TECHNICAL PAPER

AIRFREIGHT TRANSPORT OF FRESH FRUITS AND VEGETABLES - A REVIEW OF THE ENVIRONMENTAL IMPACT AND POLICY OPTIONS

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Study focusing on the issue of "air miles " (the number of miles (kilometres) a product has to be transported from the farmer/grower to various stages of production until it reaches the supermarket and the plate of the consumer) - outlines main policy perspectives surrounding the use of airfreight in food supply chains; looks at methodologies that have been used to consider the environmental impacts associated with the food supply chain; focuses on the approaches used to investigate fresh produce production and transport; provides a literature review of farm to fork studies, as well as an analysis of the energy and emissions associated with the production, trade and consumption of fresh fruit and vegetables; investigates some policy options that may be used to reduce carbon emissions in the fresh fruit and vegetable supply chain; includes bibliography (p. 35-37).

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Executive Summary

The increasing international trade in fresh fruit and vegetables has started to raise concerns about the distance that food travels and the emissions associated with its transport. The term food miles has been coined to capture the number of miles (kilometres) that food travels through a supply chain, from producer to consumer. The simple logic of food miles is the further that a food product has travelled, the more energy is consumed, the more greenhouse gases are produced, and the greater the impact on the environment. Food and air miles are simplistic concepts and not indicators of sustainability or environmental impact.

A leading UK organic certifier, the Soil Association recently proposed changes in the certification criteria for the labelling of airfreighted organic fruit and vegetables. The Soil Association was contemplating removing the eligibility of airfreighted produce to be labelled organic1. In response to this proposed change, the International Trade Centre commissioned Lincoln University's AERU to undertake a review of the literature around food miles and in particular studies that consider airfreight transport of fresh fruit and vegetables.

There is growing awareness and concern of climate change. The concepts of food miles and air miles have gained some attention and this has led to a variety of initiatives in the UK to implement carbon labelling and to improve the efficiency of the food supply chain. For example, the UK's Carbon Trust is underway with a carbon labelling initiative, Tesco's have recently announced by that they will invest £500 million to implement carbon labelling of products in their UK supermarkets, and Marks and Spencer are investing £200 million to reduce its carbon footprint over the next five years. This increasing concern appears to be influencing the call for Country of Origin Labelling (COOL) in the USA and the growing demand for locally produced food.

This raises a number of issues such as the validity of food air miles as a concept. Food/air miles only consider the transport component and ignore the full energy and emission associated with the production and consumption of the product. This also doesn't account for factors such as the total transportation of a product from production to consumption and the importance of that product in the shopping basket. Moreover, there is concern that this potential move by the Soil Association may be a disproportionate reaction to the issue of airfreight and in particular this may have an adverse impact on developing countries. For example, over one million African livelihoods are dependent on airfreighted fresh fruit and vegetable exports (Legge et al., 2006). Analysis of the carbon emissions for developed and developing nations show some stark contrasts. For example, Africa's emissions are 40 times lower per capita than the United Kingdom's.

The studies reviewed for this report include life cycle analysis (LCA), input-output, and hybrid approaches. However, no study offered a complete cradle to grave assessment. The studies varied in their scope tending to focus on production systems and/or transportation systems. Several of the studies investigated other aspects of the supply chain including supermarket to home transport, cooking and refrigeration, and waste disposal. The studies varied in terms of their unit of analysis, spanning EU, country and product level analyses.

Two Dutch studies calculated the greenhouse gas emissions associated with household consumption of fruit and vegetables. These studies estimated that fruit and vegetable consumption accounts for 9 to 10 per cent of household and per capita CO_2e emissions per

[1] (May, 2007) Airfreight Green Paper: a basis for discussion. Should the Soil Association tackle the environmental impact of airfreight in its organic standards?

annum (Kramer, Moll, Nonhebel & Wilting, 1999; Nijdam, Wilting, Goedkoop & Madsen, 2005).

In a study of the relative transport contributions to UK food transport, cars were found to account for the largest number of food kilometres (48 per cent of total kilometres) although UK heavy goods vehicles (HGV) operating locally and in Europe were the largest emitters of carbon dioxide (57 per cent of total CO2 emissions) (AEA Technology, 2005). Airfreight accounted for only a small share of total carbon dioxide emissions (10 per cent). For the period 1992 to 2002 UK urban food kilometres increased by 27 per cent, HGV food tonne kilometres increased by 36 per cent, and airfreight increased by 140 per cent. These trends have led to a 12 per cent increase in the CO2 emissions associated with food.

A UK study focusing solely on the transportation of lettuce, apples and cherries found that UK and Spanish grown lettuces had the lowest average CO2 emissions (44-45kg CO2/tonne) (Mason, Simons, Peckham & Wakeman, 2002). Apples which on average travelled the furthest (8,767 km) emitted 2.4 times more CO2. Cherries which on average travelled 7,751 km emitted the largest amount of CO2, 80 times more CO2 than for the lettuce. The main factor influencing the higher CO2 emissions for the cherries was the proportion of the imports airfreighted from North America. In contrast the New Zealand sourced apples were sea freighted and therefore had lower CO2 emissions. An important observation made in this study was the expert advice that it would be climatically and economically challenging to increase the UK grown supply of cherries and lettuce. In the case of apples, this was possible for only limited varieties. Mason et al.'s observation about the limited opportunity for replacing imported produce is even more significant when the United Kingdom's low level of self-sufficiency in fruit (9 per cent) and vegetables (62 per cent) is considered (Garnett, 2006).

Although it is predicted that fresh fruit and vegetable consumption is likely to continue to rise, and that airfreight is expected to continue to grow, the relationship between these two trends is more complex. DEFRA (2007) suggest that there are several factors that will influence the proportion of fresh produce airfreighted including labelling, airfreight costs and consumer preferences. MacGregor and Vorley (2006) observe that there is no clear evidence linking airfreight expansion to fresh fruit and vegetable consumption.

Product based LCA studies offer some important perspectives on the relative contribution that airfreight transport makes to the total greenhouse gas emissions associated with fresh fruit and vegetables. Although airfreight is an important contributor to fresh produce CO2 emissions, several studies have found that heated greenhouse production systems, home cooking methods, and consumer shop to home transport choices can also be significant contributors to a product's CO2 emissions. For example, a consumer's shopping trip of more than 10 km to solely purchase one kilogram of fresh produce will generate more CO2 emissions than the airfreighting of one kilogram from Kenya (van Hauwermeiren, Coene, Engelen & Mathijs, 2007).

Several studies have been completed investigating the emissions and energy associated with the apple supply chains sourcing fruit locally and from further a field (e.g. EU and the Southern Hemisphere). Canals, Cowell, Sim and Besson (2007) did not find that clear support that a local (UK) supply would necessarily be superior to the alternative European or Southern Hemisphere supply scenario. The period of supply and therefore the relative storage period was as an important an element, as was the road transport of European sourced fruit. For example, UK sourced fruit had the lowest energy use during its supply to market in the months of January and October, and the highest in August where the energy use overlaps with apples sourced from the Southern Hemisphere.

Canals et al.'s findings are further supported by Saunders, Barber and Taylor's (2006) LCA study of UK and New Zealand apple and onion production systems. Interestingly this research shows that the CO_2 emissions associated with the UK storage of locally produced onions is greater than from the sea freight of NZ onions shipped to the UK. In case of apples, the key driver of the greater CO_2 emissions intensity of UK produce (271.8 kg CO_2/Tonne) over NZ produce (185.0 kg CO_2/Tonne) was the cold storage of the UK apples (85.8 kg CO_2/Tonne).

Vringer and Blok (2000) compared the energy use associated with Dutch and Kenyan cut flower production. Airfreighted Kenyan roses transported to Europe were found to have a lower total energy footprint than the Dutch grown roses.

Several key themes emerged through the literature review. Few studies offer a complete farm to fork analysis and the studies varying scope and assumptions limit the comparisons that can be made between the studies. The distance travelled and in particular the transport mode used appears to have the greatest influence of CO_2 emissions. However, consumer supermarket to home transport, heated greenhouse production, storage, and food preparation methods can also be significant contributors to total CO_2 emissions.

The review highlights the growing concern regarding climate change and the carbon footprint associated with food production. The varying scope and assumptions of the existing studies makes it difficult to enable comparisons of the emissions and energy associated between different components of the supply chain. Although airfreight transport has the highest emission profile, when the whole of a product to a market is considered the emissions associated with air transport tend to be low. Most of the studies assume that the importing country could supply the market and reduce or replace imports. For many products this is unlikely to be the case and even where this may be possible this would be likely to lead to an intensification of production systems thereby raising energy and emissions intensity.

Most of the studies assume that alternative sources of supply could be found closer to the market. Within the EU it is clear that there are real limits to the expansion of fruit and vegetable production. Moreover, current EU initiatives such as the Single Farm Payment are likely to lead to less intensive production in the EU. When the low EU per capita fruit and vegetable consumption (typically below health guidelines) is considered in addition to the issue of EU farm production, it appears most likely that EU countries will typically continue to increase their proportion of imported produce.

1. Introduction

The issue of climate change has grown in importance as seen through the implementation of the Kyoto Protocol and issues such as “food miles”. ‘Food miles’ is a relatively recent issue which has arisen in the United Kingdom, Germany and other countries over food transportation. A simple definition of this concept would be: ‘the number of miles (kilometres) a product has to be transported from the farmer/grower to various stages of production until it reaches the supermarket and finally the plate of the consumer’. It has been born out of concern for the environment, especially in regard to greenhouse gas emissions such as carbon dioxide and the global warming arising from this. The argument is that the longer the transport distance (food miles), the more energy is consumed, the more fossil fuels are burned and consequently the more greenhouse gases are released into the air, which cause climate change. Arising from this argument is the issue of “Air Miles” which is the distance food is airfreighted and the fact that transport by air is particularly energy and emission intensive. Therefore the solution proposed by food miles campaigners is to source food from as close to where it will be finally consumed as possible.

This report, commissioned by the International Trade Centre, provides a review of literature most relevant to the issue of air miles. In particular, this report concentrates upon issues around the proposed changes in the Soil Association’s (a leading UK organic certification body) criteria for air-freighted products. Moreover, this is particularly relevant to the import of fresh fruit and vegetables from developing countries.

There is a wide and reasonably disparate body of literature published focusing on different elements of the fresh produce supply chain and using varying methodologies, systems boundaries and units of analysis. Likewise, a variety of policy viewpoints have evolved across a range of stakeholders and include economic, marketing, trade, localism, protectionism, labelling, transport, development, and sustainability perspectives.

The first part of the report provides an outline of the main policy perspectives surrounding the use of airfreight in food supply chains. The methodologies that have been used to consider the environmental impacts associated with the food supply chain are outlined, focusing particularly on the approaches used to investigate fresh produce production and transport. A literature review of farm to fork studies forms the central part of the report, followed by an analysis of the energy consumers expend in their purchase and consumption related activities of fresh produce. The later part of the report investigates some of the policy options that may be used to reduce carbon emissions in the fresh fruit and vegetable supply chain. The report concludes with a summary of key conclusions and recommendations.

2. Policy Issues

The food and air miles debate has highlighted the importance of the issue of climate change in consumers and politicians minds and the growing importance of reducing carbon emissions. This is an issue which is continuing to grow in importance. In the UK there is political consensus over this issue, moreover the UK has taken the lead in this area in the EU with the Climate Change Bill aiming to reduce emissions by 60 per cent from 1990 to 2050, (13 per cent of UK emissions come from food). The EU is following this lead and other countries are also following suit even countries such as the US which are not part of the Kyoto agreement. Japan also has announced a 50 per cent reduction in emissions by 2050.

In the UK recent surveys have found that 94 per cent of respondents are concerned about climate change with 66 per cent actually taking personal action to reduce their carbon footprint. In the US the issue of COOL labelling (Country of Origin Labelling) is rising in importance, as are food miles. Recent studies predict that the market for local food will grow from $2 billion in 2002 to $7 billion by 2011 in the US.

The issue of food miles and air miles has lead to increase in demand for labelling of food to show its impact on greenhouse gas emissions. This labelling in particular has led to commitments from some to carbon footprint their products and label their food accordingly.

The UK has taken the lead in carbon labelling and carbon ratings. For example, The Carbon Trust, an independent body whose aim is to help companies to reduce their carbon emissions, has launching a trial carbon-labelling scheme. Products have labels stating the carbon dioxide emitted during the full life cycle of an item. The scheme also requires the firm producing the product to commit to reducing their carbon footprint.

Tesco have stated that all products in its stores will receive a carbon rating and are investing £500 million to do this. Marks and Spencer are investing £200 million to reduce its carbon footprint by 80 percent over five years. Both Marks and Spencer and Tesco have airplane symbols on all food products airfreighted to the UK.

To develop a common methodology to calculate carbon footprints the Carbon Trust, the Department for Environment, Food and Rural Affairs (DEFRA) and the British Standards Institute (BSI) have combined and aim to have a methodology ready in 2008. In addition, a UK Select committee is examining issues around the environmental labelling of food.

The Soil Association, a leading United Kingdom organic certifier has recently published a discussion document outlining a number of issues related to the ongoing certification of organic products transported by airfreight[2]. The Soil Association is currently contemplating removing the eligibility of airfreighted fresh produce to be labelled organic. The discussion paper highlights the potential friction between the three Soil Association organic principles: minimising pollution and waste; incorporating social justice and rights; and ecologically responsible production.

In terms of the Soil Association's first and third organic principles, the airfreight portion of a product lifecycle is one of the most carbon intensive. The relatively small volumes of airfreighted fresh produce contribute a disproportionate impact in terms of greenhouse gas emissions. These emission levels are unlikely to be reduced through technological innovations in the short to medium-term. However, such a change in the Soil Association's organic

[2] (May, 2007) Airfreight Green Paper: a basis for discussion. Should the Soil Association tackle the environmental impact of airfreight in its organic standards?

standards threatens to cut developing countries access to high value niche markets. There is concern that a move against airfreight may be a disproportionate reaction to one source of transport-related greenhouse gas emissions which is small in comparison to emissions from other parts of the food system. For example, the UK's Department for Environment, Food and Rural Affairs (DEFRA) estimates that 85 per cent of the growing environmental and social effects of food transport is associated with freight movements on UK roads. In comparison, fresh fruit and vegetables airfreighted from sub-Saharan Africa equates to less than 0.1 per cent of UK greenhouse gas emissions. From a developmental perspective, 70 per cent of Africa's poor work on the land. Airfreight of fresh fruit and vegetables alone from Africa support over 1 million African livelihoods (Legge et al. 2006). Additionally, Africa's carbon emissions are 40 times lower per capita (taking Kenya as an example) than the UK, causing many to argue that African exports should not be unfairly penalised by western 'carbon guilt'. Therefore, removing the certification of airfreighted produce from these countries may be contrary to the Social Association's second principle of social justice.

Other issues which have arisen that are unrelated to this issue are the increase in the debate around seasonal consumption and consuming locally produced foods. Studies in the US show that locally grown food labels greatly influence consumers. Given a choice, consumers are more likely to purchase locally grown over organic foods produced in a distant region, even if the local foods were produced using some pesticides (Leopold Center for Sustainable Agriculture 2004). This is given impetus by the rise in popularity of local food markets.

Furthermore, some argue that food should be bought in season and locally. For example environmental groups such as the Royal Society for the Protection of Birds (2004) suggest that people who are concerned for the welfare of birds and the countryside should:

- Buy locally and in particular directly from producers.
- Buy British, which will reduce food miles and therefore the effects of food transport on global warming.

This argument is also made by local producer organisations. Peter Kendall, the president of the National Farmers Union is quoted on the Farmer Weekly Food Miles campaign website[3]:

"The best way to ensure the long term survival of a strong UK farming industry, and to reduce transport emissions and food miles, is to shop locally. By buying local food we can help to keep the countryside looking picturesque, support the high animal welfare standards upheld in the UK and share in the supply of quality, fresh produce available on our doorsteps".

Others suggest that consumers are being too demanding in their choice of food, wanting to purchase food even when these items may locally be out of season (Garnett, 2003).

The food miles debate, initially started by NGOs with environmental concerns has gradually involved a range of government organisations. In the United Kingdom, the Department for Environment, Food and Rural Affairs has a dedicated team undertaking food miles related research and policy development. In Germany, the Federal Ministry for Consumer Protection, Food and Agriculture has sought EU legislation requiring food labelling indicating the product's origin. At a recent meeting of the EU Agriculture and Fisheries Council in Brussels (28th February, 2005), there was support from a number of EU member states[4] for Germany's call for more comprehensive labelling of food product origin information.

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[3] Downloaded on 28th August 2007 from http://www.fwi.co.uk/gr/foodmiles/endorsements.html
[4] Italy, Finland, France, Ireland, and Portugal (Council of European Union, 2005)

A further issue which may influence the visibility of airfreight is the Kyoto Protocol. Air transport has been excluded from the reductions required under the protocol (Rigby & Brown, 2003). Sim, Barry, Clift and Cowell (2006) note that freight transport has been omitted from the greenhouse gas reporting for each country. This lack of visibility may limit nations seeing the bigger picture and recognising how their own consumption patterns may contribute to global greenhouse gas emissions (Jones, 2002). In addition, the lack of tax on aviation fuel has been argued as in effect, subsidising highly energy intensive airfreight transport. The absence of tax on aviation fuel is in contrast to most other freight transport modes which are dependent on highly taxed petrol and diesel.

An interesting question regarding food miles is how aware are the public of this concept? MacGregor and Vorley (2006) suggest that this concept is still relatively unknown, estimating that only about one-third of shoppers know of the concept. There is also little evidence at present that consumers have significantly changed their behaviour and are purchasing more locally produced food.

3. Methodologies

There are a number of issues around the methodology of measuring carbon footprints of products. In general there is agreement about the emissions from various energy sources and standards such as ISO 14040 and ISO 14044. However, there is still controversy around what should be included or excluded when measuring carbon footprints. For example, factors such as the capital embodied in building and machinery; waste products in the production and consumption process; the energy and emissions associated with the use of the product by the consumer. In the UK the Carbon Trust, the British Standards' Institute and DEFRA have combined to develop a common methodology to calculate carbon footprints. Another important issue less easily solved is the raw data to be used when calculating the carbon footprint and where this is sourced from.

Steen (2002) suggests that there are four main approaches for the assessment of environmental impacts. Risk assessment which is typically used to consider regulation and control mechanisms for hazardous materials or processes; environmental impact assessment which is used to ascertain the likely effects of a project and may be used to shape rules and operating conditions for a proposed development; environmental economics (e.g. cost-benefit analysis and willingness to pay/accept) which tend to be used to assess the usefulness of measures to reduce environmental impacts; and life cycle assessment[5] which is used to consider the impact of a product or production system. The evaluation of environmental impacts requires assessment across an interdependent system which includes technical, natural and social sub-systems (see Figure 3-1).

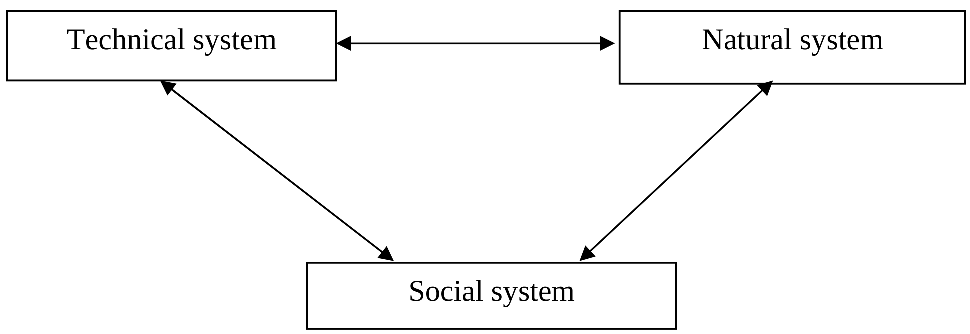

Figure 3-1: An impact evaluation combining scenarios for technique, environment and human attitudes. (Source: Steen, 2002 p.150)

In keeping with many activities, the emphasis towards more sustainable systems has led to the assessment of the environmental performance of food chains. Life cycle analysis, an integrated assessment of the environmental impacts of a product or service has been one of the more commonly applied environmental impact measurement approaches (Guinee, 2002). Life cycle analysis has been applied across a range of food products, and to a lesser extent to fresh fruit and vegetables. Life cycle analysis can be used in wider applications, for example the comparison of differing modes of freight transport (Guinee, 2002).

The life cycle analyses of food chains have tended to centre on the greenhouse gas emissions and energy consumed, although other impact measures have often been captured (e.g.

[5] Life Cycle Assessment involves four phases: goal and scope definition; inventory analysis; impact analysis and interpretation (ISO, 1996).

acidification potential, eutrophication potential and abiotic resource use). The most common measurement units for energy are megajoules (MJ). Greenhouse gases are a group of naturally occurring and anthropogenic gases that in higher concentrations have been implicated in the temperature elevation of the of earth's surface-troposphere system. The IPCC consider water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) to be the primary greenhouse gases[6]. Carbon dioxide is the most commonly published measure of greenhouse gases. Carbon dioxide is used as the reference gas that other greenhouse gases are measured against and has a Global Warming Potential (GWP) of 1.0 (IPCC). It is common for studies to report carbon dioxide equivalent (CO_2e or CO_2eq), a measure that indicates the effective greenhouse warming potential of a range of gases[7] in terms of CO_2.

The most detailed approach to life cycle analysis is bottom up or process analysis (Jansen & Thollier, 2006; van Engelenburg, Rossum, Block & Vringer, 1994). After describing the production network, the component activities required to produce, transport, consume and handle the waste associated with the product are assessed in terms of energy, physical inputs, emissions and waste. A complete bottom up life cycle analysis will cover from cradle to grave, and this can be a sizeable undertaking given the complexity and length of many product supply chains.

An alternative approach to life cycle analysis is a top down or Input-Output analysis which uses methods from economics and statistics to determine impacts through the formulation and use of matrices to determine energy and emissions. Input-Output analysis allows the impact of a complete production network to be calculated, although the accuracy for individual products is usually somewhat less than for the bottom up approach (van Engelenburg et al., 1994).

Hybrid approaches combine the relative strengths of bottom up and top down approaches by splitting the production network into two parts. The major processes which tend to contribute the largest impact are assessed with a bottom up approach, whilst the remaining processes are assessed using a top down approach (van Engelenburg et al., 1994).

However, most of published studies consider only a specific portion of the supply chain (e.g. farm to wholesaler or farm gate to supermarket). These studies tend to vary in method and coverage and thus make comparisons difficult.

[6] Other greenhouse gases include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6).
[7] UKERC Appendix – GWP assumed to include the six greenhouse gases identified in the Kyoto Protocol.

4. Trade in Fresh Fruit and Vegetables

This section reviews the trends in trade of fresh fruit and vegetables. It is estimated that over 73 million tonnes of fruit and vegetables per annum are traded globally with a value of circa $US45 billion. (Legge et al., 2006). Over the last decade, the value of the global fruit and vegetable trade has grown significantly. In the case of fruit, trade has grown by 43 per cent and vegetables by 37 per cent over this period. For 2003, international trade in fresh fruit accounted for $US26.4 billion. Non-traditional tropical fruits have been one of the fastest growing areas with the growth of fruit such as mangoes, pineapples and papayas doubling in value to over $US2.6 billion per annum. Although there has been some growth in the more traditional temperate and sub-tropical fruits, this has tended to be more modest. In 2003, international trade in fresh vegetables accounted for $US18.7 billion, with chillies, green peppers and green beans the fastest growing categories.

Mildon (2007) provides a further breakdown of global fruit and vegetable exports, tracking the growth in trade since the early 1980s and also splitting trade into fresh and product categories (see Figure 4-1). The strong growth in fresh fruit and vegetable exports is clearly shown in this graph, highlighting the more than doubling of exports for the 20-year period between 1982-1984 and 2002-2004.

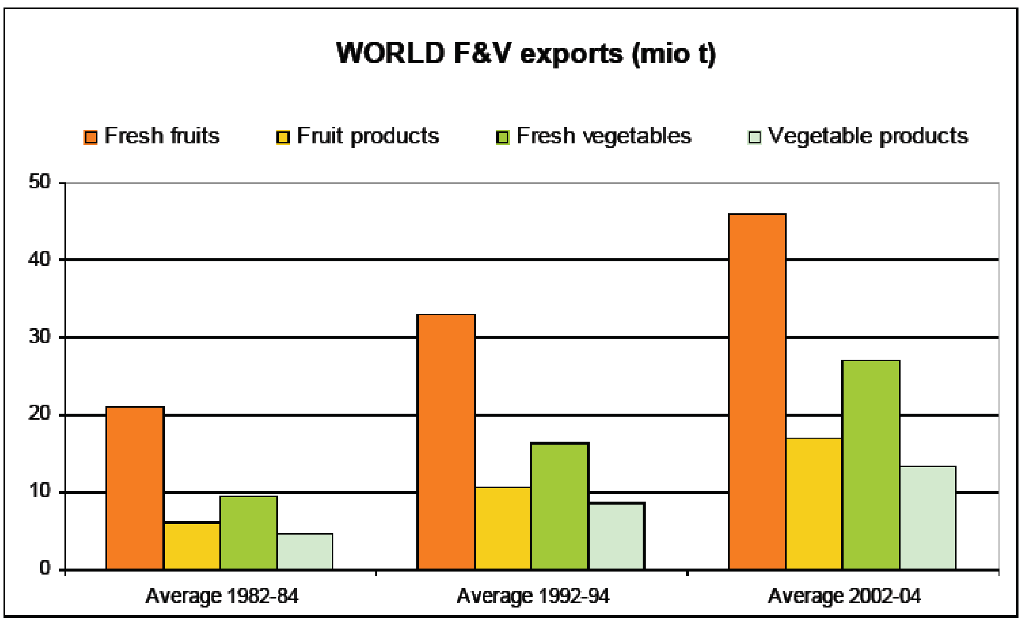

Figure 4-1: World fruit and vegetable exports. (Source: Mildon, 2007)

A number of EU member states are significant importers and exporters of fruit and vegetables. For example: Italy, Netherlands, Belgium and France are significant importers and exporters of fruit and vegetables; Spain is a significant exporter; whilst Germany and the UK are significant importers. Other key trading nations include the USA, China, Chile, Mexico, Ecuador, Canada and Japan. Figures 4-2 and 4-3 provide an outline of some of the key fruit and vegetable trading countries.

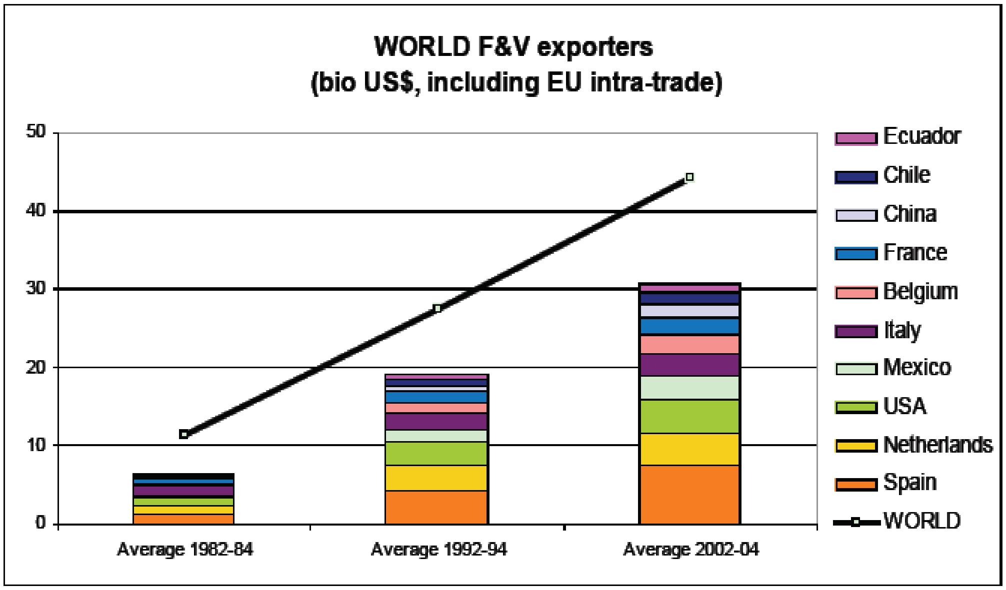

Figure 4-2: Key fruit and vegetable exporters. (Source: Mildon, 2007)

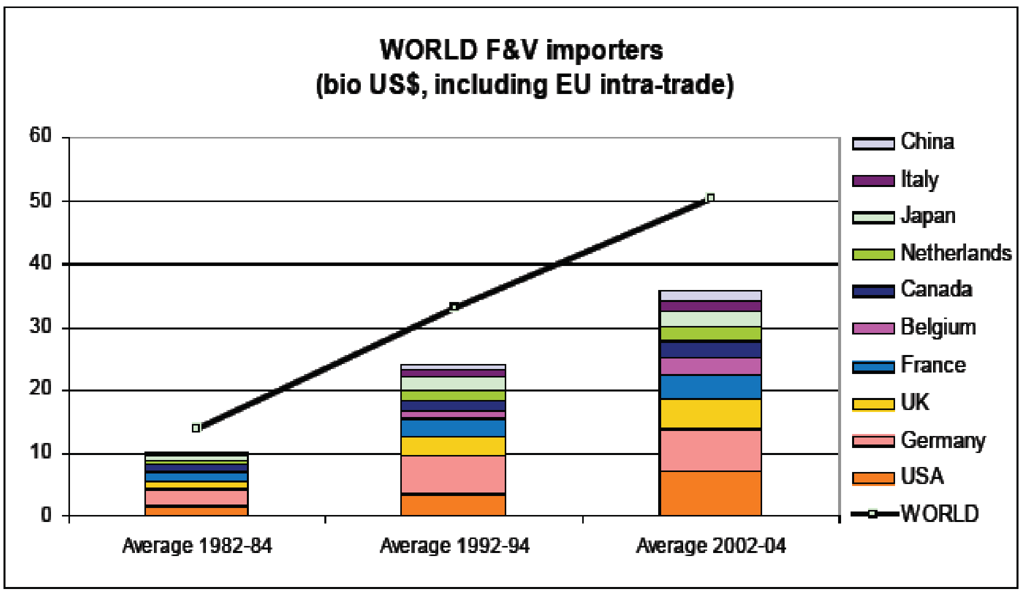

Figure 4-3: Key fruit and vegetable importers. (Source: Mildon, 2007)

With respect to the global trade in organic food and drink, in 2003 it was estimated to be $US 25 billion with Western Europe accounting for 51 per cent of this ($US 13 billion). The USA, Germany and UK are the three largest single markets accounting for 68 per cent of this trade ($US 17 billion) (Willer & Yussefi 2005).

Developing countries play an important role in the exports of fruit and vegetables, accounting for a third of this trade. Legge et al. (2006) notes that this trade is dominated by a handful of developing countries with just eight countries accounting for two-thirds of those exports. A number of factors have been cited for the ongoing growth of fruit and vegetable exports from developing countries including low labour and input costs, better production and storage techniques, and improved logistics and transport.

Over the period 2003 to 2005 fruit production in the EU-27 averaged 40 million tonnes whilst vegetable production averaged 70 million tonnes (Mildon, 2007). The EU-27 is a net importer of fruit with imports exceeding exports to the value of $US 8.2 billion and imported vegetables exceeding exports to the value of $US 1.8 billion[8].

One factor which may be driving this trade is the growing awareness of the nutritional benefits associated with fresh produce. However, only two EU member states exceed the World Health Organisation recommended fruit and vegetable intake of 400g/day per person. Greece (580g/day) and Italy (417g/day) have the highest per capita consumption rates, in contrast to the relatively low consumption rates of the UK (256g/day), Sweden (250g/day) and Ireland (245g/day) (DAFNE data cited in Mildon, 2007). The daily consumption of fruit and vegetables (g per capita) for a selection of EU member states is provided in Figure 4-4.

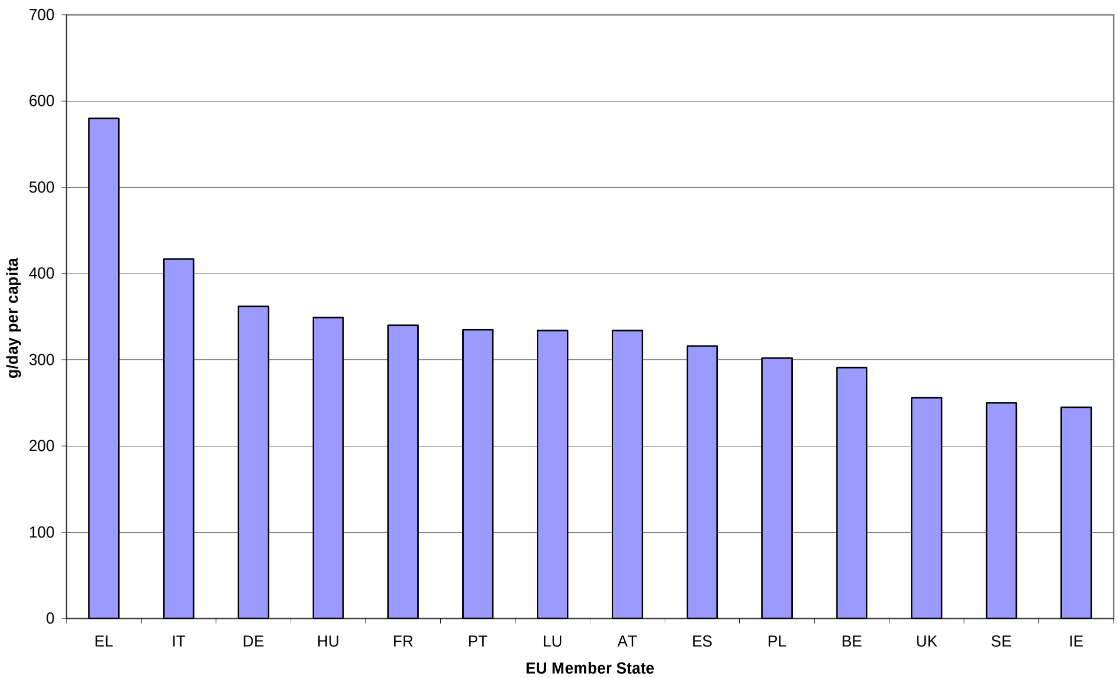

Figure 4-4: Consumption of fruit and vegetables (g/day per capita) for selected EU member states. (Source: DAFNE data cited in Mildon, 2007)

The various statistics provided in this section highlight the ongoing growth in fresh fruit and vegetable trade. At the global level there is clear evidence that the volumes of fresh produce traded have grown significantly over the last 20 years. Although the recent enlargement of the EU has lead to a slightly more self-sufficient trade unit, the EU is still a large importer of fresh produce. The relatively low rate of fresh produce consumption against the WHO suggested daily intakes means that if member states do increase their average consumption levels towards that suggested, then additional fresh produce will be needed, potentially increasing imports further.

[8] These figures are calculated from FAOSTAT import and export data averaged over the years 2003 to 2005.

5. Literature Review

There is a range of literature relevant to energy and emissions associated with the production, trade and consumption of fresh fruit and vegetables. This chapter reviews a variety of material concerned with fresh fruit and vegetable production, consumption, transport and trade. The first part of the chapter focuses on several reports that consider greenhouse gas emissions at an aggregate level, either for the EU or country level. These reports provide an indication of the greenhouse gases associated with the food sector and specifically from fruit and vegetables. This section also reviews literature focusing on the supply of fresh produce from developing countries, highlighting the role fruit and vegetable production plays in sub-Saharan African economies. The second part of this chapter reviews studies that focus on a specific product, covering various stages of the supply chain. This part of the chapter begins with several studies which investigate the transport related emissions or energy associated with fruit and vegetable supply chains and then reviews the more comprehensive studies that incorporate wider elements of the supply chain including production.

5.1 EU and country level studies

In terms of calculating the greenhouse gas emissions associated with the freight of fruit and vegetables into and within the EU there are some interesting measurement issues. Garnett (2006) notes that mode of travel information for EU produce is not freely available, making it difficult to ascertain the breakdown of transport used to freight fresh fruit and vegetables. A further complication is that once food has landed in the EU, it is then classed as local product for onwards freight purposes. As the earlier section indicated, a number of EU member states are significant producers of fruit and vegetables (e.g. Italy, Spain and France), whilst others are large consumers (e.g. Germany and the UK), underlining the large volume of fruit and vegetables traded within the EU. The trade of fruit and vegetables within the EU is largely carried out by land or water-based transportation, with little produce transported by air (Garnett, 2006).

The EIPRO study completed by Tukker et al. (2006) undertook an analysis of the Global Warming Potential (GWP) contribution made by various sectors within the EU-25. Food (including alcohol and tobacco) was found to account for 31 per cent of the EU-25 GWP, whilst vegetables accounted for 0.7 per cent and fruit 0.5 percent of GWP. However, the EIPRO study excluded from these figures the emissions and energy associated with domestic cooking (1.0 per cent of GWP), refrigeration (1.8 per cent of GWP), and eating and drinking places (8.1 per cent of GWP).

Kramer, Moll, Nonhebel and Wilting (1999) use data from the Netherlands Household Expenditure Survey to calculate the greenhouse gas emissions associated with household food consumption. The study included emissions from production, transport and consumption activities as well as the associated waste treatment for each product. Annual food consumption emits almost 2,800 kg CO_2e per household. Fresh fruit and vegetables account for slightly less than 10 per cent of household food related emissions, emitting 266 kg of CO_2e. Just five products (i.e. potatoes, apples, lettuce, oranges, and tomatoes) account for 52 percent of the household fruit and vegetable emissions. A summary of the most significant fruit and vegetables associated with household greenhouse gas emissions is provided in Table 5-1.

Household carbon dioxide emission source	Annual household emissions kg CO_2e	Source category as a percentage of total food emissions (%)
Potatoes	49.24	1.8
Apples	25.19	0.9
Lettuce	22.04	0.8
Oranges	21.11	0.8
Tomatoes	20.68	0.7
Total fruit and vegetables	266	9.5
Total food emissions	2800	100

Table 5-1: Leading fruit and vegetable sources of greenhouse gas emissions for Dutch households.

Kramer et al.'s study findings are similar to those found by Nijdam et al. (2005) investigation of the environmental impact from Dutch private consumption. Nijdam et al. found that food accounted for approximately 30 per cent of greenhouse gas emissions and fruit and vegetables accounted for 30 per cent of food's share. This equates to a greenhouse gas contribution of 9 per cent. The authors calculate that on a per capita basis the annual greenhouse gas emissions equate to 11 tonnes of CO_2e. Nine per cent of 11 tonnes suggests that fruit and vegetable consumption per capita accounts for approximately 1 tonne of greenhouse gases per annum.

Pretty, Ball, Lang and Morison (2005) estimate the external cost of farm production and transport of a basket of commodities in the UK market. They found that internal transport was significant; however the contribution of sea and air was trivial due to the low volumes.

5.2 Emissions associated with fresh fruit and vegetables from developing countries

Legge et al.'s (2006) report provides useful insights into the trade of fresh produce from sub-Saharan Africa (SSA), estimating that over 715,000 farmers' benefit from the export of fresh produce to the UK. When South African farmers are included it is estimated that well over one million African farmers benefit from this trade. The direct employment associated with this trade includes on-farm labour (most notably women), skilled and unskilled workers in packhouses, and a variety of workers engaged in ancillary services (e.g. fertilisers and tools, seeds, irrigation, transport and banking). Fruit and vegetable production also directly and indirectly supports a wider network of people.

In a review of the literature around the importation of sub-Saharan African (SSA) horticultural produce, Wangler (2006) found that 25 per cent of UK's fresh fruit and vegetables are sourced from non-EU countries. Of imports into the EU 40 per cent of all airfreighted fresh fruit and vegetables are grown in sub-Saharan Africa[9]. A summary of the fresh produce imports by mode of transport from SSA is shown in Figure 5-2.

MacGregor and Vorley's (2006) report examines the arguments surrounding fresh produce exports from sub-Saharan Africa (SSA) to the UK. The authors report that for 2005 fresh fruit and vegetables exports to the UK were worth over £200 million. Several SSA countries sell large proportions of their produce to the EU. For example, Kenya exports 70 per cent of its green bean production to the UK.

[9] This data was sourced from Her Majesty's Revenue and Customs (HMRC) (2006) and Marriott (2005).

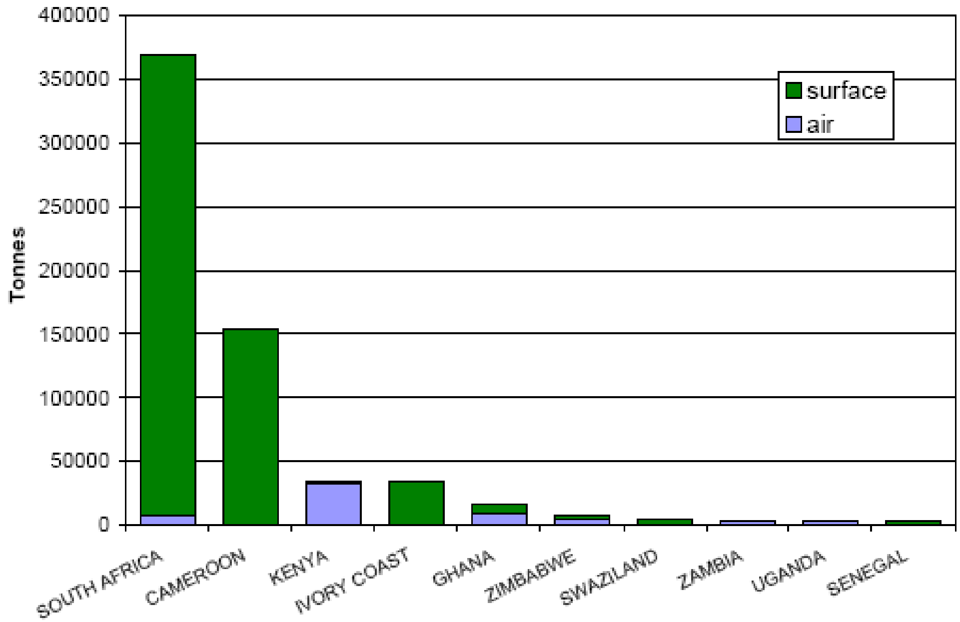

Figure 5-2: Top ten SSA fresh fruit and vegetable exporters to the UK by mode of transport. (Source: Wangler, 2006)

MacGregor and Vorley discuss a range of other factors relevant to understanding the impact and sustainability of horticultural production and export from developing countries. They observe the global inequality in terms of how different countries utilise ecological space. The current global average is 3.6 tonnes of carbon per capita, yet in the UK the average is 9.2 tonnes whilst it is only 1 tonne in Africa. Current calculations suggest that to ensure a sustainable carbon future an equitable ecological space of 1.8 tonnes per capita is required. The authors propose that countries with lower carbon emissions have the potential to offset their excess ecological space against poverty reduction and improved economic growth and development. The opportunity for developing countries to develop in an equitable and non-restrictive economic climate has been recognised under the Kyoto Protocol.

MacGregor and Vorley observe that single comparisons of indicators do not necessarily lead to sound policy. The multiple issues facing developing countries are complex; often the social and employment matters associated with trade are poorly understood. The authors argue that food miles have limited usefulness as a sustainability indicator. Food miles fail to capture some of the key social and economic benefits that may be associated with the production and trade of food, particularly in developing countries.

In terms of the outlook for emissions associated with fruit and vegetable trade with Africa, DEFRA (2007) have calculated the growth in emissions between 2005 and 2015 for a baseline plus 2 per cent growth scenario and the UK consuming the WHO recommended five portions per day target. In 2005 the UK imported 783,000 tonnes of produce, emitting 770,000 tonnes of CO_2. The 2 per cent per annum growth scenario would see total African imports increase to 940,000 tonnes and CO_2 emissions totalling 920,000 tonnes. If the UK achieved the WHO recommended five portions a day target by 2015, this would result in an increase in imports from Africa to 985,000 million tonnes and emitting 960,000 tonnes of CO_2. A summary of this data and additional details of tonne and vehicle kilometres is provided in Table 5-3.

	2005 baseline	2% per annum growth between 2005 - 2015	5 portions per day target (2015)
Total imports (tonnes)	783,000	940,000	985,000
Tonne km (billion)	5.2	9.3	6.6
Vehicle km	9,580,000	11,500,000	12,060,000
CO_2 emissions (tonnes)	770,000	920,000	960,000

Table 5-3: Potential growth of CO_2 emissions associated with African imports of fresh fruit and vegetables.

5.3 Transport focused studies of fruit and vegetable

There have been a few studies which have concentrated upon the transport and associated emissions associated with food trade and consumption. These generally are not full LCA analyses and concentrate on the transport elements of the supply chain. However, these studies do provide useful context and indicate the relative importance of different types of transport and trends in freight.

Marriott (2005) completed a study of the trends in the freight transport for fresh horticultural produce and its potential environmental impacts. For the year 2004, Marriott found that 6 per cent of non-EU fresh produce was airfreighted to the UK. However, this small proportion of airfreighted produce accounted for 81 per cent of the CO_2 emissions associated with non-EU produce imports. Figure 5-4 from Marriott's research outlines the source of transport CO_2 for fresh fruit and vegetables imported into the UK. Of particular note is that the potential CO_2 impact of three high volume imports (i.e. bananas, apples and oranges) is significantly reduced by the extensive use of sea freight for these products.

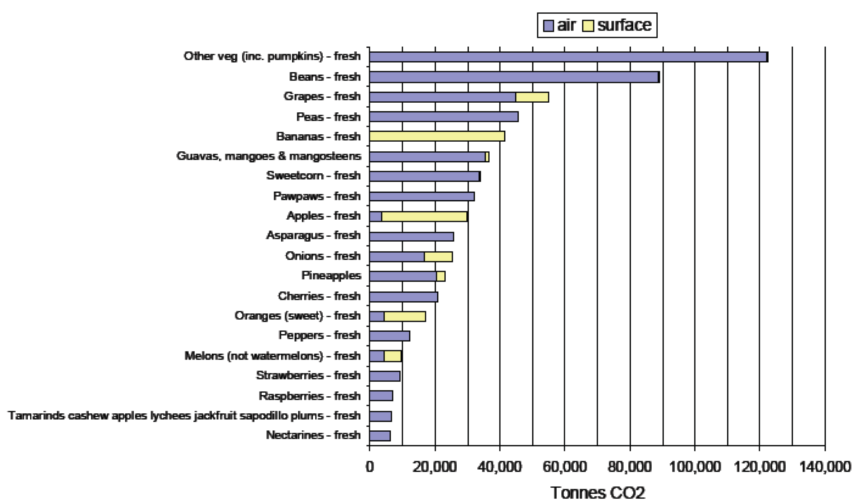

Figure 5-4: Top 20 product sources of import transport CO2 for fresh fruit and vegetables imported into the UK from outside EU in 2004 by mode of transport and tonnes of CO2. (Source: Marriott, 2005)

The AEA Technology (2005) report on food miles provides an indication of the transport emissions associated with food for the UK. The report provides a useful breakdown of food kilometres and CO_2 emissions by transport mode (see Figures 5-5 and 5-6). For 2002 the authors estimate cars account for the single largest proportion of vehicle kilometres (48 per cent) followed by heavy goods vehicles (HGV) operating in the UK (19 per cent) and light goods vehicles (LGV) operating in the UK (16 per cent). The balance of the food vehicle kilometres are made up of heavy and light goods vehicles transporting produce overseas, and sea, rail and airfreight. However, in terms of the CO_2 emissions associated with UK food transport, HGV transport is the largest contributor (33 percent) followed by HGVs operating overseas (12 per cent) and HGVs carrying export product (12 per cent). The car contributes a smaller proportion of CO_2 emissions at 13 percent, whilst sea contributes 12 per cent and air 10 per cent.

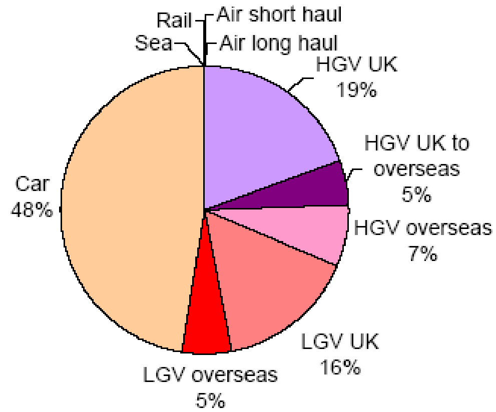

Figure 5-5: UK Food kilometres by transport mode. (Source: AEA Technology, 2005)

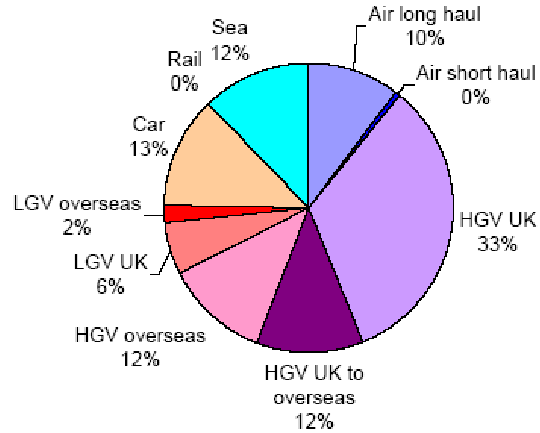

Figure 5-6: CO_2 emissions associated with UK food transport. (Source: AEA Technology, 2005)

The AEA Technology report notes that between 1992 and 2002, urban food kilometres increased by 27 per cent, HGV food tonne kilometres increased by 36 per cent, and airfreight increased by 140 per cent. The increasing amount of food transport has led to a 12 per cent increase in the CO_2 emissions associated with food. The increase in urban food kilometres has been influenced by increasing car ownership and changing shopping patterns, especially with the development of out-of-town supermarkets (Jones, 2002). Improvement in load factors and larger HGVs has helped offset the increase in HGV tonne kilometres. The authors highlight that the trend in improved utilisation may occur for only a finite period, after which there may be more significant increases in food vehicle kilometres.

Garnett (2006) provides an estimate for the transport related emissions of greenhouse gases related to the UK fruit and vegetable sector. In total the sector makes up 0.55 per cent of the total UK greenhouse gas emissions, with overseas road and sea freight contributing 0.2 percent, overseas air contributing 0.2 percent, UK road freight transport contributing 0.05 per cent and UK car shopping travel contributing 0.1 percent.

The market outlook suggests an ongoing increase in the consumption of fresh fruit and vegetables[10], whilst Boeing (2006) forecast that airfreight transport will also continue to grow. In the United Kingdom the reduction in horticultural production since 1994 and changing consumer preferences have led to an increasing reliance on imported produce. It is estimated that the UK's self sufficiency in fruit is 9 per cent (organic fruit 6.6 per cent) and 62 per cent for vegetables (organic vegetables 64 per cent) (Garnett, 2006).

[10] Mintel Fresh Fruit and Vegetable – UK – January 2007 cited in DEFRA (2007)

The DEFRA (2007) report acknowledges that the carbon emissions associated with fruit and vegetables will depend largely on how much of this produce is airfreighted. The proportion of fresh produce airfreighted will be influenced by four main factors:

- The types of produce demanded will affect the quantity airfreighted. For example, an increase in the demand for perishable produce such as legumes will require additional airfreight whilst an increase in other fruits such as bananas or apples will require less airfreight.
- The ongoing costs for air and other freight transport.
- Changes in produce specification requirements such as added value (e.g. peeled or as ready to go salad) may increase airfreight requirements. However, added value produce has also tends to have a higher ratio of economic value to carbon cost.
- The effects of country of origin or airfreight labelling on consumer buying behaviour.

MacGregor and Vorley note in their study that although there is an ongoing increase in the volume of passenger (4-6 per cent per annum) and freight transport (6 per cent per annum), there is no firm evidence linking this freight expansion to eating fresh produce. In other words, if EU consumers reduced their consumption of airfreighted fresh produce this would not necessarily result in fewer planes operating.

A study of the transportation associated with total supply to the UK market from different sources was completed for lettuce, apples and cherries (Mason, Simons, Peckham & Wakeman, 2002). Cherries travelled an average distance of 7,751km and had the highest ratio of supply chain emissions to product transported (3.128), thus reflecting the use of airfreight from North America. Apples in contrast had the higher transport distance of 8,637 km but lower emission ratio of 0.109 due to the product being sea freighted from New Zealand (NZ). The lowest distance and emission ratio were for lettuces at 907km and 0.436 reflecting their UK and European source. The authors received expert advice confirming it would be climatically and economically challenging to increase the supply of locally grown lettuce or cherries. The supply of locally (UK) grown apples could be increased; however, this was only possible for limited varieties. A summary of the key data from this study and additional information on CO_2/kg and total tonnes is provided in Table 5-7.

Product	Origin and freight mode	Total product (tonnes)	Total km (average)	CO_2 kg/ tonne	Ratio of supply chain CO_2 to product shipped
Lettuce A	UK (63%) - Road Spain (37%) - Road & RO-RO	100,083	907	44	0.0436
Lettuce B	UK (40%) - Road Spain (60%) - Road & RO-RO	36,280	957	45	0.0454
Apples	UK (22%) – Road Europe (34%) Sea & Road NZ (44%) - Sea & Road	104,002	8,767	109	0.109
Cherries	Sthn Hemisphere (7.5%)- Air UK (8%) - Road North America (48%) - Air Turkey (37%) - Road	381	7,751	3,605	3.128

*Note: RO-RO is short for roll-on roll-off shipping.

Table 5-7: Summary of CO2 transport emissions for UK fruit and vegetables.

The Sustainable Europe Research Institute (SERI) was commissioned by Agrarmarkt Austria to undertake a comparative study of the carbon dioxide emissions for the freight transport of locally (Austrian) produced and imported produce. The study calculated the CO_2 emissions for the transport of apples, strawberries, grapes, tomatoes and peppers (SERI, 2007). For the various fruit and vegetables investigated, the emissions associated with transportation are significantly greater for imported produce than for local produce. In the case of imported peppers, this produce emitted seven times more CO_2 than locally sourced produce, whilst Chilean grapes emitted 842 times more CO_2 than local produce. A summary of the data from this study is shown in Table 5-8.

Fruit or Vegetable	Location grown	Transport mode	g CO_2/kg
Apples	South Africa	Sea & Road	263.1
	Austria	Road	22.6
Strawberries	Spain	Road	264.4
	Austria	Road	6.9
Grapes	Chile	Air & Road	7410.8
	Austria	Road	8.8
Tomatoes	The Netherlands	Road	104.7
	Austria	Road	0.7
Peppers	Israel	Sea & Road	85.4
	Austria	Road	11.3

Table 5-8: Transport related CO_2 emissions for Austrian and imported produce.

The Jones (2002) study calculates the energy and emission impact for the supply of apples to UK consumers from a variety of British and North American sources. The boundaries for this study include the transport stages post production and packaging. This includes transport to the wholesale or regional distribution centre, distribution to retail store, transport from store to home, and transport of apple waste to landfill. The transport related CO_2 emissions range from zero in the case of home grown apples to 609 g CO_2/kg for apples sold to consumers in Brixton and zero to 1000 g CO_2/kg in the case of apples purchased in Denbigh. Locally sourced apples emitted 37 g CO_2/kg, some 87 per cent less CO_2/kg than imported North American apples purchased in a Brixton supermarket.

An interesting issue raised in this study is the heavy reliance of the UK on imported apples which account for over three-quarters of the fruit consumed. The authors suggest a number of means to reduce the transportation of apples including promoting the consumption of early and good keeping varieties of British apples and the use of controlled atmosphere storage. The suggested use of storage is an interesting contrast to the findings of more recent studies that highlight the energy and emission intensity of keeping apples for more than four months (e.g. Canals, Cowell, Sim, & Besson 2007; Sim et al. 2006).

The importance of information provision to consumers is also identified as enabling shoppers to make more environmentally informed decisions. The author observes that a number of factors have evolved to create the current food transport system and that to improve this system a variety of policy steps are required. Jones argues that there is a lack of consensus on the indices that should be used to ascertain the sustainability and that this has led to uncertainty as to the most appropriate way to improve the sustainability of the food system.

Wallgren's (2006) study investigated the respective energy footprints for the transport of food to a Swedish farmer's markets selling locally grown produce and for conventional food retail. The author found that the differences between product types (e.g. bread/flour/grains (0.8 – 3.8 MJ/kg) vs. fruit/vegetable (0.8 – 10.1 MJ/kg)) were greater than the differences between the food supply systems. Although the farmers market products were transported much shorter distances than conventional, this was offset by the greater transportation efficiency of the conventional system (i.e. MJ/tonne-km). There were no significant differences found in terms of energy intensity between the farmers' market (0.2 MJ/kg – 17 MJ/kg) and conventional food systems (0.45 MJ/kg – 10.1 MJ/kg) except for the products (tomatoes) transported by airfreight (50 MJ/kg). These findings are largely consistent with Van Hauwermeiren, Coene, Engelen and Mathijs's (2007) study.

These studies do highlight the importance of travel within a country and of shoppers in purchasing food as well as airfreight, but are only a partial picture. The next section reviews studies which incorporate parts of the life cycle of products including transportation. Some of the studies reviewed in the next section also provide data on comparative transportation use.

5.4 LCA Product-based studies

There are relatively few life cycle analysis which consider the whole production, transport and consumption part of a food products life cycle, especially for fresh fruit and vegetables. The studies range in their scope comparing particular products (e.g. potatoes, apples and cherries), production systems (e.g. organic and conventional systems), distribution systems (e.g. farmers' markets and conventional suppliers), sources of supply (e.g. UK, Spain, USA, Chile, New Zealand and Kenya), and the mode of freight transport (air, sea and truck). None of the studies offered a complete farm to fork analysis, tending to focus on emissions related to specific supply chain segments. The varying scope, methodologies and assumptions of these studies also limit the comparisons that can be made between the studies. Most of the studies have been conducted in just a few EU countries with Sweden, Denmark, the Netherlands, and the United Kingdom the most common. The impacts measured across the literature vary with several studies focusing on single measures of energy (MJ) or carbon dioxide (CO_2), whilst others offer an array of metrics including detail of other greenhouse gases, CO_2e, GWP_{100}, PM_{10}, abiotic depletion, acidification and eutrophication. Although the focus of this review is on greenhouse gas emissions, several studies which assess the energy associated with product life cycles are included as energy is also an indicator of global warming. A summary of the key studies reviewed for this report are provided in Appendix A.

The Carlsson-Kanyama, Ekstrom and Shanahan (2003) study investigates the energy associated with Swedish food consumption. The study included farm production, transport to the retailer and storage, preparation and cooking in the household. Production of capital goods involved in production (e.g. machinery and buildings), packaging, waste treatment and transport from shop to household were excluded from the study. The authors found that the energy associated with an individual's daily intake of food can vary by a factor of four, ranging from 13 to 51 MJ. Energy inputs per kilogram of food type[11] vary from 2 to 220 MJ, influenced by the animal or vegetable source, level of processing, processing technology and transportation distance. Interestingly, the authors observe that up to one-third of the energy inputs of food are related to products with low nutritional value (i.e. snacks, sweets and drinks).

The study calculated the energy associated with a range of locally produced and imported fruit and vegetables. The authors suggest that transportation distance and vehicle efficiency are important factors influencing energy inputs. For example, distance explains why Swedish apples (3.5 MJ/kg) require less energy than overseas sourced (8.6 MJ/kg) even though the imported produce is transported in energy efficient ships. In the case of airfreighted tropical fruit, the lower efficiency of the transportation is important in explaining the required energy inputs (115 MJ/kg).

However, transport mode and distance are not the only significant contributors to the energy footprint of fruit and vegetables. The production system can be an important contributor to total energy inputs as indicated in the comparison between Swedish greenhouse produced tomatoes (66 MJ per kg) and open grown Southern European tomatoes (5.4 MJ/kg). Similarly,

[11] The measurement unit is based on one kilogram of food ready to eat.

the choice of cooking method can have a significant effect on the energy footprints as highlighted by Swedish grown potatoes oven baked (29 MJ/kg) requiring over five times the energy of boiled (5.4 MJ/kg) potatoes. Table 5-9 summarises some of the fruit and vegetable energy values obtained for local, EU and imported produce. Most of the energy input values ranged between 4 and 9 MJ/kg, with the exception of airfreighted, greenhouse grown and oven baked products.

Fruit or Vegetable	Source and preparation	MJ life cycle input per kg
Apples	Sweden - fresh	3.5
	Central Europe - fresh	4.8
	Overseas - fresh	8.6
Cherries	Sweden - fresh	5.0
	Central Europe - fresh	6.2
	Overseas - fresh	9.6
Oranges	Southern Europe - fresh	6.8
	Overseas - fresh	9.4
Grapes	Southern Europe - fresh	7.8
	Overseas - fresh	9.7
Potatoes	Sweden - cooked	4.6
	Sweden - baked	29
Carrots	Sweden - fresh	2.7
	Central Europe - fresh	4.0
Tomatoes	Sweden – fresh, greenhouse grown	66
	Southern Europe – fresh, open grown	5.4
Strawberries	Sweden – fresh	6.2
	Southern Europe - fresh	8.6
	Middle East - fresh, airfreighted	29
Tropical fruits	Overseas – fresh, airfreighted	115

Table 5-9 Energy associated with fresh produce sourced locally, within EU and imported.

A potential limitation of the Carlsson-Kanyama et al. (2003) study is that although an energy estimate for storage has been included in this study, the energy figures (e.g. Swedish apples 3.5 MJ) suggest that out of season storage was not included in the study. More recent studies have shown that storage to allow out of season consumption of apples can account for over 40 per cent of a products energy inputs (circa 2 MJ/kg) (e.g. Saunders, Barber and Taylor, 2006).

Fogelberg and Carlsson-Kanyama (2006) completed an LCA study of the energy and emissions associated with alternative sources of fresh produce supply to Sweden. The study included farm energy and emissions for carrots, onions, broccoli and tomatoes and for all products transportation and packaging. Carrots and onions sourced from the Netherlands or Denmark had higher emissions than locally produced product. However, in case of carrots this was as much due to different production systems as transport. Tomatoes from the Netherlands had slightly higher emissions than those supplied from Sweden whereas those from Denmark were 33 per cent higher. In case of broccoli the emissions were similar across all countries of supply even including that sourced from Central and South America due to the lower use of fossil fuel in the later countries.

Van Hauwermeiren, Coene, Engelen, and Mathijs's (2007) study[12] compared energy and emissions between a variety of food supply systems. They studied the whole supply chain but excluded consumer food preparation and storage. For a sample of food products (potatoes, lettuce, tomatoes, carrots and apples) the impact of several different supply scenarios were calculated. The first part of the study calculated the energy and emissions for a local food

[12] The information reviewed in this report includes additional data from a van Hauwermeiren et al. (2005) presentation.

chain (farmers' market) and conventionally (supermarket) supplied fresh produce (farm gate to consumer). Across all produce categories, CO_2 emissions were lower for the conventional system than for the local food system. The key driver of this difference is the transport element. The larger trucks and with higher load factors generates lower emissions for the conventionally sourced produce. However, the difference between these two supply systems is still relatively small.

The authors explored several other factors that may be important in calculating the impact of food supply chains and undertook additional analysis to explore the effects of: consumer's transport efficiency; imported freight mode efficiency; greenhouse versus open grown produce; and organic versus conventional production systems.

The choice of transport mode for consumers made a large difference in terms of the energy and CO_2 emissions associated with food. An important issue in this analysis is how the impact of the car is allocated to the food purchased. In other words whether it is assumed that the car was used solely to purchase and transport the food, and how many kilograms of food are purchased in the shopping trip. The authors calculate that on a single 5 km trip to purchase 25 kg of food that is combined with other activities, the purchases will incur an impact of 100.87 g CO_2/kg of food. A summary of the authors findings per trip are outlined in Table 5-10.

Transport mode and transport distance	**g CO_2/trip**
Consumer on foot	0
Consumer on bicycle	0
Consumer by car, specifically for shopping	
5 km single trip	4034.87
10 km single trip	8069.73
15 km single trip	12104.60
Consumer by car, combining shopping with other activities	
5 km single trip	2521.79
10 km single trip	5043.58
15 km single trip	7565.38

Table 5-10: CO_2 emissions associated with different transport modes and distances.

Significant differences were found across the different types of transport and for different distances. The authors' calculations are based on averages from a variety of different sources and emphasise that large differences can occur when different load factors and flights with intermediate landings are assumed. This analysis also excludes the transport to and from the loading points. The most efficient short haul freight method is bulk transport by sea vessel (29.77 g CO_2/kg). However, only some products can be readily transported in bulk and that this form of transport is not available across and within all EU member states. A summary of the study's CO_2 emissions by freight transport mode is provided in Table 5-11.

An interesting comparison from van Hauwermeiren et al. study is that the relative impact of specific (i.e. solely to purchase food) shopping trips of greater than 10 km. In the worst case scenario of a consumer driving more than 10 km to solely purchase one kilogram of fresh produce will be greater than the CO_2 emissions associated with airfreighting one kilogram of produce from Kenya.

Based on previous research completed by Maertens et al. and Georges et al., van Hauwermeiren calculated the energy and CO_2 emissions associated with the heated greenhouse production of tomatoes and lettuce. On average it was calculated that the heated greenhouse growing of tomatoes required 26.73 MJ/kg and emitted 1459.4 g of CO_2/kg. Lettuce required 22.90 MJ/kg of energy and emitted 1250.2 g of CO_2/kg. Greenhouse tomatoes use 10 to 18 times more energy than open grown crops and for lettuce, 9 to 21 more energy than open grown crops.

Transport mode and transport distance	g CO_2/kg
Short distance (400 km)	
Truck	54.66
Electric freight train	69.15
Inland vessel	
Bulk	29.77
Non-bulk	79.72
Continental transport	
Truck	204.98
Electric freight train	259.32
Freight aircraft	2149.20
Sea vessel	
Bulk	599.82
Non-bulk	1605.98
Intercontinental transport	
Freight aircraft	8509.68
Sea vessel	
Bulk	2399.29
Non Bulk	6423.90

Table 5-11: CO_2 emissions associated with different freight transport modes

The difference between organic and conventional production systems was also investigated in this study. Organic systems were found to emit less CO_2 (11.5 g CO_2/kg) than the conventional production systems (18.6 g CO_2/kg).

Van Hauwermeiren et al. combined the additional calculations with the base data to consider a range of different food supply scenarios for tomatoes. The smallest footprint was for Belgium grown tomatoes grown in an unheated greenhouse, purchased on foot by the consumer. At the other end of the spectrum Kenyan produced tomatoes airfreighted to Belgium and purchased in a combined shopping trip of 15 km would lead to the production of 9361 g of CO_2/kg of tomatoes, almost 100 times the smallest CO_2 footprint. Table 5-12 provides a range of different supply scenarios indicating how the production system, freight transport mode and consumer transport choices each can have a significant effect on the total carbon dioxide emissions associated with fresh produce. The table highlights that even when very efficient production and distribution systems are in place, consumer transportation choices can lead to greenhouse gas emissions greater than the total of the other parts of the supply chain.

Jones (2006) completed a comparative study of UK and Kenyan green bean production. The energy requirements for the production systems were similar (UK 0.82 – 1.38 MJ/kg and Kenya 0.69 – 1.72 MJ/kg) and the same for packaging (3.92 MJ/kg). The key point of difference was the airfreight element which meant the total energy footprint for Kenyan beans (62.51 – 63.54 MJ/kg) was 12 to 13 times greater than that for UK produce (4.74 – 5.30 MJ/kg). The author notes there is some evidence that EU importers are beginning to contemplate sea freight for African vegetables, with one importer shipping beans from Egypt and asparagus from South America.

A life cycle assessment of fresh produce supply chains for a UK supermarket examined the emissions associated with supply of apples, runner beans and watercress from a variety of sources (local, regional and global) and transported by a variety of modes (road, sea and air) (Sim et al., 2006). The system boundaries for this study included farm production, packaging, and transport to a UK consolidation point. The manufacture and construction of farm buildings and machinery were excluded from the study except in the case of watercress where machinery was included. Given that the aim of this study was to ascertain the relative importance of transport, the authors consideration of the supply chain beyond this point was not seen relevant as the origin of products would not influence this and products were generally thought to have similar local profiles.

Supply chain	Production system and location where are tomatoes grown			Consumer transport	Total (g CO_2/kg)
Supermarket (83)	Organic (11)	Belgium (0)	Unheated greenhouse (0)	On foot (0)	94
Local food system (204)	Organic (11)	Belgium (0)	Unheated greenhouse (0)	On foot (0)	215
Local food system (204)	Non-organic (19)	Belgium (0)	Unheated greenhouse (0)	By car 10 km, combined trip buying 10 kg in total (504)	727
Supermarket (83)	Organic (11)	Spain (truck 1500 km) (205)	Open grown (0)	By car 5 km, specific trip buying 10 kg in total (404)	703
Supermarket (83)	Non-organic (19)	Belgium (0)	Heated greenhouse (1459)	By bicycle (0)	1561
Local food system (204)	Non-organic (19)	France (truck 400 km) (55)	Heated greenhouse (1459)	By car 10 km, specific trip buying 10 kg in total (807)	2544
Supermarket (83)	Organic (11)	Kenya (air 6000 km) (8510)	Open grown (0)	By car 15 km combined trip buying 10 kg in total (757)	9361

Table 5-12: CO_2 emissions associated with various supply chain scenarios.

The study found that the Global Warming Potential[13] (GWP_{100}) for USA grown and airfreighted watercress was up to 15 times greater than locally grown UK watercress. Airfreighted Kenyan and Guatemalan runner beans had similarly high GWP_{100}, 20 to 26 times greater than local produce. In the case of royal gala apples, the study compared locally grown produce placed in storage for 10 months against sea freighted South American apples finding that the imported apples had twice the GWP_{100} of the UK grown apples (Sim et al., 2006).

The Saunders et al. (2006) study uses LCA methodology to assess the greenhouse gas emissions and energy impact from the production and transport of apples, onions, lamb and dairy products. This is a comparative study, investigating these impacts for the United Kingdom and New Zealand. In contrast to the findings of Sim et al., the LCA study by Saunders et al. (2006) found that sea freighted apples from New Zealand had lower associated emissions (185 kg CO_2/tonne) than UK grown apples stored for 6 months (271.8 kg CO_2/tonne). However, UK grown and stored (9 months) onions were found to have slightly lower CO_2 emissions compared to sea freighted New Zealand produce (170 kg CO_2/tonne vs. 184.6 kg CO_2/tonne). Interestingly this study showed the importance of including storage in the analysis and that the energy and emissions associated with storage can be greater than shipping. For example, the energy associated with 6 months cold storage for UK apples required 2069 MJ/tonne (41 per cent of total product energy) and emitted 85.8 kg CO_2/tonne

[13] The Sim et al. (2006) study normalised the data for Western Europe.

(35.6 per cent of total CO_2). In the case of onions, the energy associated with 9 months controlled atmosphere storage for UK product required 3020 MJ/tonne (80 per cent of total product energy) and emitted 125.2 kg CO_2/tonne (73.6 per cent of total CO_2).

Llorenc Mila Canals and his colleagues at the University of Surrey recently completed a comparative study of domestic and imported apples, investigating the primary energy use for the production, transport and storage life cycle stages for UK, EU and Southern Hemisphere sourced fruit. The Canals et al. (2007) study also considered seasonality and the loss of produce during storage to enable more comprehensive comparison of the systems. In contrast to Sim et al., the authors did not find clear support that a local (UK) supply scenario would necessarily be superior to an alternative European and Southern Hemisphere supply scenario. The period of supply and therefore relative storage period was an important variable as was the road transport element of European sourced fruit. UK sourced fruit had the lowest energy use during its supply to market in the months of January and October, and the highest in August where the energy use overlaps with apples sourced from the Southern Hemisphere.

The Manchester Business School (Foster et al., 2006) investigated the greenhouse gas emissions and energy associated from a shopping trolley of 150 of the most commonly purchased food items in a UK supermarket. The report uses data from a variety of sources and takes a bottom up view across the supply chain. Included in the study are case studies of several fruit and vegetables including potatoes, apples, carrots and tomatoes. Data from Mattsson and Wallen's (2003) study on Swedish grown organic potatoes provides one of the more comprehensive pictures of CO_2e emissions across the supply chain. The production of 1.0 kg of peeled organic potatoes (approximately 1.7 kg field grown) emits 304 g CO_2e. The largest contributors to CO_2e emissions are household storage and preparation (100 g CO_2e/kg) and transport to home (60 CO_2e/kg), accounting for just over half of the total CO_2e impact. The next two largest CO_2e contributors were cultivation (55 CO_2e/kg) and distribution to the retailer (50 CO_2e/kg). Transport to packing, packing, packaging and retail related emissions accounted for the balance of the CO_2e impact[14].

Approximately 100,000 tonnes of tomatoes are grown per annum in the UK with a further 320,000 tonnes imported. The majority of the imported tomatoes are grown in Spain and the Canary Islands. The AEA Technology (2005) report includes a case study on locally (UK) grown hothouse and Spanish outdoor[15] grown tomatoes. The authors calculate the CO_2 emissions for each production system and in the case of Spanish tomatoes, the road and sea transport to the UK. The other components including packaging and within UK transport are assumed to be the same and are excluded from the calculations. The heated greenhouse produced UK tomatoes (2394 kg CO_2/tonne) were found to emit over three times the CO_2 of the Spanish tomatoes (630 kg CO_2/tonne). Again this shows the importance of including other factors than just transport such as method of production and storage.

The authors note that analysis only focuses on the emissions associated with each system and omits other sustainability factors such as the pesticide use, the lower impact of closed irrigation systems, potential improvement associated with combined heat and power (CHP) systems, and socio-economic impacts including employment in rural areas.

Wangler (2006) reviews a range of literature much of which is reviewed in this report. She reviewed eight studies investigating energy and greenhouse gas emissions associated with fresh or processed horticultural products. Although the studies had differing system

[14] Note the use of the potato peelings in a district heating incinerator reduce the methane emissions that would otherwise be associated with landfill and are hence shown as a negative value (i.e. -15 g CO_2e).
[15] These tomatoes were grown outdoors under plastic sheeting

boundaries and assumptions, Wangler concluded that except for the data on private car use, the studies values for energy use (MJ) and Global Warming Potential (kg CO_2e/kg) were largely consistent across the studies for the various life cycle stages.

Wangler highlights Vringer and Blok's (2000) study which found airfreighted produce (cut flowers) does not necessarily have greater associated environmental impacts. This study found that Kenyan grown roses airfreighted to Europe still consumed less energy (67 – 100MJ) than Dutch grown roses (317MJ)[16].

5.5 Summary of the studies

A number of the various studies reviewed have been pulled together to enable comparison. These studies are arranged in Appendix B by produce type (i.e. potatoes, apples, lettuce, onions, carrots and tomatoes) with their associated emissions (either CO_2 or CO_2e). This table highlights several interesting features of the studies completed to date. Few of the studies undertake a complete farm to fork analysis. The varying scope and assumptions of these studies also limit the comparisons that can be made between the studies. Consistent with Sim et al. (2006) distance travelled and in particular transport mode appears to be generally the greatest influence on CO_2 emissions. However, consumer supermarket to home transport and heated greenhouse production, and food preparation methods can also be significant contributors to total CO_2 emissions.

[16] Although the study's results were reported in terms of energy, these figures will be indicative of the associated greenhouse gas emissions.

6. Policy Options

There are a number of policy options that could be used to reduce emissions. This chapter outlines the main options that can be implemented by various stakeholders. These range measures may involve producers, retailers, consumers, NGOs, certification bodies or government. The issue is complex and involving a range of stakeholders from a number of different countries. No single policy measure is likely to be sufficient in addressing this issue – a range of interventions will be required.

A summary of the types of policies being proposed and discussed in this chapter are outlined in Table 6-1.

Policy option	Policy measure
Regulation	▪ Carbon taxes ▪ Inclusion of sea and air transport emissions in Kyoto Protocol ▪ Carbon permits
Soil Association certification criteria	▪ General ban on airfreighted produce from being eligible for organic certification ▪ Selective ban on airfreighted produce from being eligible for organic certification
Market oriented	▪ Carbon offsetting
Information provision	▪ Airfreight labelling ▪ Carbon labelling

Table 6-1: Outline of the policy proposals.

A common response to dealing with environmental issues concerning negative externalities has been the formulation of regulatory mechanisms. Command and control responses regulating activity or output from an activity are common ways for governments and agencies to reduce for example pollution. Although this is often a preferred approach, it is not necessarily the most efficient method as every emitter has to achieve the standard regardless of the effects of the emissions and regardless of the costs involved in reducing the emissions. Thus a firm with low abatement costs will have to abate emissions to the same level as a firm with high costs of abatement and takes no account of the value or benefit of the product.

Carbon taxes are another alternative policy to ensure the social costs of carbon emissions are included in the price of the product. Taxation of the carbon content of products has been used in some countries for a number of years (e.g. Sweden). The principle behind this approach is to ensure that the consumer pays for the negative externalities (e.g. greenhouse gas emissions) associated with the product. A key component of transportation that is untaxed in any form is aviation fuel. If this product was taxed, then the increased transport costs would also lead to higher costs for airfreighted fruit and vegetables for the end consumer. A challenge in implementing tax on aviation fuel may be gaining the common agreement of the many countries concerned. Such taxation would also increase the cost of passenger transport which is likely to be unpopular with economies dependent on tourism.

Other alternatives are carbon permits which could be traded. These types of schemes need to be carefully designed to ensure effectiveness. Trading schemes may offer reduced costs of compliance, greater levels of compliance, encourage the adoption of cleaner technologies, and help finance abatement. However, ensuring the appropriate number of permits is issued is important as too many permits can lead to greater total emission levels. It is also important to ensure that no one trader has too many permits and therefore can control the market. Allied to trading in permits is offset policy whereby emissions can be offset by some ameliorating action elsewhere in the economy.

The Kyoto Protocol is basically a regulatory mechanism but does include carbon trading. Also individual countries have and are continuing to apply different policy mechanisms to meet their Kyoto targets in a number of different ways. This includes both taxes and carbon trading.

As sea and air emissions are not included within the Kyoto Protocol another potential policy solution would be to include these. This would increase the visibility of the contribution the transport sector makes to global warming.

A further policy option frequently used in market failure is information provision. This can be through a variety of ways including education, advertising and labelling. The later has been proposed the most in the food miles, air miles and carbon footprinting debate as discussed in more detail below.

As noted in the earlier part of the report the Soil Association is contemplating action as some consider airfreight is contrary to two of its three organic principles. In response, the Soil Association have suggested five approaches: take no action, general ban, selective ban, labelling airfreight, and carbon offsetting.

However, as this paper has highlighted the issues around the environmental (and social) impacts of food production and transportation is much more complex than just concentrating on one aspect of the food supply chain (i.e. whether organic or not). Thus to exclude food from certification if it has been airfreighted would not necessarily mean the food had been produced and consumed with lower emissions.

Currently, a number of EU countries are significant importers of organic produce and this demand continues to stimulate the development of organic production systems in various exporting countries. Retaining the status quo would therefore help support the ongoing development of organic farming. The imported produce transported via airfreight is largely higher value and therefore contributes significantly to a number of developing countries employment and wider economies.

A general ban may slow the development of organic production systems and position the Soil Association as unsupportive of developing countries. Given that those most affected by this airfreight restriction would be farmers in developing countries with carbon emissions only a fraction of EU member states, this is likely to be seen as an unreasonable response to the issue. In addition, airfreight whilst significant in the emission profile of products may be similar to local transport by the consumer as well as alternative production methods. Also, as mentioned in previous sections, to replace supply by importing countries may mean more energy and emission intensive production which is greater than airfreighted energy use and emissions. This approach may be seen as inconsistent with the Soil Association’s own principle of social justice.

The selective ban option suggested would need to be implemented very carefully to help minimise the potential criticisms of unfairness or the favouring of particular parties. The Soil Association have identified the difficulties for an organic certification body in making decisions that have significant political and social ramifications. Moreover, it does not address the issues above that airfreight may not be most significant contributor to the emissions identified.

The labelling of products transported by airfreight may be seen as a broad brush approach that in some instances may mislead consumers into believing that a particular product is more deleterious to the environment than competing non-air-freighted products. However, by labelling products the choice is passed to the consumer which may over time lead to greater awareness around the environmental issues associated with airfreight.

Carbon offsetting has been criticised as preventing organisations from addressing the underlying factors contributing to greenhouse gas emissions. There is also concern as to whether some of the proposed offset schemes will actually lead to lower emission levels, especially as some schemes have been discredited. Presently there are several different schemes for certifying offset, although there is no nationally or internationally recognised standard. However, for some activities such as the operation of air transport, offsetting may be an option.

Another policy option that is being actively promoted is carbon labelling. For example, the current Carbon Trust label includes the requirement that reductions in carbon have to occur to keep the label. As stated earlier more comprehensive labelling of the origin and carbon content of food products is currently being developed by several UK organisations. Tesco have stated that all products in its stores will receive a carbon rating and are investing £500 million to do this. Marks and Spencer are investing £200 million to reduce its carbon footprint by 80 percent over five years.

A recent UKERC[17] report investigated the efficacy of labelling highlights several important issues that influence the effectiveness of carbon footprint labels on consumer behaviour. The authors note that consumer behaviour is likely to be much more nuanced than some research suggests. The influence of labels is likely to vary over time with consumers tending to settle into patterns of buying behaviour. Although there is evidence that shoppers are paying more attention to labels (e.g. fair trade and nutrition), these shoppers may also be confused by the information contained on the labels. Recent efforts to provide UK consumers with improved labelling of dietary information for products has led to the development of two systems, traffic light labelling and guideline daily amounts. There is evidence that some consumers are confused by the nutritional information provided by these competing labelling systems (Stiff, 2006). Some consumers may be either distrustful of the labels or the information provided. In some cases the consumer may be unaware of the issue highlighted by the label, or overwhelmed by the amount of information provided.

The UKERC report suggests that it tends to be ethical shoppers who are the most likely to respond to carbon labels. The report cites recent research by Thottathil that highlights the risk that carbon labelling may cause ‘concern overload’, where consumers are trying to reconcile competing fair trade, organic and carbon concerns. Some labels may cause suspicion where there appears to be varying standards in what they mean.

The UKERC report provides a summary of the key attributes important in ensuring a successful label. These include:

- Comparative labels that are easily understood
- The label must be perceived as credible
- Education of consumers so that they become aware of the issue that the label is addressing

[17] White, Boardman & Thottathil (2007) *Carbon labels: evidence, questions and issues.*

- The aesthetics of the label are important (e.g. standardised format, colour, layout, logo)
- Needs to be confidence in the label from producers and retailers
- Low costs are important in maximising participation of producers and retailers.

As stated above the introduction of policies to reduce emissions must consider the full system of production and distribution alongside alternative sources of supply. Moreover, policy mechanisms and implementation must be taken considering the full impact on the rest of the environment and social factors.

7. Conclusion and Recommendations

The above review does highlight growing concern with climate change and the carbon footprint associated with food production. This has implications for market access for exporting countries especially those that are a long distance from the market or which rely on airfreight.

In general it is very difficult to obtain information from existing studies that enable comparisons to be made between the energy and emissions for all components of the supply chain. Many studies focus just on transport and thus do not consider the full energy and emissions associated with the production and processing of the product. Of the studies concentrating on transport it is clear product transported by air has the highest emission profile. However, when the whole supply of a product to a market is considered the emissions associated with air transport tend to be low. Moreover, the energy and emissions associated with airfreight are sometimes comparable to the emissions from internal transport within the importing country.

The LCA studies enable some comparison across the different sources of emissions along the supply chain but again care must be taken as these do differ depending upon what is included in the supply chain and the methodology used. Where products are airfreighted the transport component contributes significantly to the total energy and emissions in the supply chain. In the case of sea freighted produce the transport contribution is much lower and frequently insignificant compared to energy and emissions associated with other parts of the supply chain.

Most of the studies assume that the importing country could supply the market and replace imports. For many products this is unlikely to be the case and they certainly could not do this without some intensification of their production thereby raising energy and emissions intensity. For example, in the case of airfreighted products the alternative source of production may be using heated greenhouses, which may not be more energy and emissions efficient.

It is important to consider the position of producers in the production and transport of fresh fruit and vegetables. For example, for some African producers, their geographic location and lack of other transport infrastructure necessitate the airfreighting their production. Similarly, fresh produce exporters who may normally sea freight their production may from time to time be obliged to airfreight limited quantities of their product in order to maintain the supply to the market. This situation has interesting ramifications in terms of labelling. Should all of these producers' products be labelled as airfreighted or just the airfreighted element?

In recommendation there is a real need for clarity of information over the issue of food and air miles to the general pubic, and industry among other stakeholders. At present the debate, especially in the media, has centred on air miles or the distance food travels rather than placing this in the context of the full food supply chain encompassing production and distribution.

There is a need for encouraging research which incorporates all elements of a full life cycle analysis and which are transparent and comparable across countries and products.

In discussions about the issue of air miles it is important that the full range of purchases of consumers is considered and that the airfreight component is seen in context of total purchases and their associated emissions. Furthermore, in evaluating the impact of production and transport on emissions, the carbon footprint of the country of origin could be considered. It is certainly not clear that labelling of food which is airfreighted would reduce emissions overall and therefore be the favoured option.

Finally, all the studies assume that alternative sources of supply could be found closer to the market. It is clear that the capacity of EU countries to expand their production of fruit and vegetables is very limited and certainly not with out intensification in this or other sectors. Moreover, the introduction of the Single Farm Payment and other requirements suggest that production in the EU is likely to be less not more intensive. Therefore, it is highly unlikely that alternative sources could be found for current consumption levels, never mind if consumption of fruit and vegetables increased to the recommended health guidelines.

In conclusion, food and air miles are simplistic concepts and not indicators of sustainability or environmental impact. The much wider picture has to be considered and the alternative sources of supply assessed.

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APPENDIX A
Summary of the fresh fruit and vegetable related literature

Country-level and Food Miles Studies

Year & Title	(2006) Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25.	(1999) Greenhouse gas emissions related to Dutch food consumption. Energy Policy 27, 203-216.	(2005) Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. Food Policy, 30, 1-19.	(2005) Environmental Load from Dutch Private Production: How Much Damage Takes Place Abroad? Journal of Industrial Ecology 9, 147-168.
Author/Organisation	Tukker, A., Huppes, G. et al. – European Commission funded	Kramer, K.J., Moll, H.C., Nonhebel, S., & Wilting, H.C.	Pretty, J.N., Ball, A.S., Lang, T., & Morison, J.I.L.	Nijdam, D., Wilting, H., Goedkoop, M., & Madsen, J.
Brief description	Reviews a number of product based studies and also provides new research using Input-Output analysis for products across the EU-25 measuring a range of metrics including Global Warming Potential.	This study uses data from The Netherlands Household Expenditure Survey (125 items) to calculate the GHG emissions for household food consumption.	Calculates the cost of a weekly food basket in £s. In addition to a base scenario different transport (local, national, continental and global air) and organic product are also costed. Estimates are provided for the Tonne kilometres that food travels to & within UK.	The environmental load of households was calculated for 360 expenditure categories. Food production, heating and car use were found to be the most significant contributors to household environmental load.
Products	A number of categories including food and beverages.	125 food products.	Fresh potatoes, fresh green vegetables and fresh fruit.	
Methodology	Input-Output Analysis.	Hybrid I-O/LCA.	Used data from two UK food surveys to estimate weekly an average food basket and its costs.	Input-Output analysis of Dutch private consumption.
Scope	Consumption within the EU-25.	125 food items including vegetables and fruit.	11 produce categories including fruit and vegetables.	The environmental load (direct and indirect) of Dutch households.
Freight transport	Various	Unspecified	Variety of modes	Unspecified
Host country	EU-25	The Netherlands	UK	The Netherlands
Production countries	Various	Various	UK plus imports	Unspecified
Metrics	Vegetables account for 0.7% GWP Fruit accounts for 0.5% GWP The food element does not include cooking, refrigeration and eating out: Household refrigerators & freezers GWP 1.8% Household cooking GWP 1.0% Eating and drinking places GWP 8.1%.	Annual food consumption emits almost 2800 kg CO_2e per household. Fruit and vegetables account for 14.9 per cent of these emissions (i.e. 416 kg CO_2e per household per annum). Fresh fruit and vegetables have associated emissions per household of 266 kg CO_2e which equates to 9.5%.	£s and tonne kilometres In 1998 fruit and vegetables airfreighted accounted for 0.114 Mt which equates to 0.97 billion t-km In terms of full costs of the UK food basket airfreight of imports accounts for less than 0.01% of total externalities.	Various impact measures at different levels of analysis. Fruit and vegetables account for approximately 9% of green house gas emissions associated with Dutch private consumption.

Fresh Produce Imports from Developing Countries

Year & Title	(2006) Sub-Saharan African horticultural exports to the UK and climate change: a literature review (Fresh Insights No. 2).	(2007) Overview of the benefits and costs of the African horticultural trade with the United Kingdom.	(2006) Fair Miles? Weighing environmental and social impacts of fresh produce exports from Sub-Saharan Africa to the UK (summary) (Fresh Insights No. 9).	(2006) The production of fresh produce in Africa for export to the United Kingdom: mapping different value chains.
Author/Organisation	Z. L. Wangler, IIED (Funded by the UK Dept. for International Development).	Food Chain Economics Unit, DEFRA.	MacGregor, J. and Vorley, W. (Eds.) IIED (Funded by the UK Dept. for International Development).	Legge et al. Natural Resources Institute (NRI) (Funded by the UK Dept. for International Development).
Brief description	Summary of horticultural exports from Sub-Saharan Africa, discussion of the environmental and development issues associated with this trade.	This paper summarises trade and market data associated with the transport of horticultural produce from Africa to the UK.	A discussion of some of the key issues around the importation of fresh fruit and vegetables from Sub-Saharan Africa including analysis of several previous IIED reports.	An overview of the sourcing trends for fresh fruit and vegetables and country level studies for Kenya, Ghana, Tanzania, Uganda and Zambia.
Products	Tropical fruit, oranges, tomatoes, flowers, onions, carrots, apples and green beans.	Horticultural imports.	Fresh fruit and vegetables.	Fruit and vegetable supply to the UK, with more detailed analysis at country level.
Methodology	Review and comparative analysis of a number of European studies.	Data from various sources including HMRC, EFS, DEFRA and Mintel.	Discussion of key aspects of fresh produce policy and food miles.	Analyses a variety of information on fresh fruit and vegetable trade.
Scope	Literature review.	UK fruit and vegetable imports from Africa.	Literature review of several IIED reports concerning UK fruit and vegetable imports.	Trade statistics for world, EU and UK fruit and vegetable sector.
Freight transport	Surface and air	Sea and air	Various	
Host country	UK (plus Belgium, Sweden, etc.)	UK	UK	UK
Production countries	Kenya, Sweden, Denmark, Belgium, Spain.	African	Overview of sub-Saharan Africa.	Case studies on Kenya, Ghana, Tanzania, Uganda and Zambia.
Metrics	MJ/kg, g/CO_2/kg or g/CO_2e Freight volumes, forecast freight.	Various for 2005 including Tonne km Vehicle km Airfreight tonne km CO_2 emissions.	Summarises the potential effects of reduced imports: Over 1 million people supported by fresh fruit and vegetable exports to the UK. UK carbon per capita emissions (9.2 t) c.f. Africa (1 t).	Wide range of production statistics and analysis of supply chains for a variety of countries and their fruit and vegetable production.

Transport-related studies

Year & Title	(2002) Life cycle modelling CO_2 emissions for lettuce, apples and cherries.	(2006) Fruit and Vegetables & UK Greenhouse Gas Emissions.	(2007) CO_2 Rucksacks of Food Transport.	(2002) An Environmental Assessment of Food Supply Chains: A Case Study on Dessert Apples. Environmental Management 30, 560-576.
Author/Organisation	Mason, R., Simons, D. Peckham, C., & Wakeman, T. Department of Transport, UK.	Garnett, T. - Food Climate Research Network.	Sustainable Europe Research Institute (SERI), Austria.	Jones, A.
Brief description	The emissions from the transport of three fresh produce items were quantified in terms of CO_2.	Overview of UK fruit and vegetable production and consumption. Sets out a summary of the emissions associated with the different types and sources of fresh produce.	Paired comparative study of the CO_2 emissions associated with produce produced locally (Austria) and imported.	Compares the energy required and CO_2 emissions for a variety of sources of apples including local and imported produce and variations on different local distribution systems.
Products	Lettuce, apples and cherries.	Berries, tomatoes, greenhouse crops, oranges and apples.	Apples, strawberries, grapes, tomatoes and peppers.	Apples
Methodology	Partial life cycle analysis with transport impacts quantified and other impacts highlighted and relative importance estimated.	This report reviews data from a range of studies using a variety of approaches.	Details about the methodology used were not provided other than that emissions for each transport mode was calculated.	Means/End Analysis (MEA).
Scope	Freight mileage and CO_2 emissions from production to retail store.	UK fruit and vegetable production and consumption.	Transport associated emissions.	Transport post production to home and landfill waste.
Freight transport	Road, sea and air.	Road, sea and air.	Road, sea and air.	Road and sea.
Host country	UK	UK	Austria	UK
Production countries	UK, Spain, Turkey, EU, USA, NZ and Southern Hemisphere.	UK and a number of other supplying countries.	South Africa, Spain, Chile and the Netherlands.	UK and USA.
Metrics	CO_2, T-km and ratio of supply chain C02 to product shipped Cherries mean distance 7751 km and ratio of 3.128 CO_2 Apples mean distance of 8637 km and ratio of 0.109 CO_2 Lettuce mean distance of 907 km and 0.0436 CO_2.	Provides metrics in CO_2e/ kg for food for a variety of fresh fruit and vegetables from various published resources. Includes a table categorising fruit and vegetables into low, moderate and high greenhouse gas groups.	South African apples 236.1 g CO_2 Austrian apples 22.6 g CO_2 Spanish strawberries 264.4 g CO_2 Austrian strawberries 6.9 g CO_2 Chilean grapes 7410.8 g CO_2 Austrian grapes 8.8 g CO_2 Netherlands tomatoes 104.7g CO_2 Austrian tomatoes 0.7 g CO_2.	Energy consumption MJ/kg CO_2 emissions g/kg.

Transport-related studies continued

Year & Title	(2006) Food transport indicators to 2004: Experimental Statistics.	(2006) Local or Global Food Markets: A Comparison of Energy Use for Transport. Local Environment, 11, 2, 233-251.	(2005) The validity of Food Miles as an Indicator of Sustainable Development.	(2005) From Plough to Plate by Plane: An investigation into the trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004.
Author/Organisation	DEFRA and National Statistics, UK	Wallgren, C.	AEA Technology on behalf of DEFRA (United Kingdom).	Marriott, C. (University of Surrey).
Brief description	A set of indicators for food related transport including car, truck and airfreight measured in million kilometres and emissions of CO_2, PM_{10}, NO_x and SO_2.	Comparative study of the energy associated with food available for purchase at a farmers' market versus that available through the conventional retail system. The study considers the energy intensity of the transport used freight a variety of foods.	Assesses whether a practical and reliable indicator incorporating food miles can be developed as an indicator of sustainability. The report contains a range of information including estimates of the CO_2 emissions associated with UK food transport and product case studies.	An MSc thesis investigating the importation of fresh fruit and vegetables in to the UK from non-EU countries.
Products	Food	Food basket including apples, carrots, lettuce and potatoes.	Food and food groups with a specific case study on tomatoes.	Fresh fruit and vegetables.
Methodology	Based on the approach outlined in AEA Technology (2005) report.	Collected primary data on vehicles and distances and used literature values to calculate energy intensity of transport systems.	Partial LCA for tomatoes.	This study uses UK data from her Majesty's Revenue and Customs (HMRC) to calculate imports and associated carbon emissions.
Scope	All food related transport.	Transport of food.	Food production, transportation and consumption both outside and within the UK.	All non-EU fresh fruit and vegetable imports in to the UK.
Freight transport	All transport modes.	Road, sea and air.	Study assumes road transport.	All modes
Host country	UK	Sweden	UK	UK
Production countries	UK and all countries supplying the UK	Sweden, several EU countries and NZ	Tomatoes – Spain and UK	Various
Metrics	Urban food kilometres, HGV food kilometres, air food kilometres and CO_2 emissions from food transport.	Transport energy intensity (MJ/kg) Sweden carrots: 0.8 MJ/kg Airfreighted Spanish tomatoes: 50 MJ/kg.	CO_2 kg/t, NOx kg/t and PM_{10} UK greenhouse tomatoes total CO_2 2394 kg/t Spanish open grown tomatoes total CO_2 630 kg/t	Tonnes of CO_2 resulting from fresh fruit imports in to the UK from non-EU countries Breakdown of produce by transport mode.

Product-based studies

Year & Title	(2007) Energy inputs in food systems: A comparison of local versus mainstream cases. Journal of Environmental Policy and Planning, 9, 1, 31-51.	(2006) Environmental Impacts of Food Production and Consumption.	(2003) Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Economics, 44, 293-307.	(2006) Environmental assessment of foods – An LCA inspired approach.
Author/Organisation	Van Hauwermeiren, A., Coene, G., Engelen, G., & Mathijs, E.	Foster, C., Green, K., et al. - Manchester Business School.	Carlsson-Kanyama, A., Pipping Ekstrom, M., & Shanahan, H.	Fogelberg, C. & Carlsson-Kanyama, A. Published by the Swedish Defence Agency (FOI).
Brief description	This paper provides calculations of the energy consumed and $C0_2$ emissions across different types of food production systems in Belgium including local, organic mainstream and imported food.	Using a representative shopper's trolley of 150 food items this report draws on recent top down analyses of the environmental impacts of consumption by product type.	Life cycle energy inputs for a range of foods are calculated along with the dietary energy. Up to a third of the total energy input was related to snacks, drinks and items with little nutritional value.	Provides an outline of the Swedish supply chain and the role that information may have on consumer behaviour. Outlines LCA for a variety of products.
Fruit and vegetables	Potatoes, lettuce, tomatoes, carrots and apples.	Apples, carrots and tomatoes.	Apples, cherries, oranges, grapes, Bananas, tropical fruit, carrots, cabbage and tomatoes.	Tomatoes, carrots, onions and broccoli.
Methodology	Energy and emissions data from producers, retailers and literature.	Largely bottom up, the report reviews studies that have used a LCA or closely related method.	Life Cycle energy inputs.	Partial LCA.
Scope	Farm gate to consumers house, excludes farm production system and consumer food preparation.	A sample of 150 of the highest selling supermarket products.	Farm to plate, although excludes packaging, transport from shop to home and waste treatment.	Carrots, onions, tomatoes: Farm to wholesaler. Broccoli: Farm to fork but excludes waste treatment.
Freight transport	All modes .	Various	Road, sea, air.	Surface
Host country	Belgium	UK	Sweden	Sweden
Production countries	Local, short (400 km), medium (1500 km) and intercontinental (6000 km).	Various	Sweden, Europe and overseas.	Sweden, Netherlands and Denmark.
Metrics	MJ/kg and CO_2/kg Various scenarios including locally grown, organic and different transport.	Reviews and compares data from variety of studies. Gives breakdown of GWP by supply chain for carrots. Provides breakdown of energy for German and NZ apples (MJ).	MJ/kg Swedish apples 3.5 MJ/kg Swedish greenhouse tomatoes 66 Southern EU tomatoes 5.4 MJ/kg Airfreighted tropical fruits 115 MJ/kg.	GWP, energy use (MJ), transport distance (km) and water used.

Product-based studies continued

Year & Title	(2007) Comparing Domestic versus Imported Apples: A focus on Energy Use.	(2006) The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing.	(2006) A life cycle analysis of UK supermarket imported green beans from Kenya (Fresh Insights No. 4).	(2000) The energy requirement of cut flowers and consumer options to reduce it. Resources, Conservation and Recycling 28, 3-28.
Author/Organisation	Canals, L, M., Cowell, S.J., Sim, S., & Besson, L.	Sim, S., Barry, M., Clift, R. & Cowell, S. (Marks & Spencer and University of Surrey)	Andrew Jones, IIED (Funded by the UK Dept. for International Development)	Vringer K. & Blok, K.
Brief description	Investigates the primary energy use (PEU) associated with imported NZ and South American apples versus local and European apples.	LCA on locally grown and imported Runner Beans, Royal Gala Apples and watercress. A variety of measures including GWP_{100} were used. This study has normalised the results. The effect of storing locally (UK) produced apples is modelled.	A comparative energy analysis of UK and Kenyan green bean production.	A comparative energy analysis of Dutch and Kenyan cut flower production.
Products	Apples	Runner beans, apples and watercress.	Green beans.	Cut flowers.
Methodology	Primary energy use from a range of sources including author's research and wider literature.	LCA from farm through to common UK consolidation point.	Life Cycle Analysis of energy associated with the import of green beans.	Hybrid analysis.
Scope	Orchard to shop.	Growing, packaging and transport to common UK consolidation point for organic and conventional produce.	Farm to supermarket shelf.	Cumulative primary energy requirements for the production of flowers.
Freight transport	Road and sea.	Road, sea and air.	Air	Air
Host country	UK	UK	UK	The Netherlands
Production countries	UK, EU, South America, New Zealand.	Watercress (UK and USA) beans (UK, Kenya & Guatemala) apples (UK, Italy, Chile & Brazil).	UK and Kenya.	The Netherlands and Kenya.
Metrics	Primary Energy Use (PEU) MJ/kg: All energy inputs excluding renewables UK 2 - 6.6 MJ/kg EU 2.6 – 8.7 MJ/kg NZ 4.5 – 7 MJ/kg South America 3.1 – 7.3 MJ/kg.	Various including normalised GWP_{100} USA watercress up to 15 times greater GWP_{100} than UK watercress Kenyan beans 20 times UK beans GWP_{100} Guatemalan beans 26 times UK beans GWP_{100}.	MJ/kg Kenyan beans: 62.5 - 63.5 MJ/kg UK beans: 4.7 - 5.3 MJ/kg.	Energy intensity (MJ) Kenyan grown roses 67 – 100 MJ Dutch grown roses 317 MJ Imported flowers from warmer countries can use 10 to 85 per cent less energy than Dutch grown flowers.

Product-based studies continued

Year & Title	(2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities.	(2006) Food Miles –Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry.	(2003). Environmental Life Cycle Assessment (LCA) of Organic Potatoes. Acta Horticulturae 619, 427-435.
Author/Organisation	Williams, A.G., Audsley, E., & Sandars, D.L. (Silsoe Research Institute).	Saunders, C., Barber, A., & Taylor, G. Lincoln University.	Mattsson, B., & Wallen, E.
Brief description	Assessment of the GWP_{100} and primary energy used to produce each crop type.	Comparative study of energy and CO_2 emissions associated with UK and NZ production.	An LCA based farm to fork study investigating the energy and emissions associated with organic potatoes. Consumer activities are shown to make up a significant proportion of the environmental load in terms of energy (MJ) and CO_2e.
Products	Tomatoes and potatoes	Apples & onions	Organic potatoes (peeled)
Methodology	Life Cycle Analysis of each commodities production system (i.e. on farm plus storage).	LCA	LCA analysis of organic potatoes.
Scope	On farm production plus storage for various systems culminating in a commodity level estimate.	Farm to plate (excludes waste disposal).	Farm to fork study including waste management.
Freight transport	Nil	Road and sea	Road
Host country	UK	UK	Sweden
Production countries	UK	UK & New Zealand	Sweden
Metrics	Abiotic resources used, CO_2, N_2O GWP, eutrophication and acidification Primary energy potatoes 1.4 GJ/t Primary energy tomatoes 130 GJ/t GWP_{100} (t CO_2) potatoes 0.24 GWP_{100} (t CO_2) tomatoes 9.4.	Energy (MJ) and CO_2 UK apples 271.8 kg CO_2/tonne NZ apples 185 kg CO_2/tonne UK onions 170 kg CO_2/tonne NZ onions 184.6 kg CO_2/tonne.	MJ energy used and CO_2e.

APPENDIX B
Summary of the fresh fruit and vegetable related CO_2 emissions from selected studies

Summary of fresh fruit and vegetable related CO_2 emissions from selected studies

Produce & Study	Measurement unit/ Origin of produce	Farm^	Packing & Packaging system	Storage	Distribution to Wholesaler or Retailer^^	Retailer	Transport to Home	Household	Total
Potatoes									
Foster et al. (2006) (Data from Mattsson & Wallen, 2003)	g CO_2e / kg Organic peeled* (Local, Sweden)	55	50**		50	4	60	100	304[+]
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)				78.53	Negligible			78.53
Apples									
Jones (2002) cited in Wangler (2006)	g CO_2 / kg (USA > UK)				228.97 (Sea vessel)		51.3		280
Jones (2002) cited in Wangler (2006)	g CO_2 / kg (Local, UK)				42.95		51.3		94
Mason et al. (2002)	g CO_2 / kg (UK, EU & NZ)				109 (Road/ sea)				109
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)				39.77	27.02			66.79
Saunders et al. (2006)	kg CO_2 / tonne (Local, UK)	186.0		85.8 (6 months)					271.8
Saunders et al. (2006)	kg CO_2 / tonne (NZ > UK)	60.1			124.9 (Sea vessel)				185.0
Lettuce									
Mason et al. (2002)	g CO_2 / kg (UK & Spain)				44				44
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)	1250.21 (Heated greenhouse)			78.53	22.08			1350.82

Notes: ^ Open air production unless otherwise stated ^^ Road transportation unless otherwise stated * 1kg peeled potatoes is equivalent to circa 1.7kg unprocessed potatoes
** This figure includes transport to packing [+] The total includes a subtraction of 15 g CO2e/ kg for district heating

Produce & Study	Measurement unit/ Origin of produce	Farm^	Packing and Packaging system	Storage	Distribution to Wholesaler or Retailer^^	Retailer	Transport to Home	Household	Total
Tomatoes									
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)	18.60			78.53	4.73	504 (5km single car trip, combined shopping, buying 5 kg)		605.86
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)	11.49 (Organic)			78.53	4.73	1614 (10 km single car trip, specific shopping, buying 5 kg)		1708.75
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)	1459.41 (Heated greenhous e)			78.53	4.73	807 (10km single car trip, specific shopping, buying 10 kg)		2349.67
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Spain > Belgium)	18.60			283.53	4.73	757 (10km single car trip, combined shopping, buying 10 kg)		1063.86
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Kenya > Belgium)	18.60			8509.68 (Air)	4.73	757 (As above)		9290.01
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Kenya > Belgium)	11.49 (Organic)			8509.68 (Air)	4.73	757 (As above)		9282.90

Notes: ^ Open air production unless otherwise stated ^^ Road unless otherwise stated

Produce & Study	Measurement unit/ Origin of produce	Farm^	Packing and Packaging system	Storage	Distribution to Wholesaler or Retailer^^	Retailer	Transport to Home	Household	Total
Carrots									
Fogelberg & Carlsson-Kanyama (2006)	g CO_2e / kg (Local, Sweden)	18	32		19				69
Fogelberg & Carlsson-Kanyama (2006)	g CO_2e / kg (The Netherlands > Sweden)	40	44		71				155
Van Hauwermeiren et al. (2007)	g CO_2 / kg (Local, Belgium)				78.53	10.09			88.62
Onions									
Saunders et al. (2006)	kg CO_2 / tonne (Local, UK)	42.3	2.6*	125.2 (9 months)					170.0
Saunders et al. (2006)	kg CO_2 / tonne (NZ > UK)	58.9	0.7*		124.9 (Sea vessel)				184.6
Fogelberg & Carlsson-Kanyama (2006)	g CO_2e / kg (Local, Sweden)	39	11		19				69
Fogelberg & Carlsson-Kanyama (2006)	g CO_2e / kg (Denmark > Sweden)	46	59		40				145

Notes: ^ Open air production unless otherwise stated ^^ Road unless otherwise stated * Figure denotes product grading only

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