensive pastoral farming systems). The study showed that New Zealand sheep meat is four times as energy efficient, even when including transport, than the same products in the UK. It found that on-farm production emitted 0.563 kg CO₂-e /kg CW (82% of the footprint), and shipping to London emitted 0.125 kg CO₂-e/kg CW (18% of the footprint). The UK on-farm emissions figure quoted is 2.849 kg CO₂-e/kg CW.

This result in favour of New Zealand lamb exports is consistent with that of Schlich and Fleissner (2005), who compared German lamb and New Zealand lamb transported to Germany. While New Zealand's biophysical factors were stated as a major advantage, the authors also attributed the overall smaller energy requirements of New Zealand lamb to the difference in business size (the German farms were small, while the New Zealand production benefited from economies of scale). Sea transportation and the refrigeration

¹⁴ This approach is an assessment tool which provides both a snapshot of the inter-industry interlinkages expressed in monetary input-output tables and the flow of resource inputs and outputs between the environment and the economy (Andrew *et al.*, 2005).

involved in the transport of New Zealand lamb was found to require less energy in terms of kWh/kg than local transportation and distribution efforts.

However, to assume that all New Zealand products selected by Saunders *et al.* (2006) are more energy efficient than those produced in other countries throughout Europe might be incorrect. A study comparing German and New Zealand Braeburn apples concluded that imported in-season apples from New Zealand, transported by ship, had a 27% greater energy requirement than the German apples stored for five months (Blanke & Burdick, 2005). A similar conclusion was reached by Stadig (1997 in Andersson, 2000) who found that for Swedish consumption, Swedish apples were more eco-efficient than either French or New Zealand apples. These results contrast markedly to the eight-fold energy required to produce domestic apple juice in Germany than juice imported from New Zealand (Schlich & Fleissner, 2005) and to Saunders *et al.*'s (2006) conclusion that New Zealand apples are more energy efficient than British ones. Such comparative studies highlight issues with reliance on the settings of the system boundaries and methodological choices.

The work by Saunders *et al.* (2006) is significant; however, several limitations can be observed. Only carbon dioxide was included, omitting the significant GHGs methane and nitrous oxide. The report biases New Zealand seasonality, and compares freshly picked New Zealand apples that are not cool-stored with UK apples that are. In fact, both types of apples are cool-stored for out-of-season sales. Only emissions from on-farm production and transport between countries were included; therefore New Zealand domestic freight and food processing emissions were not included. Uncertainty in emissions and margins of error were not accounted for, so that the statistical accuracy of the study is not clear. Sensitivity analyses were not conducted to determine if uncertainties and assumptions would drastically change the results. In a review of their report, Saunders and Barber (2007a) recognised additional caveats such as the lack of comparable data between countries and the lack of data for the energy use of EU production systems.

Saunders and Barber (2007b) updated their earlier report in order to incorporate methane and nitrous oxide in their calculations for dairy, and therefore to better reflect the GHG impact of this product. Their results showed that New Zealand dairy still has a smaller climate change impact than comparable UK products, which have 34 % more emissions per kg of milk solids and 30% more per hectare than New Zealand dairying, including shipping to the UK. The efficiency ratio of 2:1 (NZ:UK) for dairy in the previous report

(Saunders *et al.*, 2006) has now been superseded by an efficiency ratio 4:3. The margin of difference is now not as great, and, given uncertainties in GHG, this limits New Zealand's ability to as confidently conclude that it has lower climate change impact in the dairy sector. Updated reports that include methane and nitrous oxide have not been provided for lamb, making it unclear what impact these additional gases would have had on their conclusions.

4.6 Perceptions of the Agro-Food Sector's Environmental Impact

According to general comment in the academic literature, the food industry has a poor knowledge of the energy requirement of their activities and measured data are rare (Andersson, 2000). This section reviews research on the agro-food sector's understanding of, and attitudes towards its environmental impacts, and the public's expectations of the sector.

4.6.1 Agro-Food Sector Perceptions

The quantitative studies reviewed above also contain qualitative messages about how particular sectors consider and manage energy use. Farmers were found to be complacent about energy saving measures, probably because of the low costs of direct energy relative to farm budgets (Wells, 2001). In food processing, energy efficiency was driven by economic considerations, arising out of competitiveness rather than by concerns for conserving energy supplies or mitigating environmental effects (Earle, 1996).

For meat processing, a submission by the Meat Industry Association (MIA, 2003: 1) shows that annual energy costs to the industry are only around 5% of total plant operating costs, with 70% of these costs attributed to electricity and the remainder to gas and coal. Veritas (2005) notes that in nine meat processing plants, the dictum that "what you can't measure you can't manage" was not recognised:

There is a general need to measure energy at detailed and meaningful level if individual plants and processes are to be improved.

(Veritas, 2005: 8)

Furthermore, there is no accountability for energy use at the departmental level, only at the site level; energy management is either not in place or not well developed; energy efficient

technology appears to be limited; and there is a lack of awareness of the energy efficiency consequences of not maintaining a plant.

In a survey of New Zealand food and beverage sector businesses, Stancu and Smith (2007) found that although awareness of environmental issues has rapidly increased, producers and exporters assumed that their sector did not have a significant impact on the environment, and reported that climate change and water management were not important issues facing the sector. Producers with closer contact to their export markets appear to have better awareness of voluntary environmental requirements and tend to implement a greater range of measures than other producers; whereas producers that are more removed and lack traceability find it more difficult to communicate their practices to consumers through marketing techniques (Stancu & Smith, 2007). Specifically, the meat processing industry has been reported to be “blind to the strategic challenge” (Oram, 2007b: audio quote) because it is not keeping up to date with market trends or managing its excess capacity and decreased production, and has poor marketing and communication with farmers, based on a relationship with little trust (Oram, 2007b).

The potential of producers and exporters to demonstrate their environmental credentials is poor – with only 38% having joined a recognised New Zealand or overseas standard, supply-chain code of practice, or eco-labelling scheme – despite the fact that many (74%) have implemented some type of environmental measure (Stancu & Smith, 2007).

Stancu and Smith (2007) concluded that the sector does not take a lifecycle approach with only 3% of their respondents having undertaken LCAs, and there is a serious gap in the sector’s knowledge about its own environmental impacts and carbon emissions from cradle to grave. This compromises the sector’s ability to respond to overseas consumer concerns about the impact of New Zealand products, particularly as overseas markets are likely to increase environmental information requirements (Stancu & Smith, 2007). The lack of adherence to recognised environmental schemes also means that both international and New Zealand consumers cannot readily make informed environmental choices about New Zealand products.

4.6.2 Public Attitudes to Businesses Social and Environmental Roles

New Zealand Business Council for Sustainable Development's (NZBCSD, 2007) ShapeNZ survey offers some insight into public attitudes about businesses roles on the environment. Out of over 3000 respondents, 79% either agreed or strongly agreed that businesses should be responsible for the environmental impacts of their products from 'cradle to grave'. Seven out of ten said a company's environmental performance has a big impact on whether they'll buy their products. When asked if New Zealand companies are generally very environmentally responsible, people were almost evenly split – 39% disagreeing and 36% agreeing.

Reviewing the research on perceptions of the agro-sector's environmental impact suggests that: 1) energy is not a major proportion of operating costs, is not of concern to agro-food industries, and is therefore not well managed or accounted for; 2) the industry does not consider itself as having significant environmental impacts and does not have information on the environmental impacts of products across their lifecycle; and 3) the New Zealand public expects its businesses to be fully accountable for their environmental performance from cradle to grave.

4.7 Reviewing the New Zealand Research

While many New Zealand studies are concerned with sustainability aspects of food systems, there is a dearth of recent research that takes a lifecycle approach from food production to consumption. The range of different methods for analysing GHG emissions and energy use, and the differing system boundaries of the studies, make it difficult to consolidate results. Agricultural energy use and emissions has dominated academic attention. The observation that meat and dairy farm production systems in New Zealand are more efficient than those in the UK is generally consistent among studies. Freight and processing emissions and energy use are less well documented because of complex freight movements and commercially sensitive freight and processing industries. Research on food retail and consumer shopping is near absent. The little information on freight, processing, retail and consumer shopping available cannot serve in GHG inventories for conducting LCAs of New Zealand food systems, either because of the lack of information on energy use by source, or because data is not analysed per unit of product. What is clear is that agricultural LCA studies should include all significant GHGs, and carbon footprint studies

of other food products, particularly beef, need be to conducted to enable comparison between different products, and equivalent products grown in different production systems.

Little qualitative research on the agro-food sector's environmental impacts has been carried out. Several studies document that energy savings in the agro-food sector are not of great concern to the sector and are not well managed (Earle, 1996; Wells, 2001; Veritas, 2005). One study has shown that food and beverage sector businesses lack familiarity with the lifecycle approach to environmental issues and are not able to respond adequately to the environmental concerns of consumers (Stancu & Smith, 2007). This occurs despite a large majority of the New Zealand public expecting businesses to be responsible for the environmental impacts of their products from 'cradle to grave', and the fact that purchasing decisions are often influenced by a company's environmental performance (NZBCSD, 2007). Qualitative research gaps include an understanding of the perspectives of major industry associations' representatives, governmental officials and environmental NGOs on carbon footprints and food miles.

This research addresses several of these gaps. For its quantitative component (Objective Two), Chapter Five includes all GHGs in on-farm beef and lamb production in an LCA, and investigates freight and food processing emissions. In accordance with Objective Three, Chapter Six analyses the collective perspectives of industry, government and environmental NGOs on food miles and carbon footprints.

5

QUANTIFYING THE CARBON FOOTPRINTS OF BEEF AND LAMB

This chapter presents the results of my research relating to Objective Two. Section 5.1 compiles the inventory of the lamb and beef lifecycles using the bottom-up case-study and published sources. Section 5.2 illustrates the carbon footprints of beef and lamb, by adding the different stages of the lifecycle, and section 5.2.2 identifies reduction opportunities based on the magnitude of individual stages of the carbon footprints.

5.1 Compilation of Beef and Lamb's GHG Emissions

5.1.1 On-farm Emissions

Published sources were used to determine on-farm GHG emissions. Barber *et al.* (2007) derived emissions by combining data from ten non-cropping sheep and beef farms under the study of the Agricultural Research Group on Sustainability (ARGOS, 2007).

The following figures are based on an 'economic allocation'¹⁵ of 78.2% for sheep meat relative to other sheep products, and 83.2% for beef relative to other bovine products. The CO₂ emissions are derived from the energy requirements of 10.4 MJ/kg carcass weight (CW) for lamb and 9.5 MJ/kg CW for beef (Barber *et al.*, 2007). Table 5 shows that the average GHG emissions per kg of meat (measured in carcass weight, CW) are 15.1 kg

¹⁵ 'Economic allocation' is a method of allocating emissions across co-products in terms of economic value of each co-product. See 5.1.3 for further explanation. Economic allocation was used to allocate the sheep-related emissions to the two products of meat production, at 78.2%, and wool, at 21.8%. Likewise, cattle were divided into meat production, at 83.2%, and grazing (the grazing of cattle from other farms for a weekly fee), at 16.8%. The farm model annual meat production was 115.8 kg CW/ha for sheep, and 102 kg CW/ha for cattle

CO₂-e for lamb and 7.2 kg CO₂-e for beef. The carbon dioxide emissions shown in Table 5 (0.9 kg CO₂) are considerably higher than the 0.56 kg CO₂ per kg of lamb given by Saunders *et al.* (2006)¹⁶. However, the effect is marginal when considering the total equivalent emissions.

Table 5 Farm Greenhouse Gas Emissions (kg CO₂-e/kg CW)

	Methane	Nitrous Oxide	Carbon Dioxide	Total
Sheep	10.8	3.4	0.9	15.1
Cattle	5.0	1.8	0.4	7.2

(Source: Barber *et al.*, 2007)

Figure 6 illustrates the GHG composition of the on-farm footprint. In both types of meat production, CO₂ represents less than 6% of total GHG emissions. The dominance of CH₄ and N₂O emissions supports the argument for ensuring these are included in the carbon footprint methodology so that the climate change impact of meat and other agricultural products is accurately reflected.

Figure 6 On-Farm GHG Emissions

(Source: Barber *et al.*, 2007)

¹⁶ The two figures are based on the same methodology and the ARGOS database. The different emission factors employed may be one reason for the divergence (see Appendix Five). Because those used in Barber *et al.*'s report (2007) are more recent, includes cattle, and employs emission factors more similar to this study, Barber *et al.*'s (2007) data was preferred over Saunders *et al.*'s (2006).

For the GHG emissions associated with freight (s5.1.2) and meat processing (s5.1.3), calculations were based on case studies of one lamb processing plant and one beef processing plant in the North Island.

5.1.2 Domestic Freight

Lamb and beef plant participants were asked to provide the average distance livestock from farms were transported to their processing plant, and the transport of meat to seaport once it had been processed. The plant participants were asked which ports they used, how often they used each port, and using which transport mode (i.e. road or rail)¹⁷. Because of the complexity of the freight movements, several simplifying assumptions had to be made (as per s2.4.2) and are specified in notes to the equations.

Table 6 presents the freight data in aggregated form¹⁸, as given by processing plant participants. For the lamb plant, road transport to seaport represented 90% of total domestic freight, with a small trip (~30 km) by road to the rail network for transport to seaports. The beef plant had a much larger rail freight share, with 40% of containers transported a short road distance to the rail network, and 60% transported to storage facilities by road, of which the majority was then transported by rail to seaports. The trip proportions (determined by using weighted average distances to ports), by mode (road and rail) yielded the following results.

Table 6 Weighted Average Freight Data

	Lamb plant	Beef plant
Transport of livestock from farms to plant		
Average distance (km)	125	150
Transport of meat from plants to seaports		
Weighted average meat freight		
Road (km)	270	137
Rail (km)	34	451.5
Total (km)	329	738.5

The distances between the farm and the plant of 125 km and 150 km are similar to but higher than the 100 km distance assumed by Barber *et al.* (2007). Average weighted

¹⁷ Meat processing companies often use different shipping companies, which determine the location and time products are exported by ship. In such cases, meat works participants were asked how frequently they use each port, and a weighted distance was calculated (referred to as 'proportional trips'). Distances for road were calculated using a road map, and where distances by rail were determined by speaking to an ONTRACK (New Zealand Railways Corporation) operations manager.

¹⁸ To ensure confidentiality is maintained.

distances between the plants and the ports are around twice that of the farm-to-plant distances.

5.1.2.1 Transport of Livestock from the Farm to the Plant

The transport emissions of livestock between the farm and meatworks was calculated using the following equation:

Equation 1 Emissions associated with Animal Road Transport from Farm to Plant

Emissions of CO ₂ -e due to road transport to meatworks per unit of CW and per km	=	Emissions of CO ₂ -e per litre of diesel ^a	x	Fuel consumption per unit of gross truck weight ^b and km	x	Ratio of gross truck weight to payload	x	Ratio of live animal weight to carcass weight ^c	x	Adjustment for vehicle utilisation ^d
(kg CO ₂ -e /kg CW-km)	=	kg CO ₂ -e /litre	x	litre/kg TL-km	x	TL/PL	x	LW/CW	x	a
	=	2.65315 x 1.193	x	1.136 ^e x 10 ⁻⁵	x	2	x	lamb: 1/0.42 beef: 1/0.55	x	1.69
Lamb	=	29 x 10 ⁻⁵ kg CO ₂ -e /kg CW-km								
Beef	=	22 x 10 ⁻⁵ kg CO ₂ -e /kg CW-km								

Notes

- (a) This emission factor is based on consumer energy use but accounts for primary energy (i.e. the emissions from combustion (direct emissions) and fugitive emissions¹⁹ (indirect emissions). For direct emissions, average implied CO₂ equivalent emissions factor of regular diesel and 50 ppm sulphur diesel calculated by MED (MED, 2007b) based on gross Calorific Value (CV) were used. For indirect emissions, the multiplier of 1.193 calculated by Barber *et al.* (2007) was used. See Table 8 for more information on emission factors.
- (b) Gross truck weight (TL) represents the weight of the truck itself plus the weight of the payload (PL). In this formula, payload represents the total weight of the live animals being transported.
- (c) The ratio of carcass weight (CW) to live weight (LW) is 0.42 for sheep and 0.55 for beef (Barber *et al.*, 2007).
- (d) The adjustment a is based on the assumption that for every km of the distance from farm gate to meatworks, trucks must drive another km without payload based on the TERNZ (2005) estimate that heavy vehicle (HV) utilisation is currently estimated by the Road Transport Forum to be 49-53%²⁰ (equivalent to being fully laden half of the time, and empty for the other half); and that fuel consumption in that case amounts to 69% of the amount of fuel consumed by fully laden trucks (based on Nylund & Erkkilä (2005)). HV utilisation is only an estimate, as actual utilisation has not been measured (Baas & Latto, 2005). The utilisation figure employed was 50%, and accounts for both the fact that vehicles will not be fully loaded at all times on the journey from the farm to the meatworks (because a single vehicle often picks up livestock for processing from several farms) and the fact that most (but not all) trucks return empty.
- (e) This figure is based on a fuel consumption of 0.5 litre/km for a 44 tonne non-refrigerated truck and trailer, which was recorded by meat plant participants to be the vehicle used (estimated by Baas & Latto, 2005). This

¹⁹ Fugitive emissions are those emissions that do not come from combustion but arise as a result of processing or transforming fuels (MED, 2007b) from coal mining and post-mining, transmission and distribution, processing and flaring, oil transportation and refinery and geothermal. Fugitive emissions from constituted 5.2% of total CO₂-e emissions in 2006 (*ibid*).

²⁰ This figure compares with an utilisation of 63% in Australia (Baas & Latto, 2005).

figure is employed by MED and Ministry of Transport (pers. comm. MED and Ministry of Transport officials) and is similar to the DEFRA figure of 0.448 l/km for a maximum weight of 44 tonnes, and quoted by Saunders *et al.* (2006).

Using the average distances of 125 km for lamb and 150 km for beef (see Table 6) and the results from the above equation, the GHG emissions generated from this stage of the lifecycle are 0.036 kg CO₂-e/kg CW for lamb and 0.033 kg CO₂-e/kg CW for beef.

5.1.2.2 Transport of Livestock from the Plant to the Port

The calculation of GHG emissions associated with meat transport from the meatworks to the port of export is similar to the equation for livestock freight above. Several modifications have been made. The first is the removal of the ratio of live weight to carcass weight (as the product being transported is now meat, measured in kg of CW), The second is the inclusion of rail transport, which requires the emissions from rail transport to be calculated separately due to the differences in efficiency of rail and road. Finally the third is the inclusion of the energy required by refrigeration.

Equation 2 Emissions associated with Lamb and Beef Transport from Meat Plants to Port of Export

Emissions of CO ₂ -e due to road transport to meatworks per unit of CW and per km	=	Emissions of CO ₂ -e per litre of diesel ^a from road	x	Fuel consumption per unit of gross truck weight ^b and km ^d	x	Ratio of gross truck weight to payload	x	Adjustment for empty return trip ^c
(kg CO ₂ -e /kg CW-km)	=	kg CO ₂ -e /litre	x	litre/kg TL-km	x	TL/PL	x	a
	=	2.65315 x 1.193	x	1.136 x 10 ⁻⁵	x	2	x	1.69
	=	12 x 10 ⁻⁵ kg CO ₂ -e/kg CW-km						

+

Emissions of CO ₂ -e due to rail transport to meatworks per unit of CW and per km	=	Rail freight efficiency relative to road freight efficiency ^c	x	Emissions of CO ₂ -e per litre of diesel ^a from road	x	Fuel consumption per unit of gross truck weight ^b and km ^d	x	Ratio of gross truck weight to payload	x	Adjustment for empty return trip ^c
(kg CO ₂ -e /kg CW-km)	=			kg CO ₂ -e /litre	x	litre/kg TL-km	x	TL/PL	x	a
	=	0.25		2.65315 x 1.193	x	1.136 x 10 ⁻⁵	x	2	x	1.69
	=	3 x 10 ⁻⁵ kg CO ₂ -e/kg CW-km								

+

Emissions of CO ₂ -e due to refrigeration during truck freight per unit of CW and per km	=	Emissions of CO ₂ -e per MJ of diesel	x	Energy consumption per unit of CW and km
(kg CO ₂ -e /kg CW-km)	=	kg CO ₂ -e /MJ	x	MJ/kgCW-km ^f
	=	0.08438077 ^b	x	3.1 x 10 ⁻⁴
Lamb and Beef	=	0.26 x 10 ⁻⁵ kg CO ₂ -e /kg CW-km		

Notes

(a) to (d) as for Equation 1 except (e):

(e) All lines of the New Zealand rail network are powered by diesel, except for the suburban passenger network in Wellington (pers. comm. Ministry of Transport official, 2007), The National Rail Strategy to 2015 states that rail freight is four times as efficient in terms of Wh per tonne km than truck (200 Wh/tonne km vs 810 Wh/tonne km) (MoT, 2005) which is consistent with other studies (see Table 2). Therefore, the diesel emissions per litre for truck were divided by four to obtain an emission factor for rail, in the absence of other New Zealand specific data (pers. comm. Ministry of Transport official, 2007).

- (f) The figure of 0.31 MJ/tonne-km used is an average of the 0.16 to 0.46 MJ/tonne-km range given by Carlsson (1997 in Jones, 2002) and assumes that road and rail refrigeration are the same. The average figure also accounts for that fact that no differentiation is made between fuel use from refrigeration or freezing.

Using the distances in Table 6 and the emission factors in Equation 2, the average GHG emissions involved in the transport of meat from the meatworks to seaport are 0.034 kg CO₂-e/kg CW for lamb and 0.030 kg CO₂-e/kg CW for beef. With the inclusion of the energy required in refrigeration, these become 0.035 and 0.032 CO₂-e/kg CW respectively.

5.1.3 Meat Processing

The inputs included here are the direct inputs electricity and gas (coal was not used in either plant). Embodied energy in machinery and indirect inputs such as GHG emissions from packaging were therefore not included – consistent with the Carbon Trust's (2007) methodology.

As well as beef and lamb, a meat processing plant may also produce a range of co-products on-site – including skins, offal and rendering material (mainly used to produce tallow and 'blood and bone'). Energy consumption must therefore be proportionally allocated to each of these different products. Two methods of allocation are possible: physical allocation (according to some sort of physical relationship, e.g. by volume) or 'economic allocation' (in terms of economic value). Physical allocation is considered to be the more accurate approach to use but economic allocation may be used if such data are unknown (ISO, 2006b: 14). The plants used in this report only produced meat and offal with co-products produced offsite. The physical allocation is thus relatively simple, the direct inputs being allocated 92: 8, meat: offal at both plants, reflecting the number of containers of each product type leaving each site.

Table 7 shows the aggregated data collected in order to calculate the emissions generated at the processing stage of the lifecycle of beef and lamb. This compares to the figure of 1710 MJ/tonne of an average non-rendering meat plant given by Lovatt and Chadderton (1996).

Table 7 Beef and Lamb Processing Energy use per tonne of meat (MJ/tonne)

	Lamb plant	Beef plant
Electricity	1917	1348
Gas	3	5
Total	1920	1353

Figure 7 shows the annual energy use of the two plants, and Figure 8 shows the associated GHG emissions (mainly CO₂ from gas combustion to heat water, and electricity use). Annual energy records ensure that seasonal variability in input and output quantities do not distort the energy consumption per unit of output. Electricity is the major energy component for both plants with gas contributing only a very small percentage to both energy consumption and GHG emissions. Coal was not used in either plant.

Figure 7 Annual Energy Use of Beef and Lamb Plants

Figure 8 Annual Emissions of Beef and Lamb Plants

The GHG emissions per unit of meat mass were calculated according to the following equation.

Equation 3 Lamb Processing Emissions

Emissions of CO₂-e from meatworks per unit of carcass weight =

	Total annual electricity use (MJ)	x	Ratio of meat production by mass to total mass of products in plant (92%)	x	1/total mass of meat in plant (tonnes)	x	CO ₂ -e emission factor of electricity (tonnes of CO ₂ - e/MJ)
+	Total annual gas use (MJ)	x	Ratio of meat production by mass to total mass of products in plant (92%)	x	1/total mass of meat in plant (tonnes)	x	CO ₂ -e emission factor of gas (tonnes of CO ₂ -e/MJ)

The emission factors shown in Table 8 were used to correlate the energy inputs with the associated emissions. The emission factors employed (MED, 2007b) have been modified to include indirect energy (see Footnote 22).

Table 8 GHG Emission Factors of Electricity, Gas and Diesel

Energy Source	GHG emission factors ²¹ (MED, 2007b)	Primary energy adjustments ²² (Barber <i>et al.</i> , 2007)	Converted GHG emissions factor (g CO ₂ -e/MJ)
Electricity	0.23 t CO ₂ -e/MWh	N/A (included in MED's implied estimates)	63.9
Gas	52.3 kt CO ₂ /PJ 1.26 t CH ₄ /PJ 0.09 t N ₂ O/PJ	1.13	66.3
Diesel	69.5 kt CO ₂ /PJ	1.193	84.38

These emission factors differ somewhat to those employed in previous studies (e.g. Saunders *et al.*, 2006; Barber *et al.*, 2007). Appendix Four discusses these differences.

Table 9, building on Table 7²³ and the emission factors (fourth column in Table 8), shows the emissions associated with meat processing from direct energy inputs. Approximately 30% more GHGs are emitted per unit mass of lamb than of beef.

Table 9 Emissions Profiles of Lamb and Beef Plants

²¹ Based on Gross Calorific Value.

²² As with the diesel fugitive multiplier used for freight emissions, emissions factors for gas are based on consumer energy and include fugitive emissions (non-combustion and indirect emissions estimated from primary energy) based on Barber *et al.*'s (2007) fugitive multipliers.

²³ MJ per unit mass of lamb and beef are not stated to maintain confidentiality

	kg CO ₂ -e/t CW	
	Lamb	Beef
Electricity	122.5	86.1
Gas	0.2	0.3
Total	122.7	86.4

5.2 Overall Carbon Footprint of New Zealand Beef and Lamb

5.2.1 Freight and Processing Contributions

Table 10 shows the GHG emissions generated as a result of the freight and meat processing stages described above. Figure 9 illustrates these emissions profiles.

Table 10 Emissions Profiles of Lamb and Beef Plants and Domestic Freight

	g CO ₂ -e/kg CW	
	Lamb	Beef
Freight		
Livestock freight (farm to plant)	36.17	33.15
Meat freight (plant to port)	34.68	31.94
Processing		
Electricity	122.48	86.12
Gas	0.23	0.35
Total (excl. shipping)	193.57	151.55

Lamb processing and freight emits 28% emissions per unit of mass more than beef processing, with 43% more emissions from electricity and gas at the processing stage.

While the reasons for this difference are not certain, it is likely due to the larger mass of cattle carcasses relative to lamb carcasses: it is more efficient to process a cattle carcass than a lamb carcass.

Figure 9 Emissions of Lamb and Beef Processing and Domestic Freight

Figure 9 shows the emissions generated from each plant. For both lamb and beef, electricity is the most significant generator of emissions (64% for lamb and 57% for beef), followed by freight (36% for lamb and 42% for beef). Gas is only a very minor component. In both cases, freight from the farm to the plant (19% for lamb and 22% for beef) is similar to the freight between the plant and the port (18% for lamb and 21% for beef).

5.2.2 Domestic Carbon Footprint Profiles

Referring back to the on-farm emissions shown in Figure 6, and using this study's field data for processing and freight, a domestic footprint can be compiled. Figure 10 shows the total carbon footprint of beef and lamb in New Zealand (referred to as 'GHG footprint' or 'GHG profile'), while Figure 11 excludes animal nitrous oxide (N₂O) and methane (CH₄) on-farm emissions (referred to as 'CO₂ footprint' or 'CO₂ profile'), leaving a comparison of essentially carbon dioxide emissions²⁴. Table 11 and Table 12 provide the emissions equivalents per kg of meat. Refer to Appendix Five for the absolute values and percentage contributions of each stage to the domestic CO₂ and GHG footprints.

²⁴ But includes small amounts of nitrous oxide and methane associated with electricity, diesel and gas use.

Table 11 Domestic GHG Profiles of Beef and Lamb

	kg CO ₂ -e/kg CW	
	Lamb	Beef
On-farm	15.100	7.200
Domestic Freight	0.071	0.065
Processing	0.123	0.086
Total	15.294	7.352

Table 12 Domestic CO₂ Profiles of Beef and Lamb

	kg CO ₂ -e/kg CW	
	Lamb	Beef
On-farm	0.900	0.400
Domestic Freight	0.071	0.065
Processing	0.123	0.086
Total	1.094	0.552

Figure 10 makes clear that processing and freight contribute only small amounts (around 1%) to the domestic GHG footprints, and that methane and nitrous oxide have the largest impacts. However, when assessing these stages in terms of the CO₂ footprints, processing contributes 11% for lamb and 16% for beef and freight contributes 6% for lamb and 12% for beef, as illustrated in Figure 11.

The difference between the domestic footprints of beef and lamb are also large: the GHG and CO₂ lamb footprints are both approximately double the beef footprints. The reasons behind the on-farm difference are not altogether clear.

Figure 10 Domestic GHG Footprint of Beef and Lamb

Figure 11 Domestic CO₂ Footprint of Beef and Lamb

5.2.3 International Carbon Footprint

In order to get a sense of the total food miles of New Zealand beef and lamb, shipping emissions have been included based on secondary sources. The emission factor of shipping is 0.0026 l/tonne-km or 0.26×10^{-5} l/kg-km (Saunders *et al.*, 2006)²⁵. The energy consumption of refrigeration by ship is estimated to be 0.035 MJ/tonne-km or 3.5×10^{-5} (Carlsson, 1997 in Jones, 2002), which does not differentiate between chilled or frozen product.

Equation 4 Emissions associated with International Shipping

Emissions of CO ₂ -e due to shipping per unit of CW and per km (kg CO ₂ -e /kg CW-km)	=	Emissions of CO ₂ -e per litre of diesel ^a kg CO ₂ -e /litre	x	Fuel consumption per unit of CW and km litre/kg CW-km
	=	2.65315 x 1.193	x	2.6 x 10 ⁻⁶
Lamb and Beef	=	8.23 x 10 ⁻⁶ kg CO ₂ -e/kg CW-km		
+				
Emissions of CO ₂ -e due to refrigeration during shipping per unit of CW and per km (kg CO ₂ -e /kg CW-km)	=	Emissions of CO ₂ -e per MJ of diesel kg CO ₂ -e /MJ	x	Energy consumption per unit of CW and km MJ/kg CW-km
	=	0.08438077 ^b	x	3.5 x 10 ⁻⁵
Lamb and Beef	=	2.95 x 10 ⁻⁶ kg CO ₂ -e/kg CW-km		
+				
Lamb and Beef	=	1.12 x 10 ⁻⁵ kg CO ₂ -e /kg CW-km		

Notes

(a) as for Equation 1

(b) as per Table 8

The shipping figure without refrigeration (of 8.23×10^{-6} kg CO₂-e /kg CW-km) which accounts for primary energy, CH₄ and N₂O compares to the 7×10^{-6} kg CO₂-e /kg CW-km given by DEFRA in Saunders *et al.* (2006) which only accounted for direct CO₂ emissions. Shipping and associated refrigeration of lamb and beef, based on a distance of 21,124 km to London²⁶ (Maritime Chain, n.d.) is 0.236 kg CO₂-e /kg CW. This is almost double the figure of 0.124 kg CO₂-e /kg CW given by Saunders *et al.* (2006) which does not take the refrigeration into account.

²⁵ Based on this figure, Saunders *et al.* calculated the energy requirement to be 0.114 MJ/tonne-km which is similar to the 0.1 MJ/tonne km given by Gerbens-Leenes *et al.* (2003).

²⁶ Saunders *et al.* (2006) used a distance of 17, 840 km to an unnamed UK port.

Table 13 shows the GHG profile and Table 14 shows the CO₂ profiles including shipping to London, UK, one of the most distant export destinations (referred to as ‘international footprint’ versus the ‘domestic footprints’ referred to above). Appendix Five presents the absolute values and percentage contributions of each stage to the international CO₂ and GHG footprints.

Table 13 International GHG Profiles of Beef & Lamb

	kg CO ₂ -e/kg CW	
	Lamb	Beef
On-farm	15.100	7.200
Processing	0.123	0.086
Domestic Freight	0.071	0.065
Shipping to London	0.236	0.236
Total	15.530	7.588

Table 14 International CO₂ Profiles of Beef and Lamb

	kg CO ₂ -e/kg CW	
	Lamb	Beef
On-farm	0.900	0.400
Processing	0.123	0.086
Domestic Freight	0.071	0.065
Shipping to London	0.236	0.236
Total	1.330	0.788

Figure 12 is the international GHG footprint, which includes the domestic stages previously presented plus the shipping emissions to London. For these footprints, shipping contributes 2% of the lamb footprint, and 3% of the beef footprint, and total freight up to port of import (i.e. food miles) consists of 2% for lamb and 4% for beef. The on-farm stage remains by far the largest GHG emitter, with 97% for lamb and 95% for beef. The international CO₂ footprint (Figure 13) shows that although on-farm CO₂ still makes up the greater part by far of the emissions, total freight to port of import (23% and 38% of lamb and beef footprints respectively) now has a more significant impact.

Although slightly smaller, the difference between the international footprints of beef and lamb remain large: the beef footprints are only 50% and 60% of the lamb equivalents in terms of total GHG and CO₂ respectively. Noting the methodological differences between studies, Saunders *et al.* (2006) figure of 2.849 kg CO₂-e/kg CW for UK lamb production (s.4.5) is over double the 1.330 kg CO₂-e/kg CW figure calculated here.

Figure 12 International GHG Footprint of Beef and Lamb

Figure 13 International CO₂ Footprint of Beef and Lamb

5.3 Reduction Opportunities

These case studies do not represent an industry-wide sample and drawing broad conclusions from this data would be unwise. However, the results do at least give some sense of the magnitude of the potential emissions of the processing and freight components at an industry level. It also enables industry players to gauge the relative emissions relevant to their individual business management strategies. Reduction opportunities or priorities are discussed below based on the relative magnitude each stage has to the total footprint. Ease or cost of abatement is not taken into account. Specific reduction methods are beyond the scope of this study.

5.3.1 Domestic Footprints

It is apparent from the total domestic GHG emissions profiles that on-farm methane and nitrous oxide emissions remain the focus for reduction opportunities as suggested by previous studies (Terry, 2007), contributing 99% for both lamb and beef. Even when not taking into account these emissions, on-farm carbon dioxide emissions remain the largest source of CO₂ emissions – with 82% of lamb and 73% for beef. This supports the conclusion that only considering food miles would be spurious and that processing emissions are not large either. However, because indirect inputs, such as embodied energy in machinery, were not included in the freight and processing stages, inclusion of these inputs may raise these stages' contributions to the overall profiles. Further work is needed in this area to assess this, although the contribution is not likely to be significant.

According to the CO₂ footprint, freight emissions are not a reduction priority, as they only contribute 6% and 12% of the domestic emissions of lamb and beef respectively. Despite this, road transport is a significant source of New Zealand's total GHG emissions (17%) and reduction opportunities, discussed in Chapters Six and Seven, should not be overlooked.

Processing emissions also have a smaller footprint than on-farm emissions, but they are greater than road and rail freight emissions, contributing 11% of the lamb footprint and 16% of beef footprint. This efficiency may be the result of the competitive nature of the meat industry, and the persistent push for cost savings. The high proportion of electricity relative to gas (and the absence of coal) apparent of the case study appears to be somewhat

uncharacteristic of the meat industry generally, where a more significant component of either gas (22%) or coal (37%) was observed in nine meat processing plants, discussed in 4.2 (Veritas, 2005). Reasons for the choice of energy source include plants' distance from sources of coal or gas, the types of technologies used by the plant, existing capital geared for use of gas or coal, and relative costs of each energy source (pers. comm. industry participant, 2007).

5.3.2 International Footprint

Even after including shipping to London, on-farm emissions still account for nearly all the emissions, with 97% and 95% for lamb and beef respectively, with methane and nitrous oxide together contributing 93% of the lamb footprint and 91% of the beef footprint, leaving 7% and 9% left for on-farm carbon dioxide, domestic road and rail freight, shipping to London and processing emissions. Again animal emissions are reduction priorities.

The exclusion of the animal GHGs highlights CO₂ reduction opportunities. Now with shipping contributing 18% to lamb and 30% to beef footprints, the overall freight emissions to port of import are 23% and 38%, which are now not negligible, and more than twice greater than the processing emissions of 9% for lamb and 11% for beef.

5.4 Limits of Accuracy

Overall, the results of from processing and freight are only indicative and should be interpreted with caution. This case study is not a random sample and is only two out of approximately 80 meat plants within the country, which has several implications. Firstly, only one data set has been taken, limiting the data's ability to have upper and lower bounds (i.e. no standard deviations). Secondly, the proportion of electricity relative to gas (and the absence of coal) is uncharacteristically high. If higher use of gas and coal is in fact more typical, then emissions from these sources will be more significant for the processing industry overall, and reduction opportunities from conversion away from these fossil sources will warrant further investigation. Finally, the plants did not have rendering facilities and rendering material was taken offsite for further processing, so that direct energy use in the plants are likely to be lower.

Furthermore the results are dependent on a number of critical assumptions, such as the choice of allocation method and the definition of system boundaries.

Because of data scarcity, on-farm emissions are derived from only ten farms and the emissions of CH₄ and N₂O are highly variable, creating large uncertainties in the footprints. Average freight distances between the farms and the plants are also uncertain because of the widely ranging transport distances between farms.

While this research fills a number of gaps in the report by Saunders *et al.* (2006), it leaves additional areas for further research. As listed in s2.4, several stages of the LCA could not be included. While the exclusion of minor emissions sources, such as from packaging and cleaning products are likely to be negligible, stages of potential magnitude include the road transport between rearing and fattening farms, the refrigeration of meat in storage before export, and the freight associated with domestic retail distribution systems. More research in these areas would identify additional reduction opportunities.

The specific LCA employed here has used a combination of primary and secondary sources which has created two major issues. The first is that, although embodied energy in capital was not included for processing and freight inventories (and are deliberately excluded in the methodology developed by the Carbon Trust (2007)), the on-farm inventory did include it. Hence it is likely that if embodied energy were excluded in the secondary source (or included in the primary data), the GHG emissions from processing and freight would in fact contribute more to the overall footprint.

Secondly, methodologies for allocating energy-related emissions across co-products (either based on physical quantities or economic value) will also affect the results, as described in 5.1.3 above. For on-farm emissions, Barber *et al.*'s (2007) calculations were based on an economic relationship model, whereas the freight and processing data used in this study uses a physical volume model. In this case study's processing plants, because meat forms the bulk of both the economic and physical allocations, it is unlikely that a shift to economic allocation would affect processing emissions results significantly. However, for on-farm allocation, where there are multiple co-products from both beef and sheep, emissions numbers may significantly differ. Investigation into how different the results from each approach would be an interesting comparative study.

In the next section variables based on assumptions or uncertain data are subjected to a sensitivity analysis in order to estimate the effects of the choices made regarding methods and data on the outcome of the study (in accordance with ISO, 2006a).

5.5 Sensitivity Analysis

The variables used to determine the sensitivity of the data are presented in the first column (Table 15) and correspond to: (1) a doubling the farm-plant weighted average distance; (2) the lower bound of domestic freight refrigeration (0.16 MJ/tonne-km according to Carlsson, 1997 in Jones, 2002 compared with 0.31 MJ/tonne-km for the (0) case); (3) the upper bound of domestic freight refrigeration (0.46 MJ/tonne-km, *ibid*); and (4) processing energy mix of 41% electricity, 22% gas and 37% coal. (0) corresponds to the original values. The sensitivity analysis suggests that the data is not highly sensitive to uncertainties. All values fit within a 99.9% and 106% range of the original data. The GHG footprints are not sensitive to the variables chosen although the literature suggests that N₂O and CH₄ uncertainties may increase the sensitivity significantly (e.g. $\pm 53\%$ for enteric CH₄, $-50\%/+100\%$ for manure management-related N₂O) (MfE, 2007a; Penman *et al.*, 2000). Uncertainty assessment is not conducted for CH₄ and N₂O emissions because this sensitivity analysis is restricted to primary data, and determining the uncertainties according to IPCC guidelines for these different gases and sources would require an in-depth analysis beyond the scope of this study.

The CO₂ footprints are more sensitive to the changes, with the farm-plant variable having the greatest effect, followed by a different energy mix in processing. Refrigeration in domestic freight has little effect.

Table 15 Sensitivity Analysis

Sensitivity variable	Lamb Carbon Footprints				Beef Carbon Footprints			
	Domestic		International		Domestic		International	
	value	% of original	value	% of original	value	% of original	value	% of original
GHG Footprints (kg CO₂-e/kg CW)								
(0) Original values	15.294	100.0%	15.530	100.0%	7.352	100.0%	7.588	100%
(1) 2 x farm-plant distance	15.330	100.2%	15.566	100.2%	7.385	100.5%	7.621	100.4%
(2) Lower domestic freight refrigeration	15.293	100.0%	15.529	100.0%	7.351	100.0%	7.587	100.0%
(3) Upper domestic freight refrigeration	15.294	100.0%	15.530	100.0%	7.352	100.0%	7.589	100.0%
(4) Processing energy mix	15.317	100.2%	15.554	100.2%	7.368	100.2%	7.605	100.2%
CO₂ Footprints								
(0) Original values	1.094	100.0%	1.330	100.0%	0.552	100.0%	0.788	100%
(1) 2 x farm-plant distance	1.130	103.3%	1.366	102.7%	0.585	106.0%	0.821	104.2%
(2) Lower domestic freight refrigeration	1.093	100.0%	1.329	100.0%	0.551	99.9%	0.787	99.9%
(3) Upper domestic freight refrigeration	1.094	100.0%	1.330	100.0%	0.552	100.1%	0.789	100.1%
(4) Processing energy mix	1.117	102.2%	1.354	101.8%	0.568	103.0%	0.805	102.1%

Now that the quantitative aspect of carbon footprints, through the analysis of two New Zealand agricultural products, has been explored in accordance with Objective Two, a qualitative analysis of key stakeholder perceptions of carbon footprints fulfils Objective Three in the following chapter.

6

PERSPECTIVES ON FOOD MILES AND CARBON FOOTPRINTS

What you might call ‘the truth’ emerges from the interaction between the different viewpoints about what the facts are.

(Salmon, RP)

This chapter presents the results of the stakeholder interviews, organised according to major emerging themes. Perspectives of and issues raised by stakeholders are compared within each theme. This is the final objective, Objective Three, to investigate stakeholder views on the potential of carbon footprints for addressing consumer environmental concerns. Government representatives, agro-food industry groups and environmental NGOs (ENGOS) were asked a variety of questions on whether food miles concerns threaten New Zealand primary food exports, whether the carbon footprint concept is useful for responding to food miles concerns, the opportunities for reducing the carbon footprints of New Zealand food, the preparedness of industry to account for carbon and GHG emissions, and what are the important issues that relate to New Zealand’s ‘clean green’ image (CGI) (if seen to be important).

The 21 people who were interviewed represented 21 organisations and were organised into three categories²⁷:

²⁷ In accordance with Victoria University of Wellington’s Human Ethics Committee guidance, participants are referred to according to how they agreed to be identified in this research, i.e. either by name or as a ‘representative’ from their organisation.

Category One: Government Representatives

- 1 Ministry for Foreign Affairs and Trade (MFAT)
- 2 Ministry of Economic Development (MED)
- 3 Ministry for the Environment (MfE)
- 4 Ministry of Agriculture and Forestry (MAF)
- 5 New Zealand Trade and Enterprise (NZTE)
- 6 Energy Efficiency and Conservation Authority (EECA)

Category Two: Industry Representatives

- 7 Meat Industry Association (MIA) representative
- 8 Meat Industry Association (MIA) representative
- 9 Meat and Wool New Zealand (M&W) representative
- 10 Phil O'Reilly, Chief Executive, Business New Zealand (BusinessNZ)
- 11 Charlie Pedersen, President, Federated Farmers
- 12 Rural Women New Zealand (RWNZ) representative
- 13 Federation of Māori Authorities (FOMA) representative
- 14 Tony Friedlander, Chief Executive of Road Transport Forum New Zealand (RTFNZ)
- 15 Pastoral Greenhouse Gas Research Consortium (PGgRc) representative
- 16 Sophie Jerram, External Liaison, Sustainable Business Network (SBN)
- 17 Andrew Stewart of Sustainable Wairarapa and a beef and sheep farmer

Category Three: ENGO Representatives

- 18 Guy Salmon, Chief Executive, Ecologic Foundation
- 19 Jörn Scherzer, Research Fellow, Ecologic Foundation
- 20 Molly Melhuish from Climate Defence Network, Sustainable Energy Forum, and East Harbour Carbon Reduction Action Group (EHCRAg)
- 21 Simon Terry from the Sustainability Council

Several participants interviewed represented organisations that participate in the inter-departmental working group on food miles (IWGFM) chaired by MFAT, a partnership between the agro-food sector and the New Zealand Government. These were M&W, MIA, Federated Farmers, MFAT, MfE, MAF, MED, and NZTE.

6.1 Issue Framing – Key Perspectives

Stakeholders see food miles and carbon footprints as either consumer-driven or climate change issues. Participants emphasise the importance of consumer perceptions, and values

and trends in New Zealand's export markets, particularly the UK. Similarly, the consumers' image of New Zealand food producers and products is seen as important:

There are reputational effects at play here where we need to be careful that New Zealand does not get portrayed as the poster child of the food miles movement.

(MFAT representative)

And

I think we are going to be successful if we can get close to consumers and understand what they want and tailor our products to meet their aspirations. We are interested in seeing whether we can use this issue to add value to our products without getting into some impossible costs (...). The challenge for New Zealand is one of transforming our production systems to make them more responsive to these marketplace developments.

(Salmon)

Pedersen believes Federated Farmers has a role in addressing the demand for more environmentally sustainable products:

Yes (...) the banner under which we operate is that our organisation adds value to the business of farming in New Zealand. So if we want to stay in business and stay leading edge as producers of food, we absolutely have to address the issues that our own community and that our markets think are important. So it is absolutely essential, and yes we do have a role to play.

(Pedersen)

O'Reilly believes that BusinessNZ plays a leading role in terms of sustainable consumption, and treats climate change no differently from any other change – commenting:

We have noticed – and it's a wonderful thing actually – an increasing understanding not just of the risks of climate change (...), but also of very significant business opportunities (...) we see a lot of interest.

(O'Reilly)

6.2 Threats or Opportunities to New Zealand

6.2.1 Accounting for GHG Emissions

It is a threat if you don't take advantage of the opportunity. (Salmon)

Participants were asked whether they thought accounting for GHG emissions was a threat or an opportunity to the agro-food sector. Nine participants responded that they see it as an opportunity, namely Stewart, Friedlander, Pedersen, O'Reilly, and EECA, MAF, PGgRc, M&W and MIA representatives. The FOMA and MfE representatives consider it to be a threat. Seven participants think it is a mix and/or both, depending on which primary industry, or which specific practices are concerned (Terry, Jerram, Salmon, Melhuish, and NZTE, MED, and MFAT representatives)²⁸. Figure 14 shows participant responses according to the different participant categories.

Figure 14 Is Accounting for GHGs a Threat or an Opportunity to the Agro-Food Sector?²⁹

Figure 14 suggests that accounting for GHG emissions in the agro-food sector is generally seen as an opportunity, with responses suggesting the provisos that New Zealand producers are well informed and can respond to market requirements. The private sector generally considers it as an opportunity, government is divided on the issue, and all ENGOs consider

²⁸ N/A answer from RWNZ Representative.
²⁹ Note the number of participants by 'category' i.e. private sector/government/ENGO is not equal. Refer to the beginning of the chapter for how many participants in each category

it to be a mix or both. The MED, NZTE and MAF representatives warn that products outside of Saunders *et al's* (2006) product categories may not stack up too well in terms of carbon emissions, particularly wool (MED representative). Dairy was also identified as at risk if it continues 'business as usual' (Jerram, Melhuish and MED representative).

6.2.2 Food Miles

It [food miles] is contained at the moment. It would have been [a threat] if we had done nothing; if protectionist elements in Europe, farmer groups and some others, had picked it up and used it to mischievously denigrate New Zealand products without taking the whole lifecycle thing.

(MAF representative)

Participants were asked whether they believe food miles to be a threat to the agro-food sector³⁰. This question differs from the previous question (about GHG accounting), in that food miles is a consumer concern, whereas accounting for GHGs relates to the agro-food sector's broader capacity to measure and monitor its emissions and be able to communicate that information. Figure 15 shows the responses according to the different participant categories. No particular discerning pattern according to category can be seen.

Figure 15 Is Food Miles a Threat to the Agro-Food Sector?

³⁰ N/A answer from RWNZ and MIA Representatives.

Five participants (Stewart, Jerram, Melhuish and MfE and FOMA representatives) think that it is a threat while three participants (Friedlander, Salmon and Pedersen) do not.

Food miles is already a dead duck.

(Pedersen)

Two participants (MED and NZTE representatives) believe it to be a dissipating threat, as consumers in the UK better understand the issue and realise its shortcomings. Seven participants (O'Reilly, Terry and EECA, MFAT, MAF, M&W and PGgRc representatives) think it is both a threat and an opportunity: a threat if no action is taken but an opportunity if well managed; and/or a threat for some production stages, e.g. air freighted goods.

It [food miles] is if allowed to fester without adequate riposte.

(O'Reilly)

and

It is certainly not helpful. Although looking at it as positively as possible it gives us an opportunity to tell our broader sustainability story and to essentially do the work that we have done on carbon emissions and the efficiency of the New Zealand sheep and beef sector. In particular it has made us look comparatively [at our production] with local production in the UK. That has resulted in being able to establish facts and figures around the fact that New Zealand produces lamb for about somewhere between a quarter and a third of the emissions of lamb production in the UK.

(M&W representative)

While there has been no empirical evidence that sales of New Zealand products have decreased as a result of food miles (M&W, MFAT and NZTE representatives), food miles is a signal of a much larger picture even if it is a simplistic concept (MfE representative). The IWGFM gathers a lot of feedback from international posts confirming that food miles and carbon footprints are major issues (MFAT representative).

When referring to food miles, all participants but two think food miles is a flawed concept, with limited scope to indicate the sustainability of food products. One participant comments "most claims which make reference to New Zealand are based on ignorance" (NZTE representative). Some participants feel that New Zealand has been specifically targeted because of the geographic isolation from its key export markets (NZTE & MFAT representatives). The food miles issue is seen to be largely confined to the UK, with a slight

occurrence in Germany (Terry, MED and NZTE representatives), and the United States (Terry, MFAT representative), as ‘bioregionalism’ (Terry). The MED representative thinks the issue could “spill over into other parts of Europe”. These types of concerns frame the food miles issue in terms of trying to manage consumers’ perceptions and attitudes rather than as an issue focused on managing New Zealand’s primary products themselves, as highlighted by the EECA representative.

The MFAT representative notes the considerable positive spin-offs arising out of food miles – “the opportunity in addressing the misinformation presented in the UK to adjust New Zealand’s branding techniques to better reflect the increasing mass of environmentally conscious consumers”.

SBN and EHCRAAG are the only two organisations interviewed interested in local food production and food miles domestically. EHCRAAG is taking steps to actively reduce their personal food miles, such as by engaging in bartering and eating locally (Melhuish). Jerram comments:

We need to look at a reorientation about eating locally. As a counter discussion to export, I think we need to be looking at encouraging people to source locally, what is in season to reduce our footprints. I guess that is a philosophical question.

(Jerram)

6.2.3 Potential of Carbon Footprints to Address Food Miles Concerns

Participants unanimously agreed that carbon footprints are an opportunity to reframe the debate from just simple food miles³¹. The majority of participants highlight the need to move beyond food miles to reframe the environmental concerns of consumers by using carbon footprints and/or taking a lifecycle approach. This means that New Zealand’s agro-food sector has had to look introspectively at their management practices.

Some respondents say some sectors are more prepared than others to adopt carbon footprints (NZTE & MIA representatives). With regard to the meat industry, MIA representatives think carbon footprints to be *more* useful than food miles but MIA is not actively trying to “push” carbon footprints.

³¹ N/A answer from Friedlander and RWNZ Representative.

6.2.4 LCA Methodological and Carbon Labelling Issues

Two major themes emerge from discussions about using carbon footprints and lifecycle assessments. The first is the raft of methodological issues that need to be negotiated nationally and internationally, and the standard setting, certification, accreditation and verification processes associated with the introduction of a carbon label for agro-food products. Methodological issues are principally of concern to stakeholders with a high level of knowledge of agricultural systems, across the different participant categories.

MAF and MFAT are negotiating with the Department of Food, Environment and Rural Affairs (DEFRA) in the UK to develop an international standardised carbon footprint methodology that will lead to a labelling methodology (MAF & MFAT representatives). MAF's work on a 'GHG Footprinting Strategy' (announced in September, 2007), and their discussions with DEFRA are seen as important areas to ensure New Zealand's commodity exports are not unfairly disadvantaged in footprinting comparisons with products from other countries (Pedersen and MAF and MFAT representatives).

Pedersen supports the work but does not want to lead it, because it may "raise suspicions". He notes:

we are keen for the EU to promote and establish it and absorb the costs.

(Pedersen)

Salmon and Scherzer, who also endorse a footprinting methodology, suggest the PGgRc should have responsibility for it, and stress the need for incorporating uncertainty into the methodology and the results, referring to the absence of bounds of uncertainty in the LCA estimates by Saunders *et al.* (2006).

MIA representatives, aware of the possibilities of introducing carbon labelling to traded agricultural products, also emphasise the importance of an agreed global method with an independent standard setting authority and verifier to create a simple yet robust label. They raise concerns about practicality, inquiring about the period over which the label would last, whether it would cover lamb and beef generically, or would have different labels according to different meat products.

Salmon comments that the industry had been slow to respond to labelling initiatives in the past, in comparison to the array of labels other countries have had for decades. For

example, *Project 98*, a private-public labelling initiative launched in 1998, which Salmon was involved with, was abandoned because industry was not prepared, apparently, to implement the scheme:

One of the real killers of *Project 98* was the belief it was going to require annual on-farm inspections. And the irony of it is that Fonterra is now doing that anyway. What was previously seen as an unacceptable cost has now become an accepted part of doing business (....) What can we learn about the process of learning?

(Salmon)

Salmon also believes that more recent developments towards carbon labelling would not impose impossible costs on the agro-food sector:

The cost of doing a lot of these things does not look huge. I would not portray it as a free lunch but as making an investment that will pay off.

(Salmon)

Industry now appears more ready for the labelling challenge – or similar schemes export markets may require. MIA representatives think that although they are not pushing for carbon footprints, they would be prepared to do it if one of the market required them to do so. Pedersen positively comments on labelling:

Supermarkets like Sainsbury's and Tesco's are indicating that they want to have a global footprint easy-to-read label on food as soon as they can. We have been in contact with them and are saying that we are very confident that we will knock off all European food competition. We are very keen for that.

(Pedersen)

6.3 Knowledge, Information and Research

Participants were asked whether they think their organisation has enough knowledge and information to address the issues faced. Responses either refer to information about developments and trends relating to food miles offshore, or to domestic-focused research about the environmental performance of New Zealand's primary products and production systems.

Monitoring offshore trends appears well covered, with MFAT, MED, NZTE, Federated Farmers, FOMA, BusinessNZ, and M&W devoting resources to doing so. However,

research and monitoring of internal trends is less emphasised. The NZTE representative notes that there is no real need for independent research as businesses are doing it themselves. In contrast, Ecologic Foundation, which for many years has been carrying out its own research, highlights the need for “more integrity in the information with which we judge that [the sustainability of the agriculture sector]”:

We have the problem that we have a fairly limited range of universities and research providers and most of them are so dependent on the primary sector that you can't really get an independent environmental view into the public process unless you get enough resources together in a little group like Ecologic.

(Salmon)

Freight data are particularly sparse:

It is very hard to get that information. Transport is a very very competitive area and it is commercially sensitive. We try to get information that tells us how much is being shifted by road.

(Friedlander)

Friedlander supports food miles studies of New Zealand primary products for showing the importance of road freight to New Zealand's economy and people's dependence on it, rather than to show the environmental impact of freight.

The Saunders-led work at Lincoln University ('the Lincoln report') was widely referred to by participants (Terry, Pedersen, Friedlander, Salmon, O'Reilly, and NZTE, MFAT, MAF, PGgRc, M&W, MIA representatives). While the report is widely welcomed by participants, several concerns were also raised, in particular from MAF, Salmon and Scherzer. The MAF representative reports “we [New Zealand primary producers] may not be as good as the Lincoln report first suggested”.

Salmon and Scherzer highlight the lack of a peer review of the report:

When you look at the Lincoln Study and its findings, it is interesting how quiet the Crown Research Institutes have remained in the whole discussion. There has been no rebuttal from them even though the flaws from that study are blatantly obvious. They were aware of the flaws, yet they still they choose not to say anything.

(Scherzer)

and an inadequate statistical analysis:

We've got two countries' error margins sitting together on a graph, and the error margins overlap and so that, I think, calls for some considerable caution in making claims that one country is better than another.

(Salmon)

6.4 Opportunities for Greenhouse Gas Mitigation

When participants were asked whether they saw opportunities for more efficient energy use or GHG mitigation in order to reduce the carbon footprints of New Zealand food, responses were varied. Terry, Jerram, Salmon, Melhuish and EECA, MfE, MAF, MED, PGgRc, RWNZ representatives answered in the affirmative. Friedlander, O'Reilly, Pedersen, and M&W, FOMA, and MIA representatives did not think so³². Figure 16 shows the responses according to the participant categories.

Figure 16 Do You See Opportunities to Reduce the Carbon Footprints of New Zealand Food?

ENGOS and government are generally more positive about reduction opportunities than the private sector, with all ENGO participants believing there to be opportunities in contrast to only three of the ten industry participants. While the PGgRc representative

³² N/A answer from Stewart, and NZTE and MFAT Representatives.

believes there are opportunities, PGgRc has been tentative in promoting mitigation technologies as explained by the following:

Because of where we are at with this sort of science (...), we have kept pretty quiet. Two reasons: one, we recognise the nature of our audience in that we don't want to go out there making claims that we are going to supply them with emission mitigation which is going to get more productivity when we don't actually have the information behind it to make those claims (...). It is still early days. The second reason is to make sure that we have some information to be able to talk to farmers and get them to understand how it works in their business. If you ask a farmer how much their emissions are, a farmer won't know.

(PGgRc representative)

Salmon considers nitrification inhibitors, which can reduce N₂O emissions, are not yet readily available to farmers because of the inadequate institutional structures between the farming community and researchers:

We have an extension problem. We have some of these technologies sitting in the wings, which, at least on the evidence we have got so far, could make quite a difference. But it is not that easy to get farmers to take them up. Farmers do not have a price signal that provides a strong incentive, and there is a lack of one-on-one contact between people who know about the technology and the farmers themselves

(Salmon)

Private sector participants are the only category to respond negatively. Friedlander, Pedersen, and M&W, FOMA, and MIA representatives comment on the fact that there may be some scope for reduction but that market forces are already at play and sufficient to create energy use efficiencies:

There is a natural drive for that anyway. The economics of energy use are such that the industry is always pursuing efficiencies in that area.

(M&W representative)

and

because energy is expensive, we make the assumption that our members use it as wisely as they possibly can (...). Economic signals are heading our farmers in the right direction from a climate change point of view.

(Pedersen)

There is also concern that new technologies are not at the stage where they might be used. The M&W representative, when asked whether there are opportunities to reduce the carbon footprints of the beef and sheep sector, answered:

I am a little pessimistic in that area. It is not clear to me yet how individual farmers can make substantial impact on GHG emissions.

(M&W representative)

and

The research that PGgRc does is world leading, but we are still a long way off finding simple cost-effective technologies to reduce agricultural emissions.

(MIA representative)

Several participants refer to specific mitigation technologies, such as ‘carbon farming’ and direct drilling methods and other measures, which could reduce the GHG emissions across the supply chain of agricultural products. Pedersen and Stewart refer to non-tillage and direct drilling methods. The PGgRC and the Sustainability Council have studied nitrification inhibitors and different animal feeds such as maize (PGgRC representative, Terry (see Terry, 2007)). Melhuish proposes a mixed use system approach for beef and sheep farms whereby ‘carbon farming’ crops such as willow are introduced, which provide grazing animals with tender willow shoots, and the willow is then harvested as an energy source. In terms of reducing freight emissions, Friedlander and the EECA representative suggest that vehicle maintenance and driver behaviour could significantly increase the efficiency of the heavy truck fleet. Friedlander further proposes that increasing gross loads from 44 tonnes to 60 tonnes could achieve savings of around 20%.

6.5 Industry Preparedness

The degree of preparedness of industry to implement carbon footprinting is considered here as a function of 1) perceptions about whether there are opportunities for carbon footprint reduction; 2) leadership with regard to the risks and opportunities arising out of both external market trends such as food miles and internal industry environmental performance such as their carbon footprints; and 3) the existence of initiatives to help their members tackle environmental or climate change issues.

Industry perceptions of opportunities for carbon footprint reduction are discussed in the previous section. In terms of leadership, industry participants take seriously the concerns of

environmentally conscious export markets of New Zealand agricultural products, and this appears to have provided the stimulus for evolution and change in the business and agro-food community. Industry participants affirm that they are undertaking research into emerging trends, and in general seem well informed about food miles developments (partially aided by the IWGFM), implementation of the Kyoto Protocol, and carbon footprint research in New Zealand.

While the initial focus of industry participants was more on external UK drivers, rather than on efforts to increase information about New Zealand's internal environmental performance, this is slowly changing. Either participants are following New Zealand-specific research, have commissioned their own research, or are trialling carbon footprinting exercises internally. For example, M&W have been "putting millions of dollars over the last 3-5 years" into the PGgRc's work for on-farm GHG emissions reductions, and contributed funds to the Saunders-led work (M&W representative). FOMA have three of their members piloting carbon footprints (FOMA representative).

In terms of the latter (3) above, five of the eleven organisations currently have some form of initiative (including Federated Farmers, M&W, FOMA, SBN and BusinessNZ). None of the initiatives had yet incorporated life cycle approaches relevant to their marketing or management activities although research towards such approaches is reportedly underway for FOMA, SBN and M&W.

6.6 Wider Sustainability Issues

Many participants emphasise other specific sustainability issues that should not be pushed aside by climate concerns, and others note the importance of sustainability generically.

Stewart, Terry, Salmon, Jerram and the M&W representative express concern that other environmental sustainability issues, especially water, soil, biodiversity, and animal welfare (and genetic modification, pesticide use and residues and food safety in the case of Terry) should not be neglected.

We would prefer to think of it more in terms of the broader subject of sustainability. Meat and wool production, where farmers are very aware of the impact of their operations on the environment associated with land use and

water use. Those are things that they would tend to focus on more than GHG emissions (...), which are somewhat less visible to them I suppose.

(M&W representative)

O'Reilly, Pedersen, MfE, MED, MFAT representatives note the importance of sustainability more generally but do not mention specific environmental issues.

It [demonstrating our sustainability credentials] really does need to be across the board if we are going to position ourselves in the global market place that is much more environmentally conscious.

(MFAT representative)

O'Reilly recognises the danger of measuring and monitoring “in a non-holistic way is that you get unintended outcomes that are pretty ugly” (O'Reilly).

Pedersen and the RWNZ representative believe economic sustainability is a vital component of overall sustainability:

From a sustainability point of view, economic sustainability is essential. You will see if you do any research on the Third World, that the poor nations have dreadful environmental practices and are still creating some seriously deleterious effects on the environment, destroying waterways and soils. The reason this is happening is that they are not economically sustainable. It is absolute truism to say (...) 'you can't be green if you are in the red'

(Pedersen)

The emphasis on wider sustainability is also reflected in suggestions that IWGFM has moved from just monitoring overseas media developments about food miles to a broader sustainability focus (MAF, MFAT and MED representatives).

6.7 New Zealand's 'Clean Green' Image

If New Zealand wants to maintain its reputation as a responsible producer of agricultural products, it needs to show that it is addressing the issue, has efficient production systems and is operating at world's best practice.

(MIA representative)

Participants were asked whether they thought the 'clean green' image is important for New Zealand, and if so, what issues need to be addressed to retain and strengthen it. Most participants think the image is important to New Zealand's reputation and economy

(s6.7.1). Two participants, Jerram and O'Reilly, feel the image could be extended or redefined (s6.7.2). Pedersen and the M&W representative believe the image should be dispensed with (s6.7.3).

6.7.1 Importance of the 'Clean Green' Image

Some participants believe that to retain and strengthen the CGI, New Zealand needs to be able to demonstrate that it is living up to this image and New Zealand businesses should take an active role in upholding it, such as through robust measuring and monitoring (MAF representative), and “stronger alignment between what we do commercially and what people expect overseas” (MED representative). Terry highlights that the recent OECD *Environmental Performance Review* showed that New Zealand lags in a number of important areas, which high value consumers will want to see improved. This message is supported by the FOMA representative who outlines the misconceptions attached to the image:

There are a lot of fallacies and problems behind it [the image] (...). If you look through Māori eyes in New Zealand, there has been an enormous amount of destruction. Generally the customarily mahinga kai as our food source has been destroyed (...) The ocean was our supermarket, it was our food source. Well, if we don't manage that, we won't have it for future generations. It is the same with the land. There has been serious degradation. You would talk to very few Māori that would not say that sort of thing.

(FOMA representative)

The MfE representative suggests that consumers will be demanding better and better environmental performance, indicating that even if we currently measure up to today's standards, we will still need to adopt more sustainable practices for the future (MfE representative):

We have to prove beyond reasonable doubt in terms of our environmental credentials. Yes we trade on that but if people want to scrutinise our system, they can always find holes in them. There is an opportunity as New Zealanders to try and improve on our image by adopting even more environmentally sustainable business practices. There is plenty of scope for improvement.

(MfE representative)

6.7.2 Redefinition or Extension of ‘Clean and Green’

Jerram believes the CGI to be “massively at risk”, emphasises traceability, and thinks the image should be redefined:

Traceability is increasingly important. How can you otherwise identify that this is 'clean and green' if it is not able to be traced back to a particular piece of land, a particular cow, sheep or vine (...). I think it [the CGI] should be abandoned to be honest (...) it is clearly a misconception and so broad that people are able to dream whatever they want about it (...) I think traceability is key to that redefinition.

(Jerram)

O'Reilly thinks the CGI is important but there is a wider picture that should be built around “integrity”:

It is also about New Zealand's social standing, participation in wars, its nuclear free image, camaraderie of the many New Zealanders living offshore, the attitudes and personalities of those New Zealanders; so it is a very much wider thing than just the 'clean and green' (...). What I think we need to do is do what New Zealand always does, that is: one, lead the world where we can e.g. if anybody can work out how to stop cows burping, we can, we have got lots of them, whereas sequestering technology for coal, we have coal, but we don't burn much of it, so let's leave that to someone else. Secondly, cooperate with the world where we can.

(O'Reilly)

6.7.3 Dispensing with ‘Clean and Green’

Pedersen is not in favour of the image, and explains why:

You won't find New Zealand agriculture using 'clean and green'. We have not used it for about 15 years. It is a message we are probably sick of, because sadly, it was used as a slogan to beat us with. In New Zealand, people say “they say they are clean and green but they are not as clean and green as they say they are” (...). I think that industry has been naïve in repeating the 'clean and green' mantra (...). 'Clean and green' was coined by the NZ Dairy Board about 15 years ago (...). It has been taken over as a message about rural New Zealand. I think it is significantly overplayed. For agriculture, our image is actually pastoral, it is extensive (not housed), animals are actually outside, eating grass, living pretty natural lives (...). It is the pastoral image that is used overseas

(pictures of animals grazing on hillsides...) (...) rather than clean and green. 'Clean and green' is or has become an environmental message whereas in fact our agricultural image that we portray internationally is one of pastoral farmers. That is our unique difference.

(Pedersen)

The M&W Representative prefers to emphasise the efficiency of the New Zealand's sheep and beef production systems to 'clean and green':

In terms of lamb, New Zealand is our brand and I am not sure that clean and green is the phraseology I would use (...) We are more interested in sustainability and telling our story about our efficient production of sheep meat (...) In many cases it is more efficient for the products to be produced here than in other parts of the world. People need to take that into consideration.

(M&W representative)

Emerging from the 'clean green' theme are certain dichotomies and tensions between agro-food sector and ENGO participants. While agro-food sector participants (Pedersen and M&W representative) claim outstanding environmental credentials far beyond their equivalents offshore, ENGOs are critical of this claim. Terry criticises the farming community's proclamation of their environmental credentials to be an exploitation of the country's intrinsic natural comparative advantage, which the sector's practices are not responsible for:

On current course, relying on an innately less carbon intensive, pastoral base to deliver a sustainable position in the market is just not going to work because we would need to be seen to be acting as well as just exploiting the inherited comparative advantage.

(Terry)

Salmon views the CGI used by farmers as "a badge of complacency", and dismisses Federated Farmer's new marketing campaign, (showing New Zealand farmers as climate change heroes: see Figure 17), saying that farmers cannot claim this if they are not putting less pressure on the environment:

We still see that with Charlie Pedersen latching on to Caroline Saunders' data and saying, "NZ farmers are global warming heroes". They think we are already 'clean and green' but this is rubbish. The problem with 'clean and green' is that we have been coasting along thinking that we don't need to do anything. What we need to do is to galvanise the sense that we aren't clean and green, we are not

delivering on the promise, and that the best strategy we have for New Zealand's future development is to latch onto it, believe in it and deliver it.

(Salmon)

Figure 17 Federated Farmers Magazine Cover: 'Climate Change Hero'

6.8 Success Stories

New Zealand products generally have great stories to tell, many based on the quality of our products, production methods, environment etc.

(NZTE representative)

Six participants (Jerram, Stewart and Meat & Wool, MfE, MFAT, NZTE representatives) indicate that telling success stories is a communication strategy for New Zealand or the agricultural sector. NZTE, MfE, and M&W representatives emphasise that stories told about New Zealand's efficient production systems would help its reputation. Jerram thinks telling the personal stories of producers is a useful way to position New Zealand's products:

In terms of the way in which we market our end-products, it is about saying that if they [the meat farmers in the South Island] were able to tell the story around their lambs and the way they have been kept, the extensive grazing as opposed to intensive farming practices. That is parallel to Fair Trade and the stories like 'here is a grower in Nigeria, and this is his life'. When you are purchasing an end product, you understand where it has come from.

(Jerram)

The above stakeholder views of food miles and carbon footprints offer some important insights for evaluating the applicability of the carbon footprint concept to New Zealand for addressing consumer environmental concerns. These are discussed in the following chapter, along with a discussion of results from previous chapters.

7

DISCUSSION

In the context of strategic management of anthropogenic climate change and energy risk, the aims of this thesis have been to determine the carbon footprints of New Zealand beef and lamb and evaluate the relevance of the carbon footprint concept to New Zealand for addressing consumer environmental concerns. The analyses of the carbon footprints of beef and lamb and the stakeholder perspectives elicited from the interviews are discussed here in relation to the wider issues of the environmental aspects of agro-food systems and the opportunities for internalising externalities of food systems.

7.1 Food Systems and Climate Change

It is not easy for consumers or even academics to comprehensively encapsulate the environmental impacts of food products because food systems are complex ecological sub-systems. Research on these impacts is wide; however there is a gap between very specific LCA studies for single food products and the simplified research required for the comparison of a range of food products (Jungsbluth *et al.*, 2000). Based on this gap and the lack of methodological consistency present in LCA (Audsley *et al.*, 1997; Brodt, 2007; Núñez *et al.*, 2005; Tukker & Jansen, 2006), it is difficult to consolidate the comparative performance of different foods and provide general rules for environmentally preferable food purchasing. LCAs have suggested, however, that not only the performance of an individual company or sector is important, but the overall performance of all companies in a supply chain (Curran, 2006; Mont & Bleischwitz, 2007). When assessed per unit of product, several processes and stages in the food system recur in the literature as climate change ‘bads’: airfreighted goods, animal husbandry (especially ruminants), heated greenhouses, reliance on energy-intensive agro-chemicals, and shopping by car (Carlsson-Kanyama *et al.*, 2003; Dutlih & Kramer, 2000; Jungsbluth *et al.*, 2000; Pretty *et al.*, 2005; Steinfeld *et al.*, 2006). While shipping contributes between 1.8% and 4.5% of global CO₂ emissions (Marintek *et al.*, 2000; Vidal, 2008), it is not included among these bads as, when

measured per unit of product, it is efficient compared with road and air (Table 2). Shipping thus stands out against the food miles argument.

The increasing negative externalities associated with agro-food systems have raised concerns amongst academics, ecological citizens and society at large. For consumers to make environmentally preferable purchasing decisions, based on more than their perceptions on what is or is not detrimental to the environment, environmental assessment tools must be robust enough to provide accurate information. For example, they should avoid the transfer of environmental impacts from one stage in a food supply chain to another. LCA fulfils this requirement, although methodological freedom inherent in LCA can hinder comparability. As a tool for representing the environmental effects of food products, the academic community generally agrees that a carbon footprint based on LCA is superior to food miles, in particular, because rather than just assessing the environmental impact of food transport, it takes into account all, or at least more significant stages, such as production and processing *as well as* transport.

The reduction of information asymmetries through carbon footprinting and labelling schemes are a step towards internalising GHG externalities as they ensure more accurate information about the carbon involved in a product is made available to consumers. In order to meet the consumers' desire for more information about the external costs of their food purchases, producers must be prepared to provide such information. This has the potential to unlock unsustainable patterns of consumption and lead proactively to more sustainable production patterns (Jackson & Michaelis, 2003; Sanne, 2002).

7.2 The Carbon Footprints of New Zealand Beef and Lamb

Research on the carbon footprints of New Zealand agricultural products based on LCA has only recently emerged as a significant field of study. Research that focused on on-farm emissions and energy use has generally concluded that pastoral New Zealand agricultural systems are more energy and CO₂ efficient than intensive systems typical of Europe and the United States (McChesney *et al.*, 1981/1982; Sims *et al.*, 1996 in Wells, 2001; Wells, 2001; Basset-Mens *et al.*, 2005; Barber & Pellow, 2005; Saunders *et al.*, 2006). For lamb on-farm production, the current state of understanding is that New Zealand lamb is approximately four times more CO₂ efficient than British lamb (Saunders *et al.*, 2006; M&W

representative). New Zealand beef production is also likely to be more CO₂ efficient because of its pastoral grazing, although Saunders *et al.* (2006) did not compare it with UK production systems. One of the major causes of difference is the biophysical variables that give New Zealand a comparative advantage (Brodt, 2007; Saunders *et al.*, 2006; Schlich & Fleissner, 2005; Wells, 2001). While New Zealand enjoys a mild climate, the use of pasture as opposed to concentrated feed, many countries do not, and some cannot.

Other stages in the lifecycle are not well-documented on a per unit of product basis. Recent qualitative research indicates that food and beverage sector businesses lack familiarity with the lifecycle approach to environmental issues and are not able to respond adequately to the environmental concerns of consumers (Stancu & Smith, 2007). This occurs in spite of the expectation of the large majority of the New Zealand public that businesses should be responsible for the environmental impacts of their products from 'cradle to grave'. Such consumers' purchasing decisions are influenced by a company's environmental performance (NZBCSD, 2007).

The LCAs of New Zealand beef and lamb, two of New Zealand's major commodity exports, reported in Chapter Five, have generated some new information on the domestic freight of beef and lamb, have updated some earlier work (Lovatt & Chadderton, 1996) on the energy requirements of meat processing, and additionally include the energy requirement of shipping refrigeration.

7.2.1 Freight and Food Miles

With a more complete picture of freight, and a comparison of the GHG emissions of domestic freight with international shipping, the total transport emissions to port of import (in this case London) may be gauged against other stages of the carbon footprint. Although transport in New Zealand emits approximately 17% of New Zealand's total GHG emissions (MfE, 2007a), the land transport of beef and lamb is not a significant component of the emissions inventory, neither is shipping to London, representing 2% and 4% of the lamb and beef GHG footprints respectively. However based on the CO₂ footprints, the transport emissions become more significant with the proportions increasing to 23% and 38% for lamb and beef respectively. Without shipping, domestic freight contributes 6% of the lamb and 12% of the beef CO₂ footprints. This is consistent with Patterson's (1984)

analysis that wholesale and distribution is only a minor component of the food system's GER.

7.2.2 Processing

Several points can be drawn from analysis of the two lamb and beef plants' processing emissions and the literature review. Both plants showed negligible gas use (less than 1%) and a total absence of coal, which contrasts to the average 22% gas and 37% coal use in the study of nine meat plants (Veritas, 2005). This difference suggests that the New Zealand average processing emissions per unit mass of meat are likely to be higher than those of the two plants used in this research.

The energy requirements of processing found in this study of 1.9 MJ/kg CW for lamb and 1.4 MJ/kg CW for beef compare to the figure of 1.7 MJ/tonne of beef and lamb combined in an older report (Lovatt & Chadderton, 1996). Both studies' values are based on direct consumer energy. In contrast, when comparing this study's processing to on-farm energy ratios with Patterson's (1984) ratios, the values differ. While both studies found that the on-farm gross energy requirement (GER) is larger than the processing GER, the relative energy requirements are considerably different: Patterson (1984) found a ratio of around 2:1 for beef and sheep farming versus processing; whereas this study has ratios of 11:2 for lamb and 7:1 for beef. Reasons for these differences may include changes in processing efficiency and the intensity of agricultural production, particularly the increasing use of external fertilisers since 1984, as well as the choice of methodology (i.e. indirect emissions in processing were included by Patterson (1984) but are not included here). While indirect energy in capital and packaging has not been included in this study, Patterson (1984) found that indirect energy use in packaging is significant (15% of processing GER) but not in the construction and maintenance of factories and plant equipment (3% of processing GER).

Finally, meat processing emissions for New Zealand overall are likely to be lower than for other countries, because of the high renewable component of electricity generation relative to other countries (66% in 2006 (MED, 2007a)). However, this advantage may potentially be offset by more energy consumption per unit of mass compared to overseas plants, because of the structure of New Zealand's meat industry overall. With energy costs being a relatively small part of total costs (comprising 5% of operational costs) (MIA, 2003), low utilisation in the off-season creates inefficiencies in processing plant resources, so at low

quantities of product, higher energy cost per unit of product is incurred (Veritas, 2005). Veritas (2005) further notes that accountability for energy use generally occurs only at the site level, not at higher levels of a company, and energy management is either not in place or not well developed. There is a general need to measure energy at a more detailed level if individual plants and processes are to be benchmarked and their efficiencies improved. This has potentially important ramifications for any intentions to improve product footprints, maintain competitive advantage, and retain the CGI. Better accounting is likely to become a priority area with the planned ETS.

7.2.3 Overall Efficiency of New Zealand Beef and Lamb

This study's *domestic GHG* footprints of lamb and beef respectively are 15.29 kg CO₂-e/kg CW and 7.35 kg CO₂-e/kg CW. The *domestic CO₂* footprints of lamb and beef respectively are 1.09 kg CO₂-e/kg CW and 0.552 kg CO₂-e/kg CW.

The *international GHG* footprints of lamb and beef respectively are 15.53 kg CO₂-e/kg CW and 7.59 kg CO₂-e/kg CW. The *international CO₂* footprints of lamb and beef respectively are 1.33 kg CO₂-e/kg CW and 0.79 kg CO₂-e/kg CW.

Several points arise from these LCA estimates. The beef footprints are only 50% of the lamb footprints, perhaps due to the productivity (mass per carcass) of beef relative to lamb. Even when taking shipping into account, domestic freight, processing, and shipping refrigeration combined barely alter the greater than 95% contribution CH₄ and N₂O make to the GHG footprints of beef and lamb. Inclusion of methane and nitrous oxide exemplify how significant these on-farm animal emissions are, as they alter both the domestic and international footprints by approximately 13 fold. Excluding these emissions, on-farm CO₂ still remains the largest contributor both for the CO₂ domestic footprints (82% and 73% for lamb and beef respectively) and the international footprints (68% and 51% for lamb and beef respectively). However, domestic and international freight combined now constitute larger proportions of the CO₂ footprint: 23% and 38% contributions of the lamb and beef CO₂ footprints respectively. This suggests that, although 'food miles' is not an adequate indicator of sustainability, the transport stage cannot be neglected and must be included in LCA.

The uncertainties inherent in this study's data make it difficult to confidently deduce quantitative estimates of these carbon footprints. Caution must be exercised in extrapolating the case study data of two processing plants to the meat industry in general. Average freight distances from farm to plant were measured but distance between farms could not be determined, despite anecdotal evidence that these distances are large. More data collection is needed to complement and enhance carbon footprint inventories and calculations. However, because this information was incomplete until now, these data at least provide the first line of evidence.

Table 16 compares this study's findings with those of the only other New Zealand LCA of lamb by Saunders *et al.* (2006). The lamb's domestic and international CO₂ footprints in this study are twice as large as those calculated by Saunders *et al.* (2006), and the GHG domestic and international footprints are 27 and 23 times as large respectively. The approximate ratios 9:2 (82% to 18%) of farming to shipping, of Saunders *et al.* (2006) for lamb, compares to the 3:1 in this study (68% to 23%).

Table 16 Comparison of Lamb Footprints from this study and Saunders *et al.* (2006)

kg CO ₂ /kg CW		Domestic	International
Saunders <i>et al.</i> (2006)	excl. CH ₄ /N ₂ O	0.56	0.69
This study	excl. CH ₄ /N ₂ O	1.09	1.33
	incl. CH ₄ /N ₂ O	15.29	15.53

7.2.4 Difficulty in Making Comparative Assertions

Because lamb (and presumably beef) is more CO₂ efficient in New Zealand than in the UK based on Saunders *et al.*'s (2006) data, there are climate change arguments for supporting more production in New Zealand than in other countries. However, given that there are other significant variables in the lifecycle of beef and lamb production, further comparative research is needed to consolidate the state of the existing science on this topic, before the relative efficiencies in lamb and beef production produced in the UK and New Zealand can be asserted with confidence.

For example, CH₄ and N₂O differences between production systems need to be ascertained before conclusions are drawn. The dairy example saw New Zealand to be 50% more efficient in terms of CO₂ footprints compared to British dairy (Saunders *et al.*, 2006), but only 34% more efficient in terms of the GHG footprints (Saunders & Barber, 2007b). This

suggests that the margin of difference for lamb's GHG footprint is likely to be significantly less GHG efficient than was claimed in Saunders *et al.*'s (2006) accounting only for CO₂.

The importance of establishing N₂O and CH₄ emissions before comparing systems is supported by both the qualitative analysis (Chapter Six) and the literature review (Chapters Three and Four). Salmon (RP) notes that Saunders and Barber (2007b) have not included error margins so that uncertainties in the data have not been analysed in terms of the degree to which the countries' error bars overlap. Indeed, the state of the science on CH₄ and N₂O emissions remains patchy. The emission trade-offs from different management systems and practices that affect net GWP are yet to be determined across a wide range of agricultural systems (Johnson *et al.*, 2007), such as the extent reductions in methane emissions from grain-fed systems are offset by the emissions involved in the production and distribution of additional feed. Emission balances of CO₂, CH₄ and N₂O in different production systems need to be comprehensively reviewed in order to compare the GHG profiles of on-farm stages and thus make comparative assertions.

7.3 Carbon Footprint Reduction Opportunities

The total domestic GHG emissions profiles suggest the reduction opportunities occur in the emissions of CH₄ and N₂O. CH₄ contributes 71% for lamb and 69% for beef and N₂O contributes 22% for lamb and 25% for beef. Participants discussed specific methane mitigation measures only very little. The PGgRc is currently researching different feeds and manure management practices. The experimentation with different feeds is consistent with the literature review (Beauchemin & McGinn, 2005; Johnson *et al.*, 2007; Monteny *et al.*, 2006; Monteny *et al.*, 2001) although the net benefits of substituting different feeds needs to be assessed in terms of effects/opportunity costs of additional land use and emissions in the production and transport of the feed (Smith *et al.*, 2007).

In terms of reducing the existing climate change impact of products, ENGOs and government are more positive about reduction opportunities than the private sector, particularly in terms of the adoption of eco-technologies, 'carbon farming', and more efficient energy use. Several research participants identified nitrification inhibitors as having the potential to substantially reduce N₂O; however, some indicated that the diffusion of this technology might be hindered by uncertain scientific effectiveness when

applied *in situ* (PGgRc representative, RP) and a lack of interest among the farming community (Salmon, RP).

When considering only the domestic CO₂ footprints, emissions are less concentrated in the on-farm stage than in the domestic GHG footprints. Yet this stage still has the greatest magnitude, contributing 82% and 73% of the lamb and beef footprints respectively.

Practices such as non-tillage and direct drilling (Pedersen, RP; Stewart, RP), and offsetting schemes such as carbon farming may reduce on-farm carbon emissions (Melhuish, RP).

With processing contributions of 11% and 16% for lamb and beef respectively, better energy management and accounting and operational practices to overcome low-season inefficiencies may lower energy use (Veritas, 2005). Other plants which are likely to have higher emissions due to higher coal use may lower their emissions by switching to cleaner energy sources.

Freight only contributes 6% and 12% to the lamb and beef domestic CO₂ footprints respectively. However, the beef plant case study appears to have a relatively high rail use (over three times the kilometrage of road), and typical meat companies may use a higher proportion of road relative to rail. Furthermore, considering that road transport contributes to 44.6% of New Zealand's CO₂ emissions (MfE, 2007a), freight reduction opportunities can be seen as both possible and desirable. Opportunities may occur in modals shift of road to rail and coastal shipping, through an increase in the maximum heavy vehicle weights from 44 tonnes to 60 tonnes (Friedlander, RP), or improvement in freight logistics and supply chain competencies (Mollenkopf & Dapiran, 2005). Modal shift measures do not appear to be subject to policy or private sector priorities despite the *National Rail Strategy to 2015*, yet incentives may change with a carbon price under the ETS. The Road Transport Forum NZ is advocating for increases in maximum truck weights to increase productivity (Friedlander, RP), although this may be offset by undesirable social, environmental and economic impacts, which would require further analysis.

7.4 Relevance of Carbon Footprints to New Zealand

Since the concept of carbon footprints is relatively new, research to date has not examined either the socio-political relevance of the concept or the agro-food industry's preparedness to adopt the concept for addressing consumer environmental concerns. Thus, the

exploration of key stakeholder perspectives through semi-structured interviews in this research sheds light on these aspects. Limitations of the interviewing technique include response effects, possible deference effects and accuracy in participants' answers (see Bernard, 2000), and are considered in light of the themes discussed.

7.4.1 Key Agro-Food Stakeholder Perspectives

The interviews suggest that the agro-food industry, central government and ENGOs shared several views. Firstly, if food miles is addressed correctly (such as through replies to the editor in international media, monitoring of offshore developments and thorough demonstration of New Zealand products' performance), the potential threat of food miles will subside. Secondly, stakeholders unanimously support the use of carbon footprints for addressing food miles threats.

Industry stakeholders' leadership with respect to food miles issues is primarily related to managing risks around consumers' perceptions and attitudes rather than taking the opportunity to adopt more sustainable production methods. In this sense, its leadership is in accordance with transformational leadership theory (Beugré *et al.*, 2006). Nevertheless, now that the New Zealand agro-food sector accepts the need to reframe the food miles debate, it recognises it must be able to demonstrate its environmental credentials to its markets. While private sector participants generally seem prepared to account for their GHG emissions through carbon footprinting exercises, their preparedness to perform environmentally is a response to three major determinants: the demand of high value discerning consumers for environmentally superior food products; the potential threat food miles pose to New Zealand food; and the widely publicised Saunders *et al.* (2006) report, which lays claim to New Zealand's comparative efficiency relative to intensive production systems abroad. In this sense, the industry appears generally reactive to climate change issues rather than proactive: while willing to boast the agro-food sector's environmental credentials, the sector sees little scope to further improve its performance. Despite the sector's reactive stance, the three determinants discussed above have helped to generate a widespread acceptance of carbon footprints and unzip wider sustainability issues, which are now under the sector's closer consideration.

Public service participants believed central government has a facilitation role in creating the institutions that will enable the private sector to respond to international markets and

media, but that it is ultimately up to the private sector to control its own climate change performance within the context of the ETS. Voluntary policies such as the Eco-Verification and Greenhouse Gas Footprinting initiatives will be instrumental in this facilitation role. Public service participants are well connected to the agro-food sector in relation to food miles and carbon footprints through the inter-departmental working group on food miles (IWGFM). These kinds of public-private partnerships appear to be important institutions for generating collaborative research and robust policy. However, the exclusion of NGOs from the IWGFM is concerning in terms of risk awareness and more broadly in terms of deliberative democracy. With greater engagement of the environmental community, the IWFFM holds promising potential to move beyond climate change impacts towards wider sustainability issues.

The ENGO representatives are highly engaged with the environmental performance of the agricultural sector and voice several concerns about the current state of the research, the lack of interest and/or uptake among the farming community about eco-technologies, and, in their view, the unfounded confidence the agricultural sector in its environmental performance. In particular, the farming community is criticised for proclaiming farmers as climate change heroes; instead of recognising that the health of New Zealand's environment is based on its intrinsic natural comparative advantage rather than on the sector's deliberate practices to mitigate, avoid or remedy adverse environmental effects.

7.4.2 'Clean Green' Image, Marketing Opportunities and Success Stories

Most stakeholders consider it essential to portray New Zealand as a 'clean green' nation internationally, and many discussed the need to live up to the image through robust demonstration of performance. A related key theme that emerged is the potentially significant marketing opportunity from GHG accounting and footprinting New Zealand products in international markets. The marketing of New Zealand products is already largely dependent on market perceptions of the country's CGI. Now, the perception that New Zealand food is more environmentally benign than European food is an additional justification for telling success stories about New Zealand products. However, because of the lack of research and consensus on the relative GHG efficiency of New Zealand products, marketing opportunities based on consolidated scientific research are not yet possible. Market information requests and increasing scrutiny pose a risk to New Zealand's marketing material if actions to demonstrate performance are not taken. Some

stakeholders, who have doubts about the CGI, perceive this risk. Success stories about the CGI should not substitute traceability and accounting for GHG emissions if New Zealand is to maintain its integrity.

7.5 Wider Sustainability Issues

Analyses of the trends in thinking about food systems, the GHG inventories of beef and lamb, and stakeholder perspectives on the sustainability of food, all point to the importance of sustainable food systems beyond GHG emissions reductions. LCAs that include other impact categories provide the grounds for ecological footprints of food representing all environmental impacts instead of only GWP. In particular the impacts of New Zealand beef and sheep production on land use, water quality and non-GWP pollution related to shipping are areas which can be considered by an ecological footprint.

The widespread interest in carbon footprints, evidenced by the near 100% positive response rate when contacting stakeholders, the willingness of the private sector to prove their environmental performance beyond carbon footprints, upcoming government policies for assisting industry in climate change mitigation, and recent ministerial announcements are part of the general discourse on sustainability and wider environmental issues. Twelve of the 20 participants referred to the importance of considering sustainability in a wider sense. Generally this was in terms of needing to account for other environmental impacts – with the exception of the emphasis by Pedersen and the RWNZ representative on the precedence of economic sustainability.

The IWGFM is starting to broaden its initially narrow focus to wider sustainability issues. As a successful example of a public-private partnership, especially if NGOs were to become members, the IWGFM holds the potential to provide strategic policy discussions and development to move New Zealand forward based on an ethic of sustainability and prepare the nation to live up to its ‘clean green’ image. Such an arrangement could be used more widely to increase strategic capacity as it benefits from combining two methods of risk management: 1) spurring sectoral leadership and foresight and 2) shaping long-term policy with private sector buy-in. For example, it has the potential to better prepare New Zealand for the ETS, respond to international developments, and get closer to its markets. In general, the agro-food sector also indicates that it is now interested in showing greater

leadership to achieve broader sustainability to retain and strengthen New Zealand's reputation as a clean and green nation. Yet, the translation between intention and action is still to be observed.

7.6 Methodological Demands of LCA

The methodological aspects of LCA treated in Chapters Three to Six require some critical consideration specifically for food LCAs. Chapter Three highlighted the academic discourse on such issues. Chapter Four, which reviewed individual LCAs with reference to New Zealand food products, discussed the limitations of several studies based on their method. For example, several studies all comparing European and New Zealand apples were juxtaposed to show that the choice of method generated different conclusions. The LCAs of this thesis encountered limitations with regard to comparing primary and secondary data because of the choices about allocation in a multi-product system, and the inclusion or exclusion of indirect emissions. Commonly agreed adjustments from consumer to primary energy and emission factors for New Zealand energy sources were also not available. Chapter Six explored how several stakeholders believed the private sector may be ready to adopt carbon footprinting and labelling exercises as long as standard setters do not unfairly disadvantage New Zealand food systems and a robust carbon footprint methodology based on an internationally accepted LCA is developed. The agro-food sector appears willing to prepare for carbon labelling – or any similar scheme export markets may require – though compliance costs and complexity are currently seen as barriers.

Conclusions common to these chapters focus on the need for international harmonisation of LCA so that different LCA methodologies are standardised (e.g. ISO 14040-14044 and Carbon Trust), and that there is consistency between GHG accounting initiatives for individual companies (i.e. LCAs with EMSs such as ISO 14064, CarboNZero and WRI/WBCSD's GHG Protocol). Standardisation will avoid an LCA's system boundaries being biased towards a particular product or system, and will encourage businesses that have already implemented EMS to enter into an LCA project.

Acquisition of LCA data is a time consuming process and may discourage individual firms from undertaking an LCA without previous experience or sufficient resources. Software

helps to streamline and facilitate LCA exercises for food products, yet such software needs to be country-specific in order to allow comparative assertions between products of different countries. New Zealand-specific software does not exist (Kellenberger, 2007).

7.7 Outstanding Gaps and Further Work

While this research has generated some valuable insights into LCA-based performance of beef and lamb, more data (including data addressing uncertainties discussed in s5.4 and s7.2) are needed to adequately assess the carbon footprints of beef and lamb. This study's system boundaries have excluded impacts from domestic retailers' distribution and storage systems, shopping transport emissions, waste disposal of meat packaging and household preparation. These processes could be documented in greater detail to provide the most comprehensive LCA, although such research would be subject to diminishing returns and additional information on waste disposal and household preparation in this case may not provide such valuable insights. Identifying reduction opportunities based on ease or cost of abatement would complement the research on identifying stages with the greatest magnitude and stakeholder perspectives on mitigation options. For processing and freight, cross-company research would generate more representative impacts for these sectors as a whole. For on-farm emissions, the study of a greater number of farms would increase applicability to New Zealand's agricultural products overall. A comparative study of New Zealand beef has not been carried out as it has for lamb. Further research comparing the UK's and New Zealand's on-farm N_2O , CH_4 , freight and processing emissions is needed. Comparative studies between countries based on a standardised methodology and primary field research is ultimately an area that requires further work. Once this knowledge has been generated, research into the procedures involved in a carbon labelling initiative is the next logical area for investigation.

8

CONCLUSION

The environmental costs associated with food systems are significant sustainability issues and present risks to and opportunities for New Zealand trade. The risks considered here arise from New Zealand primary industries' contribution to climate change and dependence on fossil fuels in a carbon-constrained world.

Carbon footprints and food miles are concepts designed to communicate the environmental impact of products. In recent years, food miles, which measures the distance food travels from producer to consumer, has become the focus of discerning consumers wishing to reduce the environmental impact of their shopping choices. Popular in the UK, food miles has significant implications for New Zealand's primary product exports, of which a substantial proportion is sold to discerning European and North American consumers. Carbon footprints show the environmental impact of food products more holistically and accurately, because they consider the carbon impacts across the whole of a product's lifecycle, and not just the transport stage.

This thesis has examined the key trends involved in the food system and its environmental impacts, investigated the carbon footprints of New Zealand beef and lamb, and addressed whether the carbon footprints of food are relevant to New Zealand for addressing consumer environmental concerns. It has thus contributed to the literature on this topic by: providing a New Zealand context to food and sustainability issues; filling gaps in the current knowledge of beef and lamb carbon footprints; identifying methodological issues in agricultural LCAs when comparing different production systems; and reporting how relevant carbon footprints are to major stakeholders in New Zealand.

The systems approach provided by LCA is crucial in the assessments of the environmental impacts of food. To emphasise only food miles, as has recently happened in recent media debates, may lead to myopic and misleading conclusions. However, for LCAs to provide relevant and comparable assessments of environmental impact, they need to be standardised and applied consistently between studies. Even if a carbon labelling scheme is far off, carbon footprints provide generic information for consumers wishing to make low-carbon food choices and estimating them is a useful exercise in preparation for the New Zealand ETS by helping individual companies to manage the potential costs incurred, and is more generally useful in a strategic sense.

Although New Zealand production systems may be more carbon efficient than those in the United Kingdom, there are risks to New Zealand exports if New Zealand does not account for its emissions. Lack of comparisons of CH₄ and N₂O emissions between countries for beef and lamb, geographic isolation, consumer concerns, and methane capture technologies (which may be easier to implement in the housed, contained systems of Europe) are several examples of such risks. This research has filled some significant gaps in relation to processing and freight involved in the LCA of lamb and beef which has reinforced the conclusion that food miles by itself is not a valid indicator of sustainability. It has also highlighted that the current state of New Zealand's research on LCA for significant export industries needs to be greatly improved in order to make authoritative claims of its superior environmental performance compared with other countries.

The calculations show that the *international* GHG footprints of lamb and beef respectively are 15.53 kg CO₂-e/kg CW and 7.59 kg CO₂-e/kg CW, with domestic and international freight contributing 2% and 4% respectively to the lamb and beef footprints. Data from a case study of two meat processing plants suggest that meat processing contributes even less to these footprints. When leaving aside on-farm methane and nitrous oxide emissions, meat processing and freight contribute 18 % and 27% of lamb and beef *domestic* carbon dioxide (CO₂) footprints (i.e. excluding shipping) respectively, or 32% and 49% for *international* CO₂ footprints (including shipping) respectively.

Stakeholders generally recognise that accounting for GHGs in the agro-food sector can and ought to be seized as an opportunity. In accordance with transformational leadership theory, New Zealand appears to have first responded effectively to the threat of food miles, and is now realising the potential opportunities that can be gained by careful accounting

and through demonstrating its environmental performance. What is doubtful, however, is whether New Zealand's pastoral industries will take the opportunity to perform beyond their current performance, which is based on a natural comparative advantage, and lead through the pro-active implementation of GHG mitigation strategies. There may be a further risk to the sector if it continues to capitalise on current advantages without demonstrating that it is actively pursuing pro-environmental practices and communicating them to consumers.

The IWGFM private-public partnership between the New Zealand agro-food industry and central government is a useful collaboration mechanism to manage the risks and take advantage of the opportunities posed by food miles and environmental consumer concerns. This forum holds promising potential to move beyond climate change impacts towards wider sustainability issues, and could be enhanced through greater engagement of the environmental community.

In conclusion, this research confirms that carbon footprints are relevant to New Zealand. If carbon footprints are conducted according to a standardised methodology, they can be used as a key strategic tool for managing the risks and taking advantage of the opportunities posed by climate change, exposure to energy risk and consumer environmental concerns. Carbon footprints can enable the agro-food sector to robustly demonstrate and improve its environmental credentials and therefore give New Zealand the potential to respond to information requests from international markets, live up to and improve its 'clean green' image.

Appendices

Appendix One: Interview Themes

General Cross-Category Themes

- **Issue definition:** how stakeholders frame the issues surrounding climate change and food, food miles and carbon footprints
- **Role and Mandate:** what role and mandate stakeholders see their organisation to have
- **Information accessibility:** how much the organisation knows about the issue, and whether there are efforts to increase knowledge, through increasing research
- **Threat or opportunity?** what kinds of possible threats and opportunities to New Zealand with regard to accounting for GHG emissions, GHG emissions reductions, food miles and carbon footprints.
- **‘Clean green’ image:** whether stakeholders thought the CGI was important and what needed to be done to retain and strengthen it

Category 1 Interviews: agro-food sector representatives

- **Foresight:** whether organisations have foresight or planning mechanisms, such as strategic plans will be established.
- **Information collection:** whether organisations gather information about environmental, economic or social performance indicators from their members.
- **Role and responsibility of the agro-sector:** whether organisations feel they have a role towards addressing the international demand for more environmentally sustainable products and whether any current projects or initiatives exist that aim to communicate or improve the environmental performance of primary products, from production through to consumption. Organisations will also be asked whether life cycle thinking or approaches are relevant to their marketing or management activities.

Category 2 Interviews: public servants assigned to agriculture, trade and environmental issues

- **Types of potential or actual policies:** what types of policy measures, if any, government is implementing or planning to implement.
- **Communication strategy.** This theme will establish whether there is a communication strategy is for responding to food miles issues.

Appendix Two: VUW Ethics Committee Approval

Phone 0-4-463 5676
Fax 0-4-463 5209
Email Allison.kirkman@vuw.ac.nz

MEMORANDUM

TO	Amelie Goldberg
COPY TO	Dr Ralph Chapman
FROM	Dr Allison Kirkman, Convener, Human Ethics Committee
DATE	August 8, 2007
PAGES	1
SUBJECT	Ethics Approval: No 108/2007, A life cycle approach to measuring the sustainability of New Zealand's primary production: a carbon footprint of beef/sheep.

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved and this approval continues until 28 February 2008. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

A handwritten signature in black ink, appearing to read "Allison Kirkman".

Allison Kirkman
Convener

Appendix Three: Eco-Labelling in New Zealand

In New Zealand, there are relatively few eco-labels. The government-supported Environmental Choice³³, a Global Eco-labelling Network (GEN) Member, is the principal scheme. Environmental Choice has tended to focus on manufactured non-edible goods such as paints, paper products, printers and copiers and construction materials. The Green Tick³⁴, another New Zealand labelling body, set up in 2004, operates internationally, is ISO 17000 compliant and has a wider range of products that it certifies (Green Tick, 2007). The Green Tick is based on third party, full lifecycle assessment of products (Harris, 2007). Finally, individual companies may seek ISO³⁵ certification, the most widely recognised certification internationally.

New Zealand has its own carbon management, mitigation and certification body, CarboNZero, owned by Landcare Research, a CRI. It has been successful in providing companies with an easy tool to manage their carbon emissions so that they may become carbon neutral using a combination of mitigating and offsetting strategies. However, CarboNZero does not yet appear to offer CH₄ and N₂O abatement and offsetting schemes and it only applies to individual companies.

In 2006, the Green Tick announced its specific 'climate friendly' brand. For a product to be certified 'climate friendly', it must:

- Be carbon neutral or carbon negative over its whole lifecycle; or,
- The applicant holds sufficient carbon credits to achieve carbon neutrality; or
- The applicant holds carbon negative status for the product over its whole lifecycle to achieve the 'climate friendly' tick (Green Tick, 2007).

No businesses in New Zealand are yet certified with the 'climate friendly' brand (pers. comm. Green Tick employee) as of 10th Sept 2007.

No conventional food retailer chains in New Zealand appear to have initiated any carbon management, mitigation or labelling programmes, and operate within a system where labelling for country of origin is not required.

³³ Environmental Choice website: <http://www.enviro-choice.org.nz/index.html>

³⁴ Green Tick website: <http://www.greentick.com/>

³⁵ International Standards Organization website: <http://www.iso.org/iso/home.htm>

Appendix Four: Comparison of Emission Factors for Agricultural LCAs

In order to calculate the emissions from different energy sources, emission factors were researched for the New Zealand context. This study used MED's most recent factors (MED, 2007), and also accounted for primary energy, that is the inclusion of additional emissions lost (e.g. in distribution and transmission) as well as the direct energy consumed. The 'fugitive multipliers' used were those developed by Barber *et al.* (2007).

Table 17 Comparison of GHG Emissions Factors for Agricultural LCAs (g CO₂-e/MJ)

	This study	Barber <i>et al.</i> (2007)	Saunders <i>et al.</i> (2006) ³⁶
Electricity	63.89	54.80	19.20
Gas	66.28	62.05	-
Diesel	84.38	82.55	68.70

Table 17 compares the different GHG emission factors used by two recent studies of agricultural product lifecycle assessments in New Zealand. There are considerable differences in some of the factors, especially for electricity. All factors account for primary energy. Differences arise from the different energy sources used and different primary energy multipliers. Saunders *et al.* (2006) use the *New Zealand Energy Information Handbook* (Baines, 1993) with a primary energy multiplier for all fuel of 23%. Barber *et al.* (2007), based on MED's 2006 emission factors (MED, 2006), use primary energy multipliers of 4% for coal, 19.3% for diesel and 13% for gas. This study uses MED's most recent emissions factors report (MED, 2007b) and the primary energy multipliers of Barber *et al.* (2007).

While effort was made to corroborate the various emissions factors used by different LCA studies, there are still some overarching issues about how to account for fugitive emissions. MED's consolidation and publication of such emissions factors would enable the academic community to use the same factors for such exercises and to allow for comparability.

³⁶ These factors only include carbon dioxide emissions.

Appendix Five: Carbon Footprint Data

Table 18 Domestic Footprints of Lamb and Beef (kg CO₂-e/kg CW)

	Lamb		Beef	
	value	% of footprint	value	% of footprint
GHG footprint				
On-farm	15.100	98.7%	7.200	97.9%
Freight - farm-plant	0.036	0.2%	0.033	0.5%
Freight - plant-port	0.035	0.2%	0.032	0.4%
Processing - electricity	0.122	0.8%	0.086	1.2%
Processing - gas	0.000	0.0%	0.000	0.0%
Total	15.294	100%	7.352	100%
CO ₂ footprint				
On-farm	0.900	82.3%	0.400	72.5%
Freight - farm-plant	0.036	3.3%	0.033	6.0%
Freight - plant-port	0.035	3.2%	0.032	5.8%
Processing - electricity	0.122	11.2%	0.086	15.6%
Processing - gas	0.000	0.0%	0.000	0.1%
Total	1.094	100%	0.552	100%

Table 19 International Footprints of Lamb and Beef (kg CO₂-e/kg CW)

	Lamb		Beef	
	value	% of footprint	value	% of footprint
GHG footprint				
On-farm	15.100	97.2%	7.200	94.9%
Freight - farm-plant	0.036	0.2%	0.033	0.4%
Freight - plant-port	0.035	0.2%	0.032	0.4%
Processing - electricity	0.122	0.8%	0.086	1.1%
Processing - gas	0.000	0.0%	0.000	0.0%
Shipping	0.236	1.5%	0.236	3.1%
Total	15.530	100%	7.588	100%
CO ₂ footprint				
On-farm	0.900	67.7%	0.400	50.8%
Freight - farm-plant	0.036	2.7%	0.033	4.2%
Freight - plant-port	0.035	2.6%	0.032	4.1%
Processing - electricity	0.122	9.2%	0.086	10.9%
Processing - gas	0.000	0.0%	0.000	0.0%
Shipping	0.236	17.8%	0.236	30.0%
Total	1.333	100%	0.788	100%

Acronyms

CGI	Clean green image
CH ₄	Methane
CO ₂	Carbon dioxide
CRI	Crown Research Institute
CW	Carcass weight
DEFRA	United Kingdom Department for Environment, Food and Rural Affairs
EECA	Energy Efficiency and Conservation Authority
EHCRA	East Harbour Carbon Reduction Action Group
EMS	Environmental Management System
ENGO	Environmental non-governmental organisation
ETS	Emissions Trading Scheme
FOMA	Federation of Māori Authorities
GER	Gross energy requirement
GHG	Greenhouse gas
GWP	Global warming potential
IPP	Integrated product policy
ISO	International Standards Organization
IWGFM	Inter-departmental working group on food miles
LCA	Lifecycle assessment
MAF	Ministry of Agriculture and Forestry
MED	Ministry of Economic Development
MfE	Ministry for the Environment
MFAT	Ministry of Foreign Affairs and Trade
MIA	Meat Industry Association
MoT	Ministry of Transport
N ₂ O	Nitrous oxide
n.d.	No date of publication given
NZBCSD	New Zealand Business Council for Sustainable Development
NZTE	New Zealand Trade and Enterprise
PGgRc	Pastoral Greenhouse Gas Research Consortium
RP	Research participant in this thesis
RTFNZ	Road Transport Forum New Zealand Inc.
RWNZ	Rural Women New Zealand
SBN	Sustainable Business Network

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