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A life cycle analysis of UK supermarket imported green beans from Kenya

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Contents

Objective

This report represents an initial attempt to provide:

- A background to green bean production in Kenya and UK imports of green beans.

- Baseline information and data relating to the scale and significance of green bean production and exports from African countries to the UK, specifically:
    - Data search, identification and review in order to present a life cycle analysis of ‘energy’ in green bean exports to the UK.
    - Other associated horticultural products if data for green bean production in Kenya and/or production of beans in UK are insufficient.
    - Context: fully annotated data indicating data origin, data quality and data gaps, system boundary, stages that are included and all assumptions that have been made.

- A summary of main findings including ‘hot spots’ in the supply chain for green beans

- Potential routes forward: research and policy engagement, proposals for how DFID should consider engaging further with LCA with respect to the IIED/NRI/DFID project.

Key facts and findings

- Imports of fresh vegetables by air from Africa constitute 40 per cent of UK air freight of food products, and fruit accounts for a further 20 per cent.

- 70 per cent of Kenyan green bean exports are transported to the UK, of which over 90 per cent is transported by air.

- There was a four-fold increase in UK imports of green beans between 1990 and 2004, from 8,300 to 33,000 tonnes.

- UK green bean production fell by almost a third between 1995 and 2005 from 30,300 to 20,700 tonnes

- 87 per cent of UK green bean imports comes from five African countries, and
- 58 per cent comes from Kenya

- The energy consumption of green bean production (up to the farm gate) is 0.8–1.4 MJ/kg in Europe and 0.7–1.7 MJ/kg in Kenya.

- When the energy consumed in transporting green beans from Kenya to the UK by plane is included, the difference between the two supply chains becomes considerable. Energy use is 12 times greater when beans are sourced in Kenya rather than the UK, a difference of between 57 and 59 MJ/kg of beans.

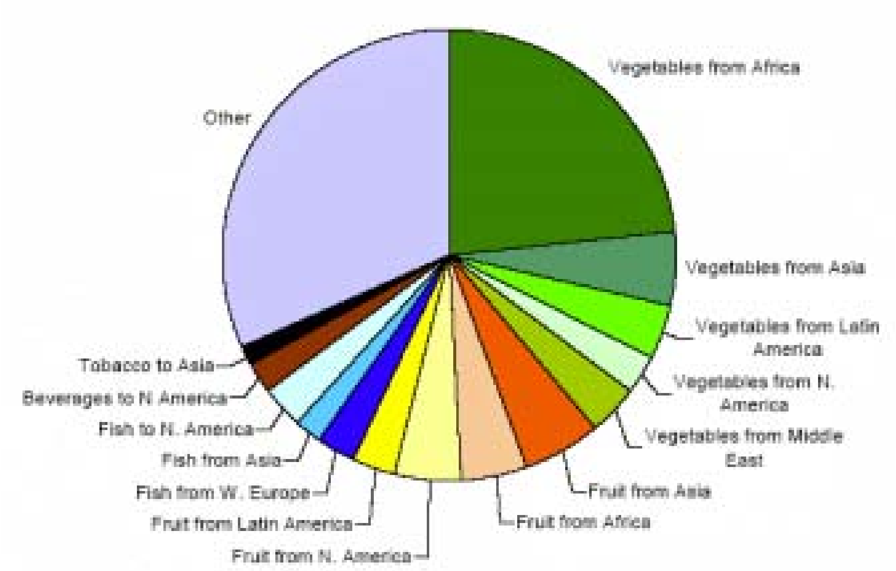
- Horticultural production in heated glasshouses in the UK is energy intensive. However, green beans are not produced commercially in the UK in this way.

- Transporting green beans from Kenya to the UK by sea (2 MJ/kg beans) rather than by plane (58 MJ/kg beans) would result in a significant energy saving of 56 MJ/kg beans.

1. Trends

There has been a large increase in the movement of food products by plane during the past decade. Between 1996 and 2004 there was an annual 6 per cent increase in fresh produce imported into the UK by air from outside EU. Air freight imports are currently small compared to sea and road freight but have a much greater environmental impact per tonne carried. **Figure 1** provides a breakdown of UK food imports and exports by air. The largest category is vegetable imports from Africa (for example, green beans, baby corn and mangetout imported from Kenya, Gambia and Egypt). In all, vegetable imports account for 40 per cent of all food air freight, fruit imports for 21 per cent and fish imports for 7 per cent.

Figure 1: Split of air imports by food type and source/destination

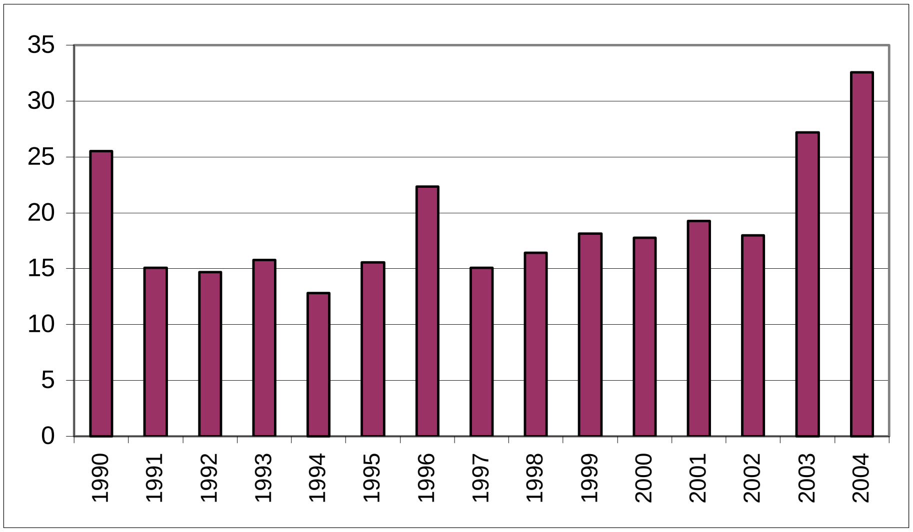


Source: AEAT (2005)

Kenya was one of the first African countries to develop systems in which high-value horticultural produce is exported to Europe. Figure 2 provides a summary of exports of green beans from Kenya, a product that has become synonymous with the debate on the economic benefits and social and environmental costs of African air freight exports.

Between 1990 and 2004, Kenya exported between 12,800 and 32,580 tonnes of beans each year, an annual average of 19,000 tonnes. This trade fluctuates, with, for example, a fall of 10,000 tonnes in 1991 and 7,500 tonnes in 1997. In terms of market access for Kenyan farmers and rural livelihoods, it is important to establish the reason(s) for these large fluctuations - whether they are due to political reasons, or to a poor harvests, or world price (including increased competition from other African producers).

Figure 2: Kenyan exports of green beans, including string beans (1000 tonnes)



Source: FAO (2006)

The UK is the main destination for Kenyan green bean exports, at 70 per cent of the total. Six European countries and the UAE account for 99 per cent of Kenyan green bean exports (**Table 1**). All of these exports are transported by air.

Table 1: Kenyan green bean exports by air by destination, 2004

Destination	**Tonnes**	**Percentage of Kenyan green bean exports**
United Kingdom	22,634	70%
France	4,769	15%
Netherlands	2,094	6%
Belgium	1,139	4%
Germany	607	2%
United Arab Emirates	545	2%
Switzerland	419	1%
Seychelles	84	<1%
Italy	70	<1%
South Africa	50	<1%
Canada	16	<1%
Bahamas	14	<1%
Total (of above)	**32,441**	

There was a four-fold increase in UK imports of green beans between 1990 and 2004, from 8,300 to 33,000 tonnes (Figure 3). Most UK green bean imports arrive from Kenya (58 per cent). In total five African countries (Kenya, Egypt, Morocco, Zimbabwe and Zambia) account for 87 per cent of all UK green bean imports (Table 2)

Figure 3: UK imports of green beans, including string beans (1,000 tonnes)

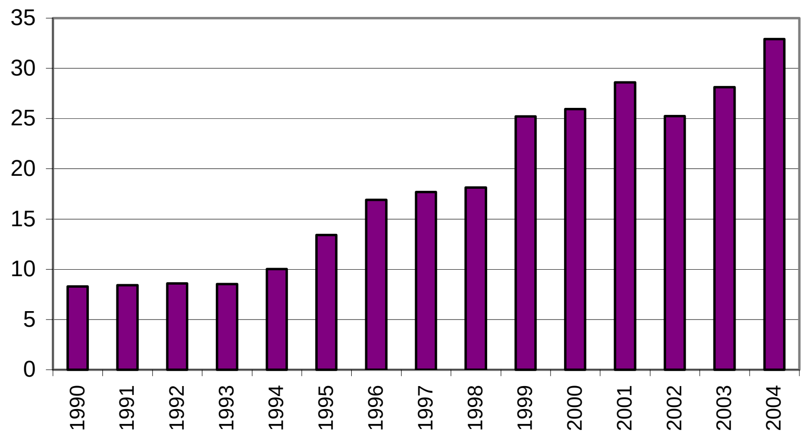


Table 2: United Kingdom green bean imports in 2004, including string beans (1,000 tonnes)

	Tonnes	**%**
Kenya	19,188	58%
Egypt	3,077	9%
Morocco	3,036	9%
Zimbabwe	1,707	5%
Zambia	1,464	4%
Spain	1,353	4%
Netherlands	1,193	3%
Total of above	**31,018**	**94.2**
All UK green bean imports	32,915	100.0

In the UK, green bean production fell by almost a third between 1995 and 2005 from 30,300 to 20,700 tonnes (BHSGB, 2006)[1].

[1] Includes data for runner beans as there is not a separate category for green beans

2. Background to life cycle analyses, energy analyses and the carbon footprint of food products

The use of tools such as life cycle analysis (LCA), energy analysis, ecological footprint and carbon footprint analysis is becoming an important aspect of the sustainable development process and the provision of product-related environmental information for consumers and policy-makers. These analyses provide a measure of the energy and resource efficiency and the carbon emissions associated with the production and distribution of products and the options available during each stage of the supply chain.

The food supply chain (FSC) has evolved into a complicated system in which there can be many different options for producing, sourcing, distributing and marketing each food product. For example, there are numerous ways in which vegetables can be cultivated, packaged, processed and moved from farm or market garden to the consumer's household. Produce can be sourced locally, nationally or imported. It can be packaged and stored in numerous ways, and it can be purchased at a supermarket, greengrocer, outdoor market or through a home-delivery fruit and vegetable box scheme. The consumer, as well as policy-maker, is often unaware of the environmental impact associated with the various supply chain options and the extent to which this impact can vary for seemingly identical produce. This information, which is essential for informed purchasing decisions and policy development, can be provided by energy and carbon footprint analyses.

Analysis of consumer products, including food items, is not new. Following the oil crisis of 1973, concerns about the increasing price and security of supplies of crude oil prompted a number of studies to consider the energy intensity of food production, distribution and marketing systems (e.g. Brown and Batty, 1976; Hirst, 1973; Olabode et al.,1977). These techniques are likely to become a central feature of policy development, particularly if individual or personal carbon allowance schemes are introduced.

3. Methodology

3.1 Supply chains for green beans consumed in the UK

The FSC comprises all of the stages involved when delivering a food product to the consumer, and the subsequent waste management processes. In terms of an individual fresh food product, the FSC will therefore involve one or more of the following functions: cultivation; sorting, processing and packaging; retailing; storage, preparation and consumption; and waste management. It also includes all of the transport stages that link these subsystems, as they are often geographically dispersed. The total number of stages involved when moving a product to the consumer is described as the product life cycle or the product supply chain.

The focus of this analysis is supermarket supply chains for green beans. Two sourcing options are assessed: beans produced in the UK, and beans produced in Kenya and transported to the UK by plane. The aim is to highlight any major differences between these two supply chains, in particular, the significance of air freight transport.

For UK imports of Kenyan green beans the life cycle is considered up to the point of entry into the UK and for beans produced in the UK up to the farm gate. Following these stages the supply chain will be identical for both options when entering the supermarket distribution, storage and retailing system. If at a later stage these stages are to be assessed, in order to make a comparison with the energy use in bean cultivation, packaging and air freight from Kenya, it would require prior approval and data from one or more of the UK multiple retailers (see recommendations).[2]

3.2 Functional unit

The inventory in an LCA can contain up to 51 criteria, including eight categories of energy carrier, air emissions (13 categories), water emissions (14 categories) and soil emissions (16 categories) as well as solid wastes. Interpreting and making decisions based upon 51 criteria is extremely difficult and can involve 'trading off' or substituting one environmental burden for another or transferring pollution from one place to another. For example, when considering a particular food product, one supply chain could have low energy consumption but make a large contribution to nitrate pollution while another supply chain for the same product consumes a large amount of energy but does not result in significant levels of nitrate pollution. For this reason many studies consider one or two key environmental indicators, for example, primary energy use and greenhouse gas (GHG) emissions. It is now accepted that climate change is taking place and that it is caused by human activity. In terms of priorities it is acknowledged as being the main environmental challenge that we face. There is also a direct link between energy use and GHG emissions, particularly when energy is derived from fossil fuels.

The other reason for focusing on energy use is that energy costs, particularly those associated with crude oil and natural gas, have increased sharply over the last few years. Some analysts believe that at least part of the reason is that we have, or are about to reach 'peak oil' – the point at which half of available crude oil reserves are depleted. Whether or not this is the case, many commentators are predicting that the price of crude oil remain above $50 a barrel and could increase to over $100 a barrel in the near future. High energy

[2] Marks and Spencer are carrying out research in this area and would therefore be a useful information source.

costs will have a significant impact on the food system, and in particular on energy intensive processes such as air freight, fertiliser production, food packaging and food storage (refrigeration and freezing).

In this study energy consumption is the indicator used to measure environmental performance. The basis of all calculations is a kilogram of green beans: the functional unit to which energy consumption is ascribed. The results are presented in terms of the standard energy units of megajoules per kilogram of green beans (MJ/kg).

3.3 System boundary

The system boundary describes the supply chain for the product being assessed and indicates which stages are included in the analysis. **Annex 1** provides a graphic description of the supply chain for the production of green beans in Kenya that are exported to the UK.

Energy use is often separated into direct and indirect inputs. In farming systems, direct inputs relate to the use of energy on the farm, for example diesel or electricity to power machinery. Indirect energy use is associated with the manufacture and supply of farm inputs such as fertilisers and pesticides.

Historical inputs, the energy consumption associated with the manufacture of machinery such as tractors, irrigation equipment, sorting equipment, packaging equipment, refrigerators and vehicles used during distribution are not included in the analysis. Neither is the energy use associated with the construction of fertiliser, pesticide and packaging manufacturing plants or any building on the farms being assessed. The energy used during maintenance, repair and waste management of farm machinery and equipment is also omitted.

The energy inputs associated with bean cultivation that are covered include fertiliser, pesticide, irrigation and tractor fuel. In Kenya many farm tasks, such as pesticide and fertiliser application and weeding are carried out by hand, whereas in Europe these stages use farm machinery. The post-farm-gate stages that are included are sorting, packaging and transportation.

The energy consumed during seed production and supply is not included in the analyses of European or the Kenyan green bean production systems. In terms of this comparison, and the aim of highlighting major differences, with Kenyan production it is likely that they would cancel each other out, particularly if the seed used in Kenya is imported from Europe (rather than being produced by the Kenyan farmers).[3] The only additional stage would be transport of seed to Kenya. In terms of energy use, this is likely to be by ship, and in relation to the functional unit of a kilogram of beans, very small.

3.4 Green bean production in Kenya

Details of green bean production in Kenya were obtained from the National Resources Institute (NRI) at the University of Greenwich. Researchers at NRI have been working with Kenyan producers, which allowed access to the information required for the analysis. A summary of the data required was sent to NRI in the form of a questionnaire (**Annex 2**). NRI provided a detailed description of Kenyan green bean production systems (N=900) with a breakdown based on small- and medium-scale farms (**Annex 3**).

[3] NRI did not have details of sources of green bean seed used by Kenyan farmers. However, based on previous experience, it was confirmed that much of the seed is imported from sources in Europe and Asia.

Table 3 provides a summary of the structure of the holdings being assessed with a breakdown for small- and medium-sized farms. The information provided by NRI is based on Kenyan farmers who market their produce through the distributor/exporter Home-grown. The average yield is 2.9 tonnes per hectare on small farms (described as having an average productive area of one hectare) and 7.4 tonnes per hectare on medium sized farms, which are on average 10 hectares.[4]

Table 3: Breakdown of the structure of Kenyan farms being assessed

Factor	Small-scale	Medium-scale
Number of farms	750	150
Organic production	NO	NO
Inorganic fertiliser and pesticide used	YES	YES
Manure / compost	NO	NO
Direct drilling	YES	YES
Nursery beds	NO	NO
Average farm size (ha)	1	10
Green bean plot size (ha)	0.15	0.4
Area (ha) used for green beans per year	1.8	3.64
Crop cycle and planting/harvesting period	1 planting per month over 12 months, with rotation around the 0.15ha plots	3 plots per planting and 3 plantings per year

Production in Kenya is not highly mechanised. Planting, weed control, fertiliser and pesticide application and harvesting are carried out manually. Tractors are used to plough and prepare land on medium-scale farms.

Details of bean cultivation in Kenya are listed in Table 4. Researchers at NRI indicated that medium-sized farms were more likely to have input application rates that fall within (or below) the recommended rates specified in the Assured Produce Protocols. But smaller farms, because of the high cost of synthetic fertiliser, pesticide and irrigation and their ability to pay for them, were less likely to meet the minimum recommended rates. In some instances smallholders are unlikely to be using anywhere near the recommended amount.

In order to reflect varying levels of use of farm inputs, low and high input scenarios were used for small- and medium-sized farms (Table 4). For example, on smaller farms, low levels of fertiliser use were assumed to be 40kg per hectare and high input fertiliser use at 80 kg per hectare.

Average yields are used for both low and high input systems. The relationship between inputs and yield requires further research. Similarly, the relationship between soil nutrient level, soil type and yield requires additional information.

Produce can be distributed by plane on dedicated freight aircraft or in the belly hold of passenger aircraft. Information provided by NRI indicated that Kenyan green bean exports are normally in the belly hold of passenger planes.

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[4] These data refer to gross yield. On average 60 per cent of green beans produced are exported. If the remaining 40 per cent were waste then net yield would be used in the analysis, however this fraction is either consumed by the farmers and their families or fed to livestock.

A recent DEFRA report stated that 80 per cent of cargo is currently carried as belly freight on passenger planes, but that there has been a trend towards more use of air freighters (AEAT, 2005). However, another study found that most food freight is now carried on dedicated freighters, because this allows easier handling of pre-packed containers and foodstuffs with special storage requirements such as refrigeration or modified atmosphere (Garnett, 2003).

A more detailed analysis of Kenyan green bean air freight exports would require a breakdown of the quantity transported in belly hold and on dedicated aircraft and further information relating to air freight energy use and GHG emissions (See Note 8 in Table 4 below).

Table 4: Description of Kenyan green bean production, packaging and distribution systems being assessed

	SMALL SCALE		**MEDIUM SCALE**	
	Low Input	**High Input**	**Low Input**	**High Input**
YIELD, kg per hectare (1)	2900	2900	7400	7400
Land preparation (2)	Manual	Manual	Tractor	Tractor
Drill, weed, fertiliser and pesticide application and harvest	Manual	Manual	Manual	Manual
Irrigation (3)	2hp pump, 2 dm3 per m2 per day	2 pump, 4 dm3 per m2 per day	5 hp pump, 4 dm3 per m2 per day	5 hp pump, 8 dm3 per m2 per day
Inorganic fertiliser (4)	40kg per hectare	80kg per hectare	80kg per hectare	120kg per hectare
Pesticide (5)	1 application of Insecticide and 1 of fungicide	3 applications of Insecticide and 3 of fungicide	1 application of Insecticide and 1 of fungicide	3 applications of Insecticide and 3 of fungicide
Transport to packing house/airport (6)	80km by Isuzu 4x2FRR truck 8.2 L diesel engine, 10 tonne	80km by Isuzu 4x2FRR truck 8.2 L diesel engine, 10 tonne	80km by Isuzu 4x2FRR truck 8.2 L diesel engine, 10 tonne	80km by Isuzu 4x2FRR truck 8.2 L diesel engine, 10 tonne
Packaging (7)	Rigid PET punnet & film covering	Rigid PET punnet & film covering	Rigid PET punnet & film covering	Rigid PET punnet & film covering
Transport to UK: air freight (8)	Belllyhold of Boeing 777-200 Nairobi to LHR	Belllyhold of Boeing 777-200 Nairobi to LHR	Belllyhold of Boeing 777-200 Nairobi to LHR	Belllyhold of Boeing 777-200 Nairobi to LHR

Notes and Data Sources

1 More detailed data would be required to investigate the relationship between input levels and yield.

2 Massey Ferguson 150hp diesel. Data on energy use for ploughing obtained from Salter (2005).

3 Drip feed rather than overhead irrigators. The pump size on most farms is in the 2-5hp range. These deliver between 2 and 4-7dm3 of water per second. Crop protocols supplied by the exporter recommend 4-8dm3 of water per day for each m2 of production.

4 Assured Produce Protocols recommend between 80 and 120kg / hectare of NPK fertiliser incorporated into the soil prior to planting. Energy consumption of fertiliser manufacture obtained from Appendix 10 of Carlsson-Kanyama and Faist (2000).

5 See Annex 3 for details of pesticide type and application rates supplied by NRI. The energy consumption of pesticide manufacture from MAFF (2000) and Helsel (1992)

6 Does not include the energy consumed for refrigeration during storage at farm, packhouse or during transit to airport

7 The beans are contained in 200g packs, consisting of PET punnets covered in plastic film. The 15 g of PET

requires 40 MJ/kg to manufacture and a further 10 MJ/kg to process into the punnet.

It is assumed that the packaging is transported by ship from the east coast of Canada to Mombasa. If the point of departure is on the west coast of Canada the energy consumption will be higher. If the packaging is transported by plane between Canada and Kenya the energy consumption will be considerably higher.

This value does not include the energy content of the feedstock used in PET manufacture, at 39MJ/kg. If the packaging is not recovered/recycled this would add 2.9 MJ to the energy consumption of this stage.

The energy consumed in manufacturing the film covering was not calculated, as the material was not specified.

Note that the functional unit is 1 kg of beans – which is equivalent to five 200g packs.

8 Energy use for air freight is based on the values for aviation fuel and carbon dioxide emissions in Tables 2 and 10 of DEFRA's Guidelines for Company Reporting on Greenhouse Gas Emissions, as follows:

Air Freight (short haul)	23.7 MJ/tonne-km
Air Freight (long haul)	8.5 MJ/tonne-km

However, in a recent DEFRA report - The Validity of Food Miles as an Indicator for Sustainable Development (p69, information below Table 28) - a figure of 84 MJ/tonne-km is quoted for short-haul air freight. An error may have occurred in their calculation because of a mix up between C and CO2 (based on Table A3-2 in Appendix 3). DEFRA confirmed on 22nd August this to be the case, but have not provided more detailed data on energy and fuel use for air freight, for example, belllyhold, dedicated freighter and different aircraft types. If the DEFRA figure is correct then the value for long haul would be around 30MJ/tonne-km. Using this figure, the energy consumed in transporting green beans from Nairobi to Heathrow would rise to 205MJ

Does not include the energy consumption of refrigeration during flight

The results of the analysis of bean cultivation in Kenya are presented in Table 5. The energy consumed is between 0.87 and 1.72 MJ/kg beans on small farms and 0.69-1.28 MJ/kg beans on medium-sized farms.

Table 5: Energy use during green bean cultivation in Kenya (MJ per kg beans, and percentage)

	SMALL SCALE				**MEDIUM SCALE**			
	Low Input		**High Input**		**Low Input**		**High Input**	
YIELD, kg per hectare	***2900***	***%***	***2900***	***%***	***7400***	***%***	***7400***	***%***
Land preparation	0	*0%*	0	*0%*	0.10	*15%*	0.10	*8%*
Planting, weeding, fertiliser and pesticide application and harvesting	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Irrigation	0.31	*35%*	0.62	*26%*	0.20	*29%*	0.31	*24%*
Inorganic fertiliser	0.43	*50%*	0.86	*36%*	0.34	*49%*	0.51	*40%*
Pesticide	0.13	*14%*	0.24	*38%*	0.05	*7%*	0.36	*28%*
	0.87		**1.72**		**0.69**		**1.28**	

The value of 1.72 MJ per kilogram of beans on small farms is likely to be too high as there was no information available on the relationship between fertiliser, water and pesticide use and yield. Also, high input cultivation on smaller farms would not be the norm because of the cost and affordability of fertilisers, water pumps and pesticides.

In Table 6 the energy use associated with transportation to the airport, packaging and air freight to the UK and bean cultivation is listed. The total energy consumed, up to point of arrival in the UK is between 62.5 and 63.5 MJ/kg beans.

Table 6: Energy use for production, packaging and distribution of Kenyan green beans to the UK (MJ/kg and %)

	SMALL SCALE				**MEDIUM SCALE**			
	Low Input		**High Input**		**Low Input**		**High Input**	
YIELD, kg per hectare	***2,900***	***%***	***2,900***	***%***	***7,400***	***%***	***7,400***	***%***

Farm Inputs	0.56	*0.9*	1.10	*1.7*	0.39	*0.6*	0.87	*1.4*
Cultivation	0.31	*0.5*	0.62	*1.0*	0.30	*0.5*	0.41	*0.7*
To Farm Gate	0.87	*1.4*	1.72	*2.7*	0.69	*1.1*	1.28	*2.0*
Transport to packing house/airport	0.07	*0.1*	0.07	*0.1*	0.07	*0.1*	0.07	*0.1*
Packaging (1)	3.92	*6.3*	3.92	*6.2*	3.92	*6.3*	3.92	*6.2*
Transport to UK (air freight)	57.83	*92.3*	57.83	*91.0*	57.83	*92.5*	57.83	*91.6*
TOTAL	**62.69**		**63.54**		**62.51**		**63.10**	

3.5 Green bean production in the UK and Northern Europe

There has been no detailed analysis of and there is no data available on green bean production in the UK. In order to overcome this data gap, values for green bean production in several European countries were used to estimate values for the UK. The following European green bean production systems provide data for several systems: irrigated production, early production with coverage, conventional and integrated production (Table 7). All are in the open or field production and provide data on energy consumption based on various production systems as well as different conditions, such as soil type.

Information on green bean cultivation in Europe is summarised in Tables 7 and 8. Yields range from 8 to 12 tonnes per hectare. There is a wide variation in the amount of fertiliser applied, between 57and 321 kg/hectare. The highest value is primarily due to the sandy nature and low fertility of the soil, and the lower value is due to Sweden's being an irrigated crop and in the Swiss example no pesticide is applied.

Table 7: Inputs in green bean production systems in Sweden, the Netherlands and Switzerland

	Sweden: irrigated crop	**Netherlands**: early with coverage, sandy area	**Netherlands**: conventional, sandy area	**Switzerland**: beans for processing industry, integrated production
Yield, kg/ha	**12,000**	**8,000**	**9,500**	**8,120**
Diesel, l/ha	220			180
Electricity, MJ/ha	2,160			
N-applied, kg/ha	60	100	50	15
P-applied, kg/ha	45	55	55	5
K-applied, kg/ha	120	166	166	37
Total synthetic fertiliser, kg/ha	225	321	271	57
Pesticides, active substance kg/ha		5	6	0
Limestone applied, kg/ha	100			

Source: Carlsson-Kanyama and Faist, 2000

The energy consumption of green bean production in these four examples ranges from 0.8 to 1.4 MJ/kg of beans (Table 8). The average for these four systems is 1.1 MJ/kg beans.

Table 8: Energy consumption of green bean production in Sweden, the Netherlands and Switzerland (MJ/kg)[5]

	Sweden: irrigated crop		**Netherlands**: early with coverage, sandy area		**Netherlands**: conventional, sandy area		**Switzerland**: beans for processing industry, integrated production	
Diesel	0.706	51%					0.854	84%
Electricity	0.180	13%						
N-applied	0.241	17%	0.602	49%	0.253	31%	0.089	9%
P-applied	0.134	10%	0.245	20%	0.207	25%	0.022	2%
K-applied	0.100	7%	0.208	17%	0.175	21%	0.046	5%
Pesticides, active substance			0.179	14%	0.181	22%		
Lime	0.016	1%						
Total	**1.377**		**1.234**		**0.816**		**1.011**	100%

[5] The energy content of diesel is based on IEA (2004). The energy consumption of pesticide manufacture from MAFF (2000) and Helsel (1992). Data on the energy consumed in fertiliser production was obtained from Carlsson-Kanyama and Faist (2000).

4. Green bean production in Kenya and the UK: a comparison

The energy consumption of bean cultivation per unit output in Kenya and Europe (in terms of MJ/kg) are very similar. The energy consumed in green bean production is 0.8–1.4 MJ/kg of product in Europe and 0.7–1.7 MJ/kg in Kenya. The reason for this is that although yields are higher in Europe (see below), more energy is consumed in the form of diesel for machinery and to manufacture and supply synthetic fertiliser. In the four European production systems, for example, fertiliser application rates are on average 218 kg/hectare and are as high as 321 kg/hectare. In Kenya the recommended rate is 80-120 kg/hectare, with many of the smaller farms applying less than 80 kg/hectare due to high fertiliser costs.

When packaging and distribution are included, however, the difference in energy consumption becomes considerable (**Table 9)**. Energy use is 12–13 times greater when beans are sourced in Kenya rather than the UK. The difference between sourcing in the UK and in Kenya is 57–59 MJ per kilogram of beans.

Table 9: Energy consumption of green bean production, packaging and transportation (MJ/kg)

	UK	**Kenya**
Cultivation	0.82 - 1.38	0.69 - 1.72
Packaging	3.92	3.92
Transport		57.90
Total	**4.74 - 5.30**	**62.51 - 63.54**

Green bean yields in Kenya and Europe are summarised in **Table 10**. On average the yield in Europe is 1.8 times that in Kenya. The highest average yield in Kenya is lower than the minimum average yield in Europe.

Table 10: Yields for green bean production in Kenya and Europe (kg/hectare)

	Min	**Max**	**Average**
Kenya	2,900	7,400	5,150
Europe	8,000	12,000	9,405

In the UK, average yields are very similar to those in the three European countries listed above. Between 1995 and 2005 the average yield for green bean production in the UK was 10.4 tonnes per hectare and ranged from 8.2 to 12.1 tonnes per hectare.[6]

4.1 Importing Kenyan green beans by sea

Currently no green beans are exported from Kenya to the UK by ship. However, there is evidence that European importers are beginning to consider the shift from air to sea freight due to the increasing cost of air freight distribution.[7] It has been reported that one importer is now transporting beans from Egypt and asparagus from South America, which used to be flown into Europe, by ship.

[6] The data on yield includes that for runner beans as well as green beans. Source: Basic Horticultural Statistics for the UK, DEFRA, 2006.
[7] See http://www.freshplaza.com/2006/21apr/1_nl_marine.htm

Developments in modified atmosphere packaging and modified atmosphere container systems are making shipping of fresh produce over longer distances with longer transit times more viable.

A modal shift from air to sea could result in a significant reduction in energy consumption and carbon emissions. The journey by ship from Mombassa to Southampton is 6,041 Nautical Miles and takes 21 days at 12 nautical miles per hour and 11.5 days at 22 nautical miles per hour. This requires 1.7 MJ per kilogram of beans, which is 56 MJ/kg less than air freight transport of beans from Kenya to the UK.

This calculation does not include the energy costs associated with modified atmosphere containers or packaging or increased refrigeration time. However, shipping horticultural produce to the UK could also reduce transport impacts in the UK by transporting produce to a port that is close to each distribution centre or retail outlet. At present it appears that all Kenyan green bean imports, as well as many other air freighted horticultural imports, arrive at Heathrow and are subsequently distributed from there to all parts of the UK by lorry.

The energy consumed in transporting produce from Heathrow to Glasgow, for example, is 0.7 MJ/kg. This journey could be avoided altogether if the produce were transported by ship to Glasgow and could contribute to a reduction in the external environmental, social and economic costs of road freight in the UK. Congestion in and around Heathrow and the South-East region would also be reduced.

Port capacity in the UK and Kenya as well as other logistical issues such as the distance, mode of transport and storage requirements between Kenyan farms and the port at Mombassa are likely to arise. Nevertheless, policy options allowing for a shift from air to sea freight of vegetables from developing countries could be considered. This would require a more detailed assessment of the environmental, social and economic impacts of this as well as all other options for UK green bean supply (see Recommendations).

5. Seasonality and protected and heated production in the UK

Seasonality of supply is an important issue. Green beans that are produced in the field (outdoors) in the UK are available for four to five months, between June and September/October.[8]

The options to extend the availability of UK produced beans include production in:

- unheated glasshouses and polytunnels;
- glasshouses and polytunnels heated by fossil fuels (primarily natural gas);
- polytunnels and glasshouses with artificial light, humidity and modified atmosphere (such as increased carbon dioxide levels) as well as heating; and
- glasshouses and polytunnels heated by combined heat and power (CHP) or renewable energy sources (such as wood burners or biogas).

Horticultural production in heated glasshouses is energy intensive and, if this energy is provided by fossil fuels, results in large quantities of carbon emissions. The energy use for UK glasshouse production ranges between 43 and 68 MJ/kg for tomatoes and 47 to 87 MJ/kg for peppers (Table 11).

Table 11: Energy use of UK horticultural production in heated glasshouses [9]

	Hectares	Key Sites	Energy Use (million MJ/hectare/year)		Yield (tonnes/hectare)	Yield (kg/ hectare)	Energy (MJ/kg)	
			Low	High			Low	High
Tomato	200	40	18	29	423	423,000	42.6	68.1
Cucumber	200	60	13	23	454	454,100	27.7	51.5
Pepper and other edibles	80	10	13	23	267	267,300	47.1	87.5

Other studies have produced different values for glasshouse production. For example, for tomatoes produced in heated glasshouses, between 27 and 40 MJ/kg (AEAT, 2005; Van Hauwermeiren et al, 2005). Another study commissioned by DEFRA found that heated glasshouse production of tomatoes showed huge variation, from 79 to 505 MJ/kg (Silsoe Research Institute, 2006).

Currently, the annual Basic Horticultural Statistics for the UK, produced by DEFRA do not include data on protected green bean production in glasshouses or polytunnels in the UK.[10] One industry analyst has stated that he had not come across any examples of commercial green bean production in the UK in heated or unheated glasshouses.[11] There are likely to be smaller producers, with say one or two polytunnels, who produce beans without heating. It is worth noting that studies have shown that the energy use associated with the manufacture

[8] Based on information from the HDRA – The Cook's Garden Planner, Monthly marketing patterns in BHSGB from DEFRA and BBC Easy Gardening, Early Spring 2003

[9] Based on data on energy use from *UK Greenhouse Horticulture,* Chris Plackett, Commercial Director, Farm Energy Centre, FCRN Meeting, 1st December 2005, and average yields from Basic Horticultural Statistics for the UK, DEFRA 2006.

[10] When contacted DEFRA stated that data on UK green bean production in heated and unheated glasshouses and polytunnels are not collected (personal communication with Lesly Lawton at DEFRA Agricultural Statistics & Analysis, Crops Branch on 24th August 2006).

[11] Personal communication with Chris Plackett, Farm Energy Centre, Stoneleigh Park, Kenilworth on 14th September 2006.

of glasshouses and polytunnels is equal to the energy consumed during cultivation (see Antón et al., 2005). If green beans were produced in similar conditions on a commercial scale in the UK, further analysis would be required in order to determine the energy consumed and to compare this to the air freight energy consumption of Kenyan bean imports.

Methods are being developed and examples beginning to appear in which glasshouses are heated with reduced environmental impact. For example, a British Sugar processing plant in East Anglia now uses combined heat and power (CHP) to heat adjoining glasshouses. Maximising the use of CHP could reduce the primary energy consumption of glasshouse production by about 70 per cent (Silsoe Research Institute, 2006). One tomato producer in Lancashire has installed a wood burner to provide heat, which will have close to zero net carbon emissions if the wood is sourced locally.[12]

The other options that could be considered in a more detailed analysis are:

- a shift to a seasonal diet;
- tinned, bottled or frozen beans; or
- substituting another vegetable product for beans during certain times of the year.

[12] Blairs Nurseries, Pilling, Lancashire (personal communication with Chris Plackett, Farm Energy Centre, Stoneleigh Park, Kenilworth on 14th September 2006).

6. Comparison with other studies and analyses of other food products and supply chains

An ADAS study for MAFF (now DEFRA) considered the energy consumption during the cultivation of six vegetable products in the UK (up to the farm gate) (MAFF, 2000). Energy use ranged from 0.8 MJ/kg for cabbage to 4 MJ/kg for calabrese. Apart from calabrese, the vegetables required between 0.8 and 1.7 MJ/kg to produce.

Another study considered the life cycle energy inputs of 150 food items available in Sweden. As well as cultivation, the energy use associated with distribution, packaging, processing and in some cases cooking was also included. Energy inputs in food life cycles showed considerable variation, from 2 to 220 MJ/kg. However, in most instances the supply of unprocessed vegetables to households required between 3 and 20 MJ/kg.

The study also found that the energy inputs for diets, per person per day, could vary by a factor of four, from 13 to 51 MJ. The energy consumed when exporting a kilogram of vegetables from Kenya to Northern Europe by plane (57.8 MJ/kg) is therefore greater than that used to produce, package, process and distribute all of the food and drink consumed by a person in a day.

Previous studies have also highlighted the large quantity of energy consumed when food is transported by plane (e.g. Marriott, 2005 and Garnett, 2003). Other ‘hot spots’ in the life cycle of food products include heating glasshouses, fishing and seafood products, storage during transit, in stores and in the home (freezing and refrigeration) and shopping by car. Waste food generated through the supply chain is also significant, particularly for fresh produce.

7. Issues to consider in more detail

7.1 A comprehensive LCA of the supply chain for green beans sourced in Kenya and the UK

In the case of the two supply chains described and analysed in this study, a more detailed analysis would include the following:

- Additional information on production systems in Kenya, for example, the relationship between fertiliser, pesticide and water application rates and yield on both small- and medium-sized farms. Also, any variation in input levels, yield and energy use during different times of the year, particularly during the dry season, as beans are produced in Kenya 12 months of the year.
- Analysis of green bean production in the UK to discover if there is any considerable variation, in terms of input levels and energy use, from the four European studies used in this report. Ideally this information would be obtained directly from a sample of UK green bean producers.
- The inclusion of historical inputs such as the manufacture, maintenance and repair of farm machinery and plastic sheet protection and polytunnels to determine their significance.
- A comparison of conventional, IPM and organic production in both the UK and Kenya and production on various scales in the UK (different holding size).
- The stages in red in **Annex 1** that were not included in this analysis would be considered. An extended study would cover supermarket distribution systems, shopping by car, home storage and cooking. As with production in Kenya, it would be useful to provide minimum and maximum values as well as an average value for each stage. This would require detailed information from one or more multiple retailer to find out how the beans that are imported from Kenya and those sourced in the UK are distributed within the UK. For example:
- are any distributed within the UK by plane?; and
- to model distribution channels from point of entry (Heathrow for Kenyan imports) or UK farm to regional distribution centres to supermarket stores.
- Other supply chain factors that could be considered in a more detailed analysis include refrigeration both during transit and at supermarkets and wastage levels during each stage of the supply chain.
- A breakdown for all Kenyan air freighted horticultural exports in dedicated freight planes and bellyhold would be useful as well as more detailed data on energy and fuel use for air freight, for example, bellyhold, dedicated freighter and different aircraft types.
- Seasonal availability of UK produced green beans - for how many months of the year is outdoor, unheated glasshouse and heated (with CHP or renewable energy) glasshouse production in the UK feasible? It would be important to determine the primary energy consumption and GHG emissions for each option.

7.2 A detailed analysis of all possible supply chains for green beans

In a comprehensive analysis the complete supply chain of all of the options for the cultivation, sourcing, transportation, packaging, processing, retail, storage and cooking of green beans would be considered. This would include:

- Green beans that are sold frozen, bottled and canned (whether they are sourced in UK, Europe or Africa)
- All possible sourcing, distribution and marketing systems for green beans. This would include local, UK, European and African sourcing and distribution via multiple retailers or wholesale markets.

7.3 Indicators other than energy use

Apart from energy use other indicators that could be considered relate to climate change and GHG emissions (see companion Briefing Paper "Sub-Saharan African horticultural exports to the UK and climate change: a literature review"). These include:

- Carbon dioxide emissions (grams CO2 per/kg)
- Carbon emissions (grams C/kg)
- Carbon equivalent, which includes GHG emissions other than carbon such as nitrous oxide (N2O) and methane (CH4) (grams Ceq/kg)
- Global warming potential - of particular importance due to the various non-energy related global warming impacts of aircraft.

The most useful of these would be carbon equivalent or global warming potential. The reason being that air freight distribution and fertiliser manufacture and use result in climate impacts other than carbon dioxide emissions, for example, NOX and soot emissions from aircraft and the impact of contrails.

Other possible indicators that could be used include: fuel use (for analysis of transportation in particular) in terms of litres per kilogram of produce (litres/kg); nitrate emissions and eutrophication; and acid deposition.

8. Discussion and recommendations

A more detailed analysis of supermarket green bean supply chains for imports from Kenya and UK sourced beans could highlight other ‘hot spots’. For example, shopping by car, cooking and refrigeration could have relatively high energy values. However, in terms of a comparison between Kenyan imports and UK sourced green beans, an extended analysis would not add significantly to the insight provided in this limited analysis. The reason for this is that the latter part of the supply chain, the stages following arrival at UK airports for Kenyan beans and the post-farm-gate stages for UK beans will be virtually identical.

Further analysis of bean production in Kenya, covering issues such as different input levels (for fertiliser, pesticide and water) and yield during different times of the year (particularly the dry season) would be of interest. More detailed information on the relationship between yield and fertiliser, pesticide and water application rates would also be useful. A more detailed analysis would improve data quality, but is unlikely to alter the values for cultivation in Kenya significantly and therefore the balance between energy use for bean production and for air freight transport.

Similarly, it would be useful to obtain data specific to UK cultivation of green beans by collecting information from UK bean producers. However, these are unlikely to be significantly different from, and would probably fall within, the range of values provided in this study for the four European bean production systems. Nevertheless this is worth checking.

Due to the considerable environmental impact of transporting beans from Kenya to Europe, exporting Kenyan beans to the UK at times of the year when they could be sourced in the UK will remain a contentious issue. The issue of seasonality and import substitution is likely to receive more attention as attempts are made to minimise GHG emissions. Air freight, as well as passenger travel on aircraft, is likely to come under increasing scrutiny. For this reason, together with the prospect of aviation fuel costs increasing during the next decade or so, it would be wise for DFID to consider investigating the option of importing Kenyan green beans and other Africa horticultural products by ship.

In terms of wider issues such as climate change, sustainable development and identifying systems in which fossil fuel use and greenhouse gas emissions are minimised, a wider study would provide useful information. In this, all options for green bean sourcing, packaging, storage, distribution and marketing would be assessed. This type of analysis may be of interest to DEFRA as well as DFID, to establish joined-up positions on these issues.

In terms of data quality and availability, it is recommended that DFID and DfT together with DEFRA and UK Research Councils collect and verify LCA data to form a database. This would include data on food production, transportation, processing, and packaging; in other words all of the baseline data required to carry out a study of this type. Standard units should be used, for example MJ/kg, and all aspects in the life cycle of food products should be covered, whether this be manufacture of fertiliser or packaging or storage of produce in a refrigerator. The data could be presented in terms of various functional units, for example, energy use, fuel use, carbon emissions and global warming potential. Average as well as maximum and minimum values for each process would be of use, for example, based on different loads for freight transport and literature values for the manufacture of pesticide, fertiliser and packaging. This would allow for greater consistency in studies of this type, which are likely to become an integral part of the policy development process and the provision of information for the consumer.

The issue of higher farm input costs and transport costs, due to higher crude oil and natural gas prices, and the impact that this will have on the production and export of horticultural produce in Africa is one that DFID should be aware of and should if it has not already done so, assess the implications and the risks of this. The correlation between aviation fuel costs and the price of crude oil is very close, compared to that of other transport fuels.[13] Further increases in the price of crude oil and therefore aviation fuel could have serious implications for farmers in Africa who rely on air freight to export their produce.

[13] See for example, an analysis by IATA of recent increases in the price of aviation fuel at http://www.iata.org/whatwedo/economics/fuel_monitor/price_development.htm

Annex 1:The Life cycle of green beans produced in Kenya, exported by plane to UK and sold in supermarkets

Annex 2: Questionnaire: Data requirements for the LCA of green bean production in Kenya

General

1. Are the production systems organic or are pesticide and synthetic fertiliser applied (is manure also applied)
2. Are the beans drilled directly or are seedlings cultivated and planted out (if so are the seedlings produced on each farm)
3. Number of producers being assessed
4. Size of holding(s)
5. Crops produced
6. Area devoted to each crop
7. Output (kilograms or tonnes) of each crop

Specific green bean related information

8. When is the harvesting period (are there several sowing/harvesting periods)
9. Yield (tonnes per hectare)
10. Amount of synthetic nitrogen, phosphorous and potash fertiliser applied (kilograms per hectare)
11. Amount of pesticide by type applied (kilograms, before being diluted, per hectare)
12. Is the crop irrigated, if so are electric pumps used
13. Is the bean crop protected in any way - plastic sheeting, mesh etc.
14. Fuel use for farm machinery associated with ploughing, sowing and weed management (litres per hectare).
15. Is harvesting by hand or mechanised
16. Pack size (grams)
17. Type of packaging used and quantity per pack (grams)
18. Location of the farms, which airport(s) are used, distance to airport, type of vehicle used to transport produce (is it refrigerated) and average load of each.
19. Is the produce air freighted in belllyhold or dedicated freight planes.
20. The aircraft type.

Annex 3: Data on green bean production supplied by NRI

KENYAN GREEN BEAN INFORMATION FOR LCA USE

Key: 1 = Yes & 0 = No

Category	Detail	Small-scale	Medium-Scale
Organic production		0	0
Inorganic fertiliser used		1	1
Manure / compost		0	0
Direct drilling		1	1
Nursery beds		0	0
Number of farms		750	150
AVERAGE FIGURES PER FARM SITE - NOTE INDIVIDUAL SITES ARE NOT UNIFORM AND VARY IN LAND AREA AND YIELD OBTAINED			
Total area in production (ha)		1	10
Green bean plot size (ha)		0.15	0.4
Area (ha) used for green bean per year	1 planting per month over 12 months, with rotation around the 0.15ha plots for small-scale and 3 plots per planting and 3 plantings per year for medium-scale	1.8	3.64
Production season	Planting goes on all year round with multiple plots and rotations to ensure continuous availability	All year	All year

Gross yield of green beans per hectare in tonnes	Per hectare yields are derived from the total annual production, rather than per planting	2.9	7.4
Net yield of green beans per hectare in tonnes	Average exportable percentage = 60% of gross	1.7	4.4
Other crops grown for export	Babycorn had a gross yield of 7.5 tonnes/ha and net yield of 2.7 tonnes per hectare (10% exportable yield)	0	Babycorn
Other crops for local market	Yields for local crops are not known as farmers do not maintain written records for these crops	local beans, coffee, banana, maize, tomatoes & cabbages	tomatoes, cabbages, onions, maize & banana
Protected crops	All crops are open air with no protection	0	0
Irrigation	Borehole with electric pump	1	1
Irrigation type	Important point as drip feed is the most efficient, overhead irrigators require double the amount of water to provide the same result (based on trials by students at NZTT farm in Zambia)	Water run from a flexible pipe into ground level channels	Drip feed irrigator
Pump ratings	Pump sizes vary between farms but are mostly in the range 2-5hp and farmers complain that these are inadequate they want 10-15hp pumps but cannot afford them. Because of small pump often have to irrigate at night (during the dry season = 7 months of year) as well as during the day. The 2-5hp pumps deliver between 2-4.7dm^3 of water per second dependent on capacity.		
Power consumption in kWh	Using the types of pumps available to these farmers electricity consumption per hectare = 2,500 kWh		

Water consumption /ha	Water consumption varies according to dry and wet season and small & medium scale farmers are unaware of volume used. They think in terms of watering time and cost of electricity to achieve healthy looking plants. However, crop protocols supplied by the exporter recommend 4-8dm^3 of water per day for each m^2 of production. Given that the crop cycle is 60 days a hectare of production watered at 6dm^3 per m^2 would require 60,000dm^3 per day or total water supply of 3.6 million dm^3 per ha.	Unlikely in real life to be using anywhere near the recommended amount of water	Operate closer to recommended levels but will cutback because of high costs
Inorganic fertiliser types	On farms in Africa the levels vary correspond to soil types 3-2 under the Assured Produce Protocols. This is between 80 and 120kg / hectare of NPK fertiliser incorporated into the soil prior to planting. Top dressing may be added later if the plants appear nutrient depleted.	Wide variation in levels of fertiliser applied but rarely use recommended amounts due to high cost.	Use recommended levels in most cases, but farmer judges appearance of crops and may increase or decrease accordingly.
Crop protection products (CPP)	CPP usage is based on scouting rather than routine application, for insect problems most common compounds are Dimethoate 40EC (1.0dm^3 per hectare = 0.4dm^3 of active ingredient), Karate 1.7EC (1.0dm^3 per hectare = 0.017dm^3 of active ingredient) and Decis 25EC (0.5dm^3 per hectare = 0.125dm^3 of active ingredient). Fungal problems are treated with Kocide WP (3.0kg per hectare of copper hydroxide powder), Thiovit 80 (2.0kg per hectare = 1.6kg of active ingredient) and Dithane M45 (2.5dm^3 per hectare = 1.125dm^3 of active ingredient). All values are maximums and allow for single application only. Small & medium-scale growers do not buy in bulk and only maintain small quantities on farm. Typical container sizes for liquid chemicals range from 0.5-2.5dm^3 and powders range from 5-25kg.	Manual application using a knapsack sprayer, small-scale growers will only normally have one fungicide and one insecticide available at a time but exporters ensure rotation of chemicals to prevent build up of resistance	Application and rotation techniques are same as for small-scale grower, but some larger farms have larger range of chemicals available.
Land preparation	Manual = 1 Mechanised = 2	1	2

Tractor type	Most tractors seen are Masey Fergusons and I am told that the engines run on diesel and are normally 150hp units		
Amount of fuel used by tractor for land preparation	Figures not available as tractor is hired for fixed price with driver & fuel included. I will check on the amount of time required to see if anyone can estimate, farmers hire on the basis of area to be ploughed rather than time required for the job.	Not applicable	1
Fertiliser application	Manual = 1 Mechanised = 2	1	1
Planting	Manual = 1 Mechanised = 2	1	1
Weeding	Manual = 1 Mechanised = 2	1	1
Application of CPP, manual operation using knapsack sprayer	Manual = 1 Mechanised = 2	1	1
Harvesting	Manual = 1 Mechanised = 2	1	1
Transport from farm to field depots	Only applicable to small-scale, medium-scale have direct pickup from farm site	0-3.5km transport by headload or bicycle	Not applicable
Transport to airport packing facility by reefer truck /tonne	Company runs 15 x 10 tonne trucks for 26 days per month, (type Isuzu 4x2FRR medium duty truck 8.2 litre diesel engine)	1	1
Mean distance from farm sites to packhouse (km)		80	80
Pack size (net weight of product /g)		200	200
Packaging type	Rigid punnet with film covering, type TPL1062	1	1
Material	Polyethylene terphthalate (PET) & film covering	1	1
Weight of packaging (g)		15	15

Origin of packaging	Thermopak Canada	1	1
Air freight	Carried in belllyhold of scheduled carrier direct to UK - LHR	1	1
Aircraft type		Boeing 777-200	Boeing 777-200
UK transport	Reefer transport to dedicated reefer distribution centre 43km from LHR	1	1

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