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Sub-Saharan African horticultural exports to the UK and climate change: a literature review

Zoë Lelah Wangler

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DFID Department for International Development

Natural Resources Institute

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Contents

Acronyms and Abbreviations

CAA	Civil Aviation Authority
CO2e	Equivalent tonnes of CO2
DEFRA	Department for the Environment, Food and Rural Affairs
DFID	Department for International Development
DfT	Department for Transport
FCRN	Food Climate Research Network
FFV	fresh fruit and vegetables
FoE	Friends of the Earth
GW	Global Warming
GWP	Global Warming Potential
HMRC	HM Revenue & Customs
IEA	International Energy Agency
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
LCA	life cycle analysis
MtC	mega tonnes of carbon
NCC	National Consumer Council
NOx	Nitrogen oxides
NRI	Natural Resources Institute, Greenwich University
ppmv	parts per million by volume
RCEP	Royal Commission on Environmental Pollution
RFI	Radiative Forcing Index
SSA	Sub-Saharan Africa (not including South Africa)
UK	United Kingdom of Great Britain and Northern Ireland
UNFCCC	United Nations Framework Convention on Climate Change

Objective

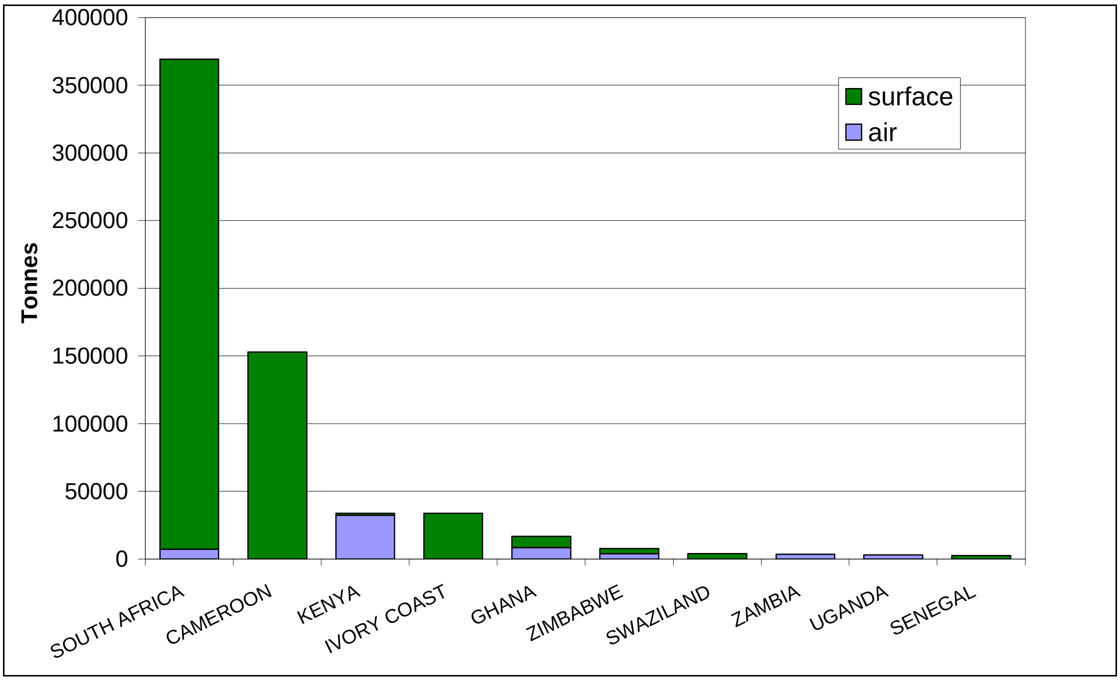
This study aims to provide:

- Baseline information and data relating to the scale and significance of horticulture production and exports from African countries in generating/ exacerbating/ driving environmental factors compared to production in other countries. Methodology is a literature survey and a comparative study of ‘food miles’.
- Short pieces of information to support public statements by DFID
- Potential routes forward: research and policy engagement, especially around trade-offs between food miles and fair trade.

1 Introduction

Growing environmental criticisms of air-transportation of fresh fruit and vegetables (FFV) have raised concerns that UK government objectives for 'trade not aid' in sub-Saharan African (SSA) are in danger of being undermined. Currently 25 per cent of the UK's FFV imports from non-EU countries and 40 per cent of all air-freighted FFV imports are grown in sub-Saharan Africa (HMRC, 2006).[1] Air freight is particularly important to Kenya's horticultural export market (**Figures 1 and 2**), which in 2004 transported 91 per cent of all its FFV exports to the UK in aircraft (Marriott, 2005).

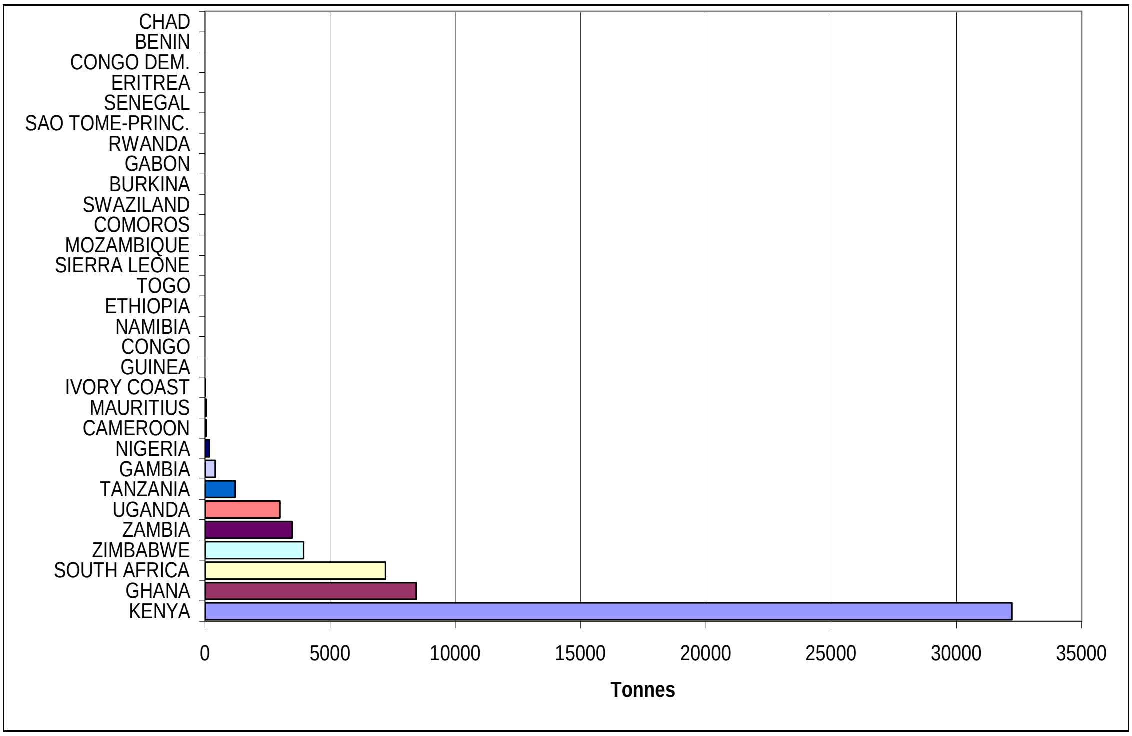
Figure 1: Top ten SSA FFV exporters to the UK by mode of transport, 2005



Source: UK Import Modal Statistics for Fresh Fruit and Vegetables 2005. Data collected by HMRC

[1] There is no information on mode of transport of FFV imports from within the EU but it is reported (Defra, 2005c; Garnett, 2006) that air freight within the EU is insignificant. For non-EU countries, SSA countries account for about 40 per cent of FFV imports arriving in air-transportation (HMRC, 2006; Marriott, 2005)

Figure 2: UK air-freighted FFV imports (tonnes) from SSA countries, 2005



Source: UK Import Modal Statistics for Fresh Fruit and Vegetables 2005. Data collected by HMRC

Part One of this report outlines three central environmental arguments against air freighting food, and looks at whether available research supports or negates them. The report then looks specifically at information available on the climate impact of the SSA FFV export market. Finally, as requested by DFID, emissions from a typical air-freighted product are calculated and compared with those from other modes of transport, including sea-freight and with emissions from other activities.

A summary of the studies reviewed for this report can be found in Appendix 1.

2 Environmental critiques of importing horticultural produce

Responding to the growing distances that foods consumed within the UK travel, environmental campaign organisations, academia and government have been increasingly examining the environmental costs of this trend. Their publications, campaigns and the supporting research were reviewed for this part of our literature review, focusing on the critiques of air transportation. This section sets out three central arguments against air freight and examines whether existing research supports or negates them:

1. Air freight has the highest global warming potential of all modes of transport
2. Air freight has the highest global warming potential of any other stages of the life cycle of horticultural produce
3. Air freight is increasing faster than passenger flights, and as the fastest growing emitter of greenhouse gases, aviation is threatening the UK's ability to stabilise emissions.

2.1 Air freight has the highest global warming potential of all modes of transport

The foremost argument made against air-freighted FFVs is that air transport has by far the highest global warming potential per kilogram of product compared with other modes of transport (DEFRA, 2006; van Hauwermeiren et al, 2006; DEFRA, 2005c; ISIS, 2005; NCC, 2006; Sustain, 2001; Sustain, 1999). Recently, air-food-kms was recommended by AEA Technology (DEFRA, 2005c) as one of four indicators for government to use when evaluating the impacts of food transportation on sustainability.

Based on DEFRA emission factors (DEFRA 2005a), air-freighted fruit, vegetables or flowers could produce up to ten times their weight in CO2 emissions, or eighty times the amount of CO2 produced by sea-freighting the same product in a large bulk carrier. Furthermore, according to the IPCC (1999), CO2 emissions from aircraft represent just a third of a flight's global warming potential. Based on DEFRA's emission factor and the IPCC's radiative forcing index (RFI) for aircraft, an index which accounts for the climate impact of non-CO2 emissions (see Box 1), the flight between South Africa and the UK would alone be responsible for 15 kg of CO2e (carbon dioxide equivalents) per kilogram of produce. These transport emissions compare with 0.1 kg of CO2e per kilogram of produce for the sea-transportation from South Africa in a large bulk carrier, or 0.1 to 0.15 kg of CO2e per kilogram of produce transported in an articulated lorry from Almería (southern Spain) to St. Helens (Merseyside).[2]

Box 1: Radiative forcing by aircraft

Aviation emissions are discussed in terms of tonnes of carbon, carbon dioxide and carbon dioxide equivalent. Carbon dioxide can be calculated by multiplying carbon emissions by 44/12. Some calculations apply the IPCC's Radiative Forcing Index (RFI), a multiplier (2.7), which accounts for the change in climate caused by other, non-CO2, emissions from aircraft. These are expressed as carbon dioxide equivalents or CO2e. The IPCC has concluded that CO2 only represents about a third (37 per cent) of the global warming potential of aircraft emissions. The index equates the climate impact of these other emissions with the effect a similar quantity of carbon dioxide. The other mechanisms are:

Mechanism	Contribution to Global Warming
NOx (via ozone changes)	47%
NOx (via methane changes)	-29%

[2] This example used DEFRA (2005a) emission factor for 75% weight-laden articulated lorry. Other factors used: lorry maximum capacity is 30 tonnes and travelled 2,600kms. Emissions from sea-transportation across the Channel are based on a large ro-ro travelling from Calais to Dover.

Contrails	41%
Stratospheric H2O	4%
Sulfate aerosol	-6%
Soot	6%

(-ve represents cooling effect)

There is considerable uncertainty regarding the radiative forcing induced by aircraft. Some argue that a single figure for RFI is inappropriate (Forster et al., 2006) while others (RCEP, 2002; Tyndall Centre, Bows et al., 2006a) consider that the radiative forcing induced by aircraft is likely to be higher than reflected in the IPCC's current RFI for aircraft.

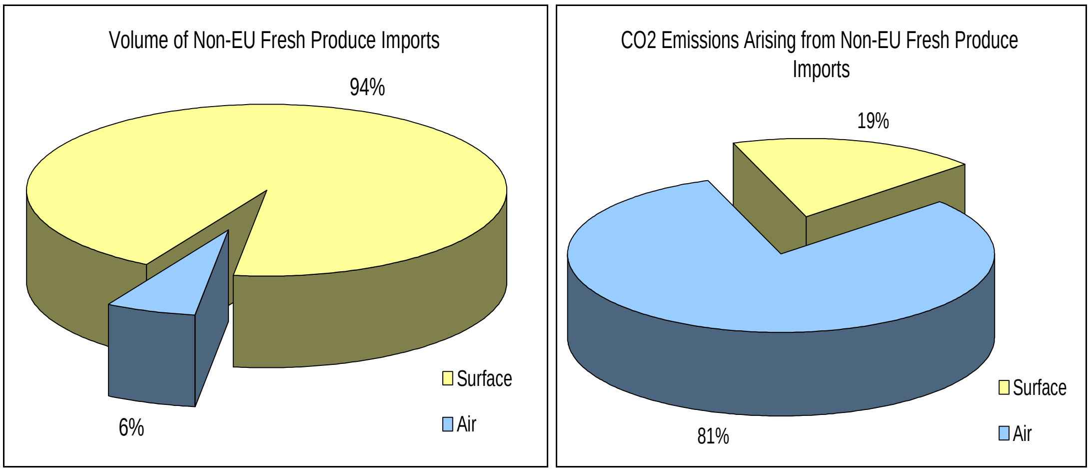
Table 1: CO2 and CO2e emissions from the specified transportation stage for 1 kilogram of product. (The figure for CO2e accounts for the climate impact of non-CO2 emissions and equates this to the effect of a similar quantity of CO2)

	CO2 emitted per kg	CO2e emitted per kg
Flight from Cape Town to London	5.5	14.9
Sea journey from Cape Town to Southampton	<0.1	<0.1 – 0.12[3]
Road journey from Almeria, Spain to St. Helens	0.1	0.1-0.15

Reflecting this disparity between modes of transport, according to Garnett (2006), the 1.5 per cent of imported fruits and vegetables arriving in air transportation in 2005 produced half of all emissions from this fruit and vegetable transportation (excluding consumer travel). Garnett calculates that this equals 0.2 per cent of total UK greenhouse gas emissions and writes that "this 0.2% is almost the same as the contribution made by produce travelling by road and sea [overseas] (according to the Defra study [DEFRA, 2005c]), despite the massive differences in volumes carried; this throws into sharp relief the greenhouse gas intensity of air travel" (ibid). When calculating carbon dioxide emissions for non-EU FFV imports, Marriott (2005) found that the 6 per cent non-EU of imports that arrived in air-transportation were responsible for 81 per cent of total emissions (**Figure 3**).

[3] For surface transportation the RFI index ranges between 1 and 1.5.

Figure 3 Volumes and CO2 emissions from non-EU FFV imports by mode of transport, 2004



Source: Marriott, 2005

No research was found that argued against the statement that air transport has the highest global warming potential of all major modes of bulk freight transport. However, points relevant to the statement were that: the total environmental cost of international food-miles, including air-miles, is trivial compared with UK domestic food miles (Pretty et al., 2006); and that air freight is the only possible mode of transport for some highly perishable produce and for locations where no other infrastructure exists (Marriott, 2005).

Of note is that the emission factor provided by DEFRA, also used in the DEFRA *Validity of Food Miles* study (DEFRA, 2005c), is for dedicated freight planes[4] and does not account for freight travelling in belllyholds of passenger aircraft. There is no consensus on how to allocate emissions from FFVs transported in the belllyhold of passenger aircraft, nor data available to determine the ratio. The only data available simply provides a split between belllyhold and dedicated freight/cargo aircraft for 'freight' as a whole.

2.2. Air freight has the highest global warming potential of any other stages of the life cycle of horticultural produce

The research reviewed for this briefing supports the statement that air-freight is one of a small number of life cycle stages that can have a significantly higher positive (warming) climate impact. Unlike the other stages in this group, including heated greenhouse production and private car use, air-freight will (using current technologies) always have a high positive climate impact, whereas the other stages may or may not have a high positive impact; their impact is dependent on a number of factors, including type and quantity of fuel consumed.

We have reviewed research comparing energy consumption as well as greenhouse gas emissions as so little research comparing the latter is available. It should be noted however that energy consumption does not directly correlate to climate impact.

Supporting: Van Hauwermeiren et al. calculated the carbon dioxide equivalent emissions for local and supermarket supply chains for a number of food products. The

[4]Ascertained by Andy Jones, IIED consultant in correspondence with Melanie Hobson at AEA Technology Environment, August 2006. See study 'A life cycle analysis scoping study and comparison of UK and Kenyan green bean production for supply to UK supermarkets', Briefing Paper in this series.

researchers collected primary data for processing, storage and transportation to the retailer, and used default emission factors for energy use for heated greenhouses, consumer transportation and for international bunker transportation. They concluded that air-transportation was the single most significant stage of the life cycle. Emissions produced from the consumption of a kg of tomatoes ranged by two orders of magnitude: from approx. 100g to 10kg of CO_2. Heated greenhouse production added approx. 1.5kg CO_2 per kg produce while air-freight (Kenya) added approx. 8kg CO_2 per kg. In comparison processing and storage were calculated at 4.73g CO_2 per kg and 5.19g for supermarket and local distribution chains respectively.

Illustrative examples from van Hauwermeiren et al. (2006):
Supermarket selling **organic** tomatoes from Kenya (6000 km by **aircraft**) produced in open air, purchased by a consumer by **car** (15 km single trip, combined shopping), buying 10kg in total:
83 + 11 + 8510 + 0 + 757 = 9361g CO_2/kg

Supermarket selling **organic inland tomatoes** produced in a **heated greenhouse**, purchased by **car** (15 km single trip, combined shopping), buying 10kg in total:
83 + 11 + 0 + 1459 + 757 = 2310g CO_2/kg

One other study supports the findings of van Hauwermeiren et al. (ibid), while one study challenges the findings. Carlsson-Kanyama et al. (2003) found that the single largest consumer of energy within the FFVs examined was air-freighted 'tropical fruit', which consumed 115MJ per kilo compared with 66MJ per kilo (closet equivalent - heated greenhouse tomatoes) and 6.8MJ per kilo (Spanish open-air tomatoes).

***Challenging*:** Vringer and Block (2000) however found that Dutch cut flowers can consume as much as 195 MJ per stem and while Dutch roses required 9.5 MJ per stem, Kenyan flowers required just 2-3MJ per stem including air-transportation. If each stem weighed 30 grammes, a kilo of Kenyan roses would consume 67-100MJ of energy compared with a Dutch rose – 317MJ per kilo. The authors do note however that energy consumed in Kenyan production is set to rise while the energy consumed in Dutch production systems is set to decrease. Both systems for producing and distributing roses are high consumers of energy, comparable only with other hothouse or air-freighted produce. This latter study does challenge the conclusion that air-freighted produce will always consume more energy than produce grown in heated greenhouses. Unfortunately neither of these studies reported their findings in terms of greenhouse gas emissions.

In addition to van Hauwermeiren et al. (2006), seven studies were examined that calculated energy used, carbon emissions and/or greenhouse gas emissions from one or more life cycle stages of a fresh or processed horticultural products. The complete findings are contained in Appendix 1. The following tables reproduce example values for energy (MJ) and emissions (CO_2 and CO_2e) from the eight studies. Although here they are presented in a single table, each of the studies has different system boundaries, assumptions, methods to determine emissions, and methods to determine energy consumption. Some studies are explicit in their methodology, while others provide only a brief description. Some stages overlap. The tables are therefore only to provide the reader with a rough indication of the relative significance of each stage of the life-cycle.

It would appear that with the exception of the values for private car use, the values for energy use (MJ/kg) and GWP (kg CO_2e/kg) are broadly consistent across all of the studies.

Table 2: MJ consumed per kilogram of produce per life cycle stage or life cycle stages – comparison of reviewed studies

	Heated greenhouse production	Farm (not including heated greenhouse)	Packing	Surface transportation	Air transportation	Processing & storage	Consumer collection In private car	Total for stages marked ✓ or for row values
From Carlsson-Kanyama, Ekstrom, Shanahan (2003).								
Tropical fruit ('overseas' to Sweden)		✓	✓	✓	✓	✓	✓	115.0
Oranges (Southern Europe to Sweden)		✓	✓	✓		✓	✓	6.8
Inland tomatoes (Sweden)	✓	✓	✓	✓		✓	✓	66.0
From van Hauwermeiren et al. (2006)								
Inland tomatoes (Belgium)	26.73			1.07 - 2.72		0.10 – 0.11		33.4 – 46.0
Imported tomatoes (Spain to Belgium)				3.87		0.10		9.4 – 20.4
Imported tomatoes (France to Belgium)	26.73			3.47		0.11	5.47 - 16.40	35.8 – 46.7
Imported tomatoes (Kenya to Belgium)					103.33	0.10		108.9 – 119.8
Inland apples (Belgium)				0.50- 0.54		0.56 - 0.84		6.5 – 17.8
From Hatirli et al. (2006)								
Turkish tomatoes		0.67 – 0.84						
From Vringer and Block (2000)								
Dutch cut flowers	✓	✓	✓	✓		✓		3-195 (per stem)
Dutch rose	✓	✓	✓	✓		✓		317[5]
Kenyan rose		✓	✓	✓	✓	✓		66-100[5]
Fuentes C. & Carlsson-Kanyama (Eds) (2006)								
Imported onions (Denmark to Sweden)		1.49	0.98	0.55				3.0
Inland tomatoes (Sweden)	✓	✓	✓	✓				51.4
Inland carrots (Sweden)		0.22	2.16	0.26				2.6
Frozen inland carrots (Sweden)		✓	✓	✓		✓		7.6
Frozen inland broccoli[6]		✓	✓	✓		✓	✓	30
Imported frozen broccoli (Central and South America to Sweden)		✓	✓	✓		✓	✓	23-25
From Jones (2002)								

[5] The per stem value was multiplied by 100/3 to obtain a value for a kilogram. Each stem was assumed to weigh 30 grams.
[6] Values for frozen broccoli are for 1.1kg of broccoli which the authors state have the same nutritional value as 1kg of fresh broccoli

Imported apples (USA to UK)				3.35			1.04	4.4
Inland apples (UK)				0.75			1.04	1.8
From Jones (for this project)								
Imported green beans (Europe)		0.82 – 1.38						0.8 - 1.4
Imported green beans (Kenya)		0.69 – 1.72			57.83			58.5 – 59.6

Table 3: Grams CO2 or CO2e (where stated) per kilogram of produce per life cycle stage or life cycle stages – comparison of reviewed studies

	Heated Greenhouse Production	**Farm (not including heated greenhouse)**	**Packing**	**Surface transportation**	**Air transportation**	**Processing & storage**	**Consumer collection In private car**	**Total for stages marked ✓ or for row values**
From van Hauwermeiren et al. (2006)								
Inland tomatoes (Belgium)	1459.41	11-19		78.53 – 198.70		4.73 – 5.19	403.49 – 1,210.46	1,957 – 2,892
Imported tomatoes (Spain to Belgium)		11-19		283.53		4.73		703 – 1,518
Imported tomatoes (France to Belgium)	1459.41	11-19		253.70		5.19		2,133 – 3,352
Imported tomatoes (Kenya to Belgium)		11-19		78.53	8,509.68	4.73		9,008 – 9,822
Inland apples (Belgium)				36.69 - 39.77		27.02 – 40.72		467 – 1,291
Fuentes C. & Carlsson-Kanyama (Eds) (2006)								
Imported onions (Denmark to Sweden)		46 CO_2e	59 CO_2e	40 CO_2e				145 CO_2e
Inland tomatoes (Sweden)	✓	✓	✓	✓				2,724 CO_2e
Inland carrots (Sweden)		18 CO_2e	32 CO_2e	19 CO_2e				69 CO_2e
Frozen inland carrots (Sweden)		✓	✓	✓		✓		267 CO_2e
Frozen inland broccoli		✓	✓	✓		✓	✓	1,000 CO_2e
Imported frozen broccoli (Central and South America to Sweden)		✓	✓	✓		✓	✓	1,000-1,300 CO_2e
Mason et al. (2002)								
Average for UK cherry imports - all sources				✓	✓			3,128
Average for UK apple imports from all sources				109				109
Average for UK lettuce imports from all sources				43.6				44
Jones (2002)								
Imported apples (USA to UK)				228.97			51.3	280

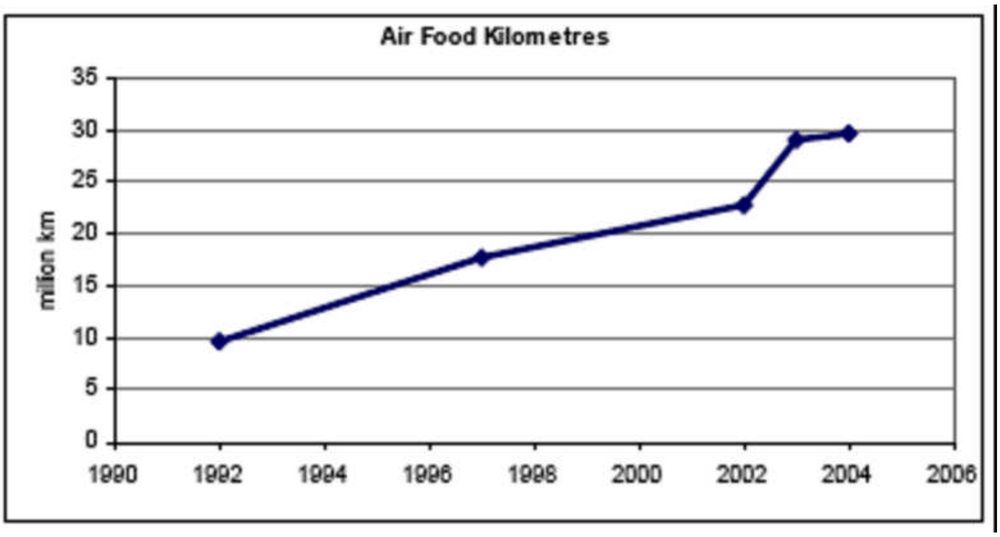
Inland apples (UK)				42.95			51.3	94

2.3 Air freight is increasing faster than passenger flights, and as the fastest growing emitter of greenhouse gases, aviation is threatening the UK's ability to stabilise emissions

The final central criticism of air freighting food is that it is one of the drivers of airport expansion and increased air traffic, and aviation is threatening our ability to reduce the UK's climate impact (FoE, 1999; FoE, 2001; Bows et al., 2006b)

Air freight is reported as the fastest growing mode for transporting food (DEFRA, 2006; DEFRA, 2005c), having grown by 140 per cent over the period 1992 to 2002 (Watkiss, 2006 – see **Figure 4**). FFV imports into the UK by air from outside the EU grew by 6 per cent per annum over the period 1996 to 2004. Freight is growing faster than passenger travel and freight transported in dedicated cargo planes is growing faster than belllyhold freight (DfT, 2000; Boeing, 2006 – see **Figure 5**). Boeing reported this year that "over the next 20 years, world air cargo traffic will triple over current levels, and the freighter fleet will double", and that "air cargo exports from Africa to Europe have grown at an average annual rate of 6.3 per cent since 1995 … [and] principal air exports from Africa continue to be perishables and apparel".

Figure 4: Growth in air food kilometres



Source: DEFRA (2006)

Figure 5: Growth in freighter vs. belllyhold air freight. In the years 1992-1998, freight transported in dedicated freighter grew by 12 per cent annually while freight transported in the belllyhold of passenger aircraft grew by 8 per cent annually (DfT, 2000)

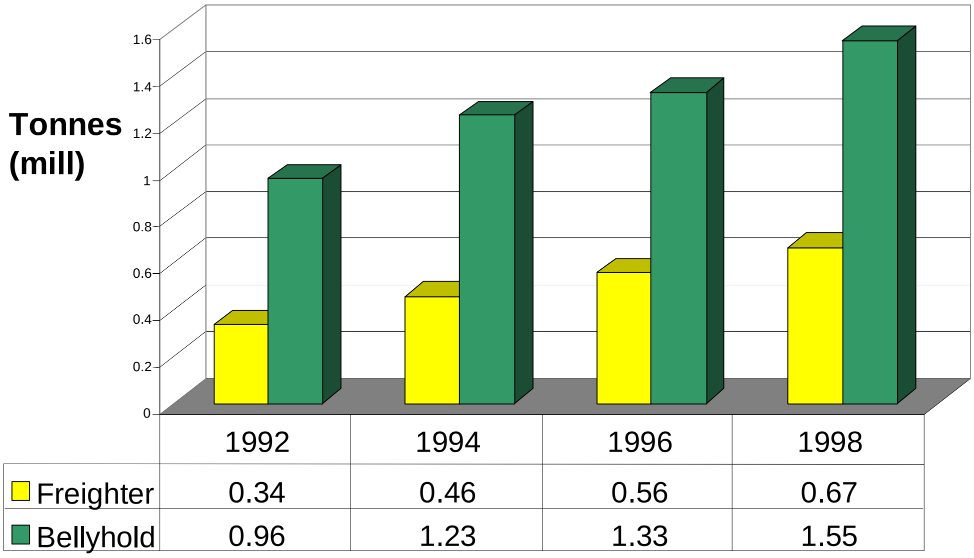


Table 4 shows that currently dedicated cargo planes are responsible for an estimated 5 per cent of the UK's aviation emissions (domestic and international), with passenger flights accounting for 90 per cent. Freight is also carried by passenger flights, although the nature of this as a driver or a an opportunistic top-up is unclear.

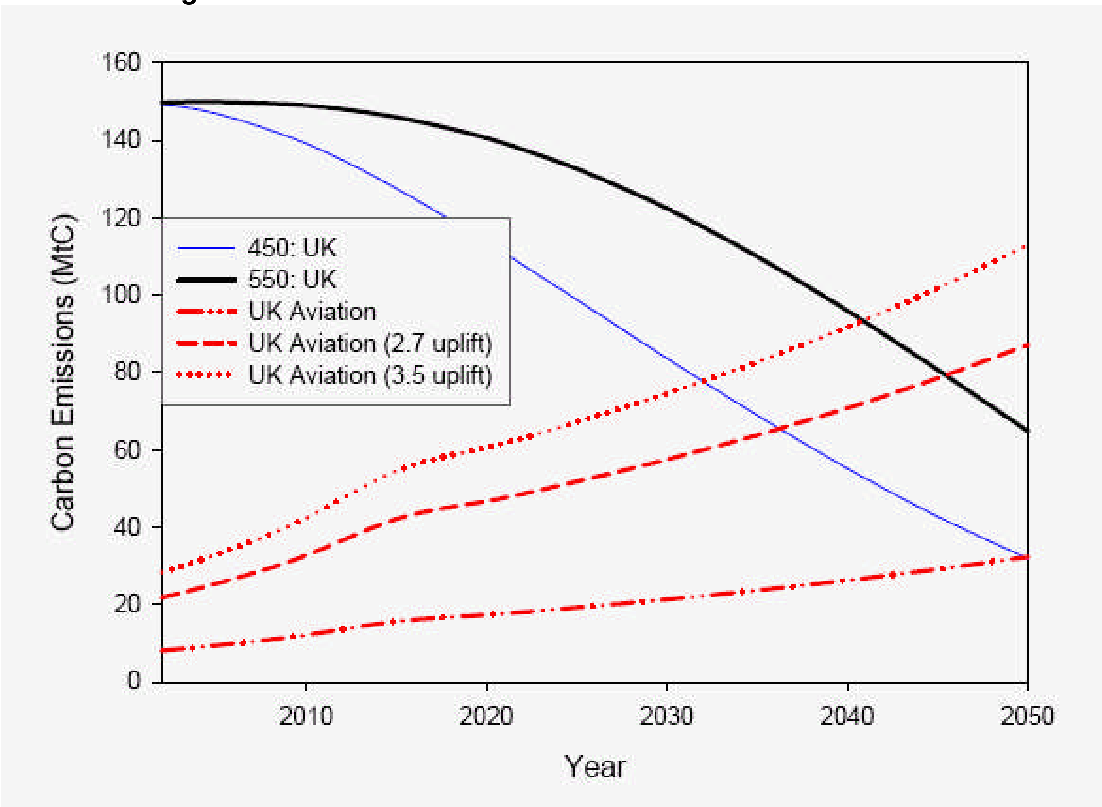
Table 4: CO2 emissions allocated to passenger aircraft and freighters – 2002 (DfT).

Passenger (international)	85%	23.68Mt
Passenger (domestic)	5%	1.40Mt
Freight (international)	5%	1.36Mt
Freight (domestic)	0%	0.09Mt
Surface access	5%	1.28Mt
Total aviation emissions		27.81Mt

According to researchers at the Tyndall Centre for Climate Change Research, "more than any other industry sector, aviation emissions threaten the integrity of the world stabilising carbon emissions at a level that avoids dangerous climate change." (Bows et al., 2006a). While total greenhouse gas emissions reported by Annex 1 Parties to the UNFCCC decreased between 1990 and 2000, international aviation emissions were singled out in the UNFCCC reports for their marked increase of 48 per cent (UNFCCC, 2003). From 1990 to 2000 the UK's annual CO2 emissions decreased by 8 per cent (DEFRA, 2005b) while emissions from aviation increased by a massive 90 per cent (Owen and Lee, 2005).

The concern is that as the UK works to reduce emissions, emissions from aviation will continue to rise and cancel out reductions made in other sectors. To illustrate, the Tyndall Centre (Bows et al., 2006a) has calculated, without accounting for radiative forcing (see Box 1), that by 2050 aviation emissions would exceed the UK's entire permitted carbon emissions under its projected contraction and convergence profile (currently set at 450ppmv) [7,8]. If aviation emissions stabilised at 2030 values the sector would still require 67 per cent of the 450ppmv profile and 33 per cent of the 550ppmv profile in 2050. This means that emissions from all other sectors of the UK economy would have to be constrained. As seen in **Figure 7**, if radiative forcing is factored in (represented by the lines for 2.7 and 3.5 uplift), aviation emissions would exceed the 450ppmv profile as early as 2035, leaving no room for emissions from any other part of the UK economy.

Figure 7: Aviation emissions forecasts and scenarios compared with carbon reduction targets



Source: Bows, A., Upham, P., Anderson, K. (2005). The values 2.7 uplift and 3.5 uplift refer to two different radiative forcing values (see Box 1)

[7] This is not UK Government policy and emissions from international marine and air bunkers are not included under the Kyoto Protocol.

[8] The contraction and convergence policy is advocated for by the RCEP. The policy states that over decades each country will shift from current levels to a uniform per capita amount allocated across the entire globe. For more information on contraction and convergence policy see the work of the Global Commons Institute: http://www.gci.org.uk/model/ideas_behind_cc.html

3 Climate impact of sub-Saharan African fresh fruit and vegetable production and distribution

3.1 Calculating transport emissions

No existing data set was found on greenhouse gas emissions from sub-Saharan African (SSA) FFV exports. Here a rough calculation of emissions from the international sea and air shipping stage has been conducted. Weight of horticultural produce arriving each month from non-EU countries is available from HMRC.[9] The dataset breaks imports down into mode of transport, country of origin and produce type (e.g. table grapes). This data can been used to roughly estimate transport emissions for SSA FFVs.

Aviation emissions are calculated in a number of different ways (see **Box 2**). The author used the CO2 emissions factors provided in DEFRA's *Guidelines for Company Reporting on Greenhouse Gas Emissions* (**Table 5**) and multiplied the volume of produce given by HMRC by the distance between London and the capital city of each country (for flights), and Southampton and the nearest major port (for marine bunkers). As did AEA Technology,[10] we multiplied this by 2.7 for air travel to account for other, non-CO2, aircraft-induced radiative forcing. Calculations made without the application of the RFI have also been included for some results. These are rough calculations as they use standard emission factors, do not incorporate emissions from road transportation to and from loading points, and do not distinguish between goods arriving in bulk and non-bulk transport.

Table 5: DEFRA's freight and passenger mileage conversion factors (DEFRA 2005a)

Freight transport mode		Tonne km	x	Factor	Total kg CO_2
Air	Long haul		x	0.57	
	Short haul		x	1.58	
Ship	Large bulk carrier		x	0.007	
Passenger transport mode		Km	x	Factor	Total kg CO_2
Petrol car	Medium petrol car From 1.4 – 2.1 litres			0.22	
		Person/kms	x	Factor	Total kg CO_2
Air	Long haul			0.11	
	Short haul			0.18	

[9] Concerns have been raised on the accuracy of this data. According to the trade data providers, Business and Trade Statistics Ltd, goods from a non-EU country and stored temporarily in an EU country are sometimes being coded as of EU origin or being coded with the correct origin but with the last mode of transport. For example, in 2004 Government statistics showed that 11per cent of bananas entering the UK came from other EU states, predominately Belgium, France, Ireland and the Netherlands (Marriott, 2005).

[10] DEFRA (2005c) *the Validity of Food Miles as an Indicator of Sustainable Development*. Report produced for DEFRA by AEA Technology.

Box 2: How aviation emissions are calculated and allocated

Emissions from international aviation are not currently allocated to parties in the Kyoto Protocol and no methodology on how to allocate emissions has yet been agreed within the UNFCCC. Those currently allocating emissions to national inventories for other purposes are in-the-main allocating emissions to the country where bunker fuel is sold or uplifted. This is UNFCCC allocation option three. Equally, future allocation will need to account for other principles of the Kyoto Protocol such as equity and economic development and deal with issues such as historical emissions.

There are also tremendous variations in the way in which emissions are being calculated. Some governments, such as the Finnish, are using sophisticated computer modelling which when calculating emissions from domestic aviation draws on the averages for all emissions for each aircraft engine as provided by the engine manufacturers. The computer then uses traffic statistics which include type of aircraft, flight time, take-off and landing airport and calculates emissions for each pollutant for each flight segment. Other methods employed, such as those employed by AEA (DEFRA, 2005c) to calculate emissions from the air-transportation of food, include the use of existing standard emission factors, such as those provided by DEFRA. There is a range of emission factors for long-haul air freight in circulation, some of which account for radiative forcing. A sample of existing emission factors for long-haul air freight is provided below.

Source	Emission factor	Used by
DEFRA (2005a)	0.00057 CO_2 kg per kg/km	Marriott (2005) to calculate emissions from air-freighted fresh produce
AEA from *Validity of Food Miles* (DEFRA, 2005c)	0.001539 CO_2e kg per kg/km	By AEA/DEFRA (2005c) to calculate CO_2e emissions from air- freighted food
CE Solutions for environment, economy and technology, Netherlands	0.00141828 CO_2e kg per kg/km	By van Hauwermeiren et al. (2006) to calculate CO_2e emissions from air-freighted Kenyan tomatoes
VTT Technical Research	0.000719 CO_2 kg	No examples found

Depending on whether the RFI is incorporated into calculations, emissions from the air and sea shipping stages for SSA FFV were found to range from 279,000 tonnes to 686,000 tonnes (**Figures 8 and 9**). Comparing across SSA countries, it is clear that air freight emanating from Kenya alone rises from nearly 350,000 tonnes of CO2 when a RFI of 2.7 is applied (**Figures 10 and 11**).

Figure 8: CO2 emissions from the sea and air transportation of FFV imports to the UK from SSA for 2005 (thousand tonnes C02) – the standard DEFRA emission factors were used and no RFI was applied

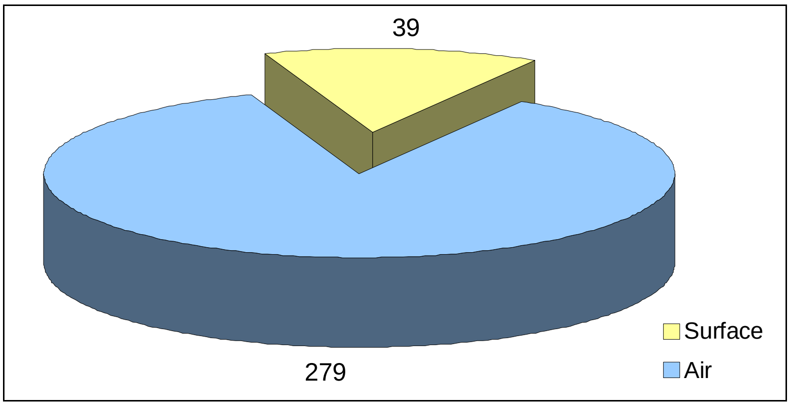


Figure 9: CO2 emissions from the sea and air transportation of FFV imports to the UK from SSA for 2005 (thousand tonnes C02) – the standard DEFRA emission factors were used and a RFI of 2.7 was applied

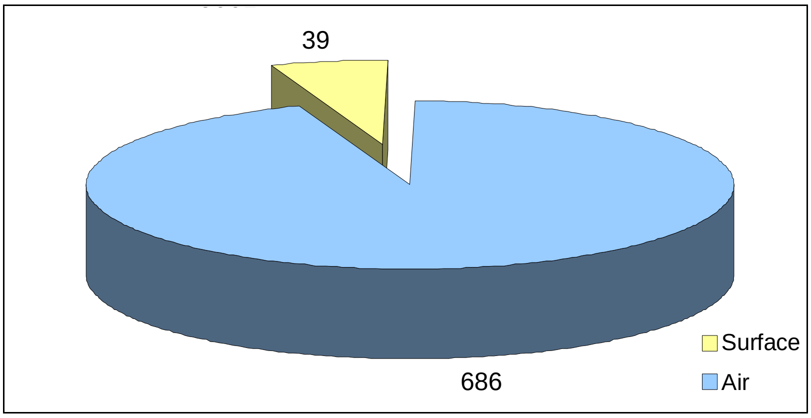


Figure 10: Tonnes of CO2 from the sea and air transportation of FFV imports to the UK from SSA – 2005 – the standard DEFRA emission factors were used and no RFI was applied

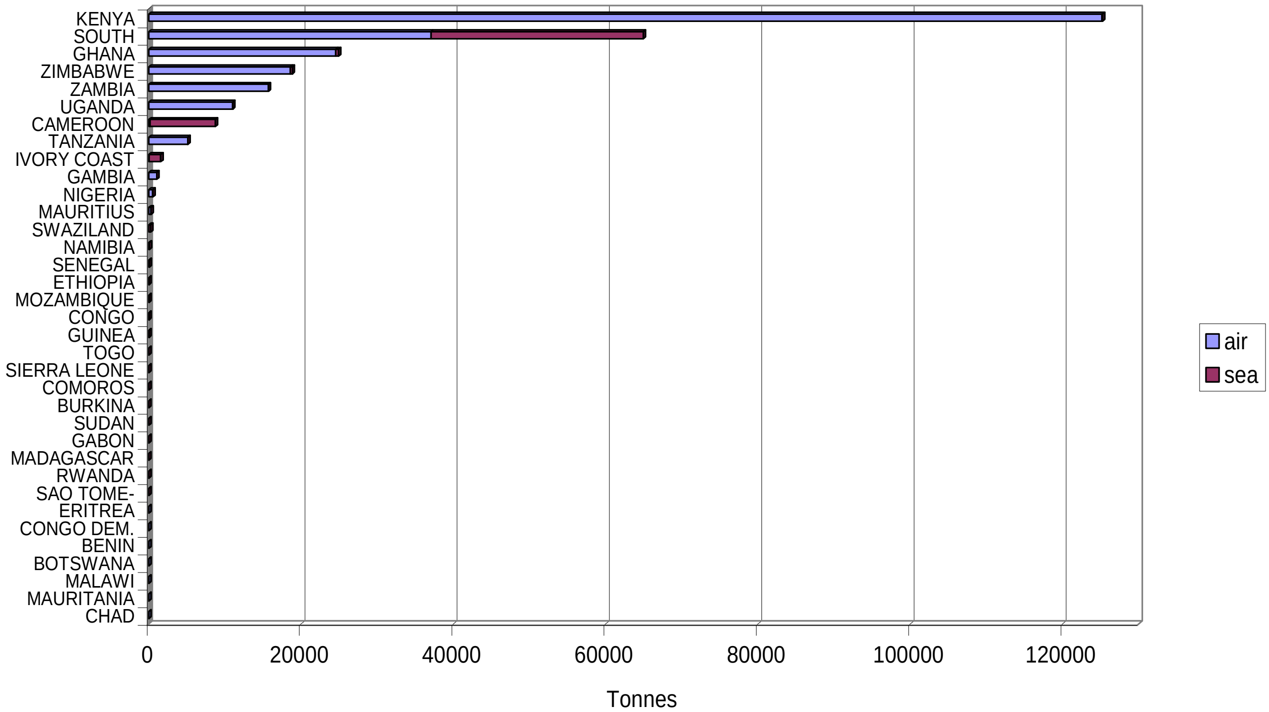
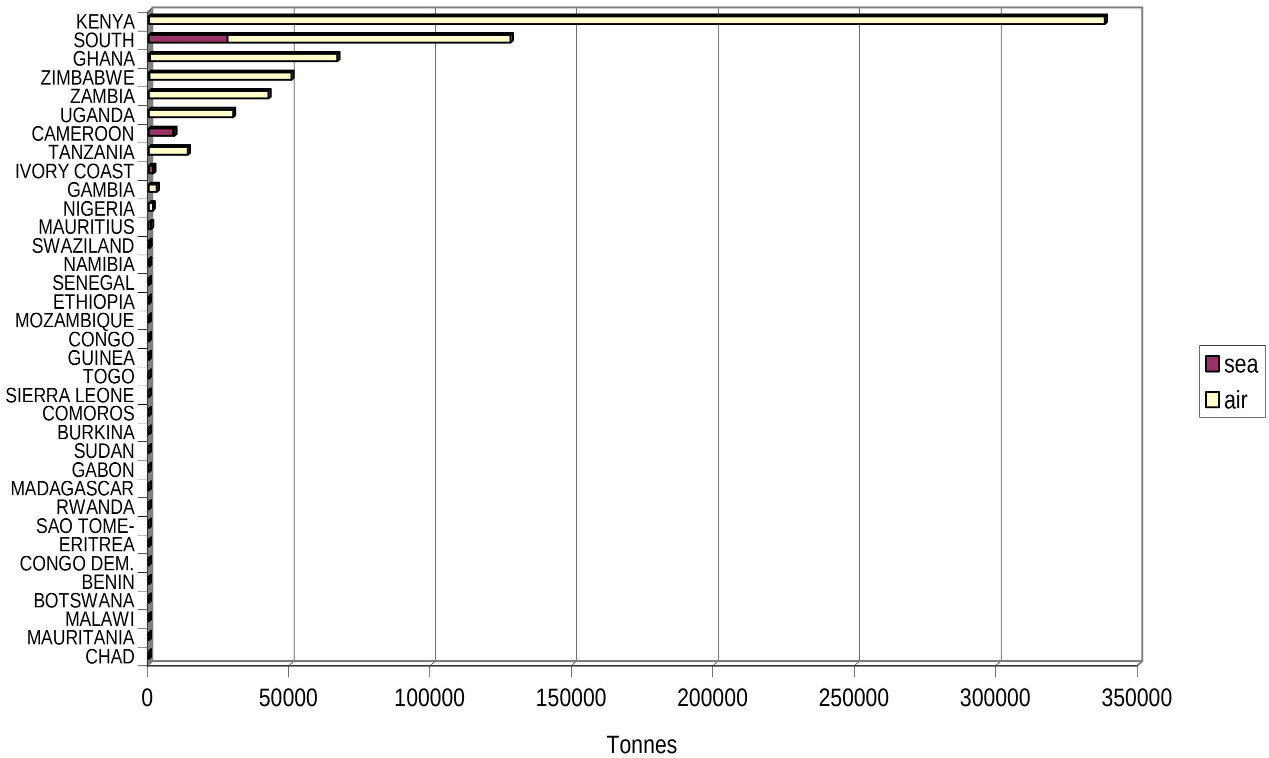


Figure 12: Tonnes of CO2 from the sea and air transportation of FFV imports to the UK from SSA – 2005 – the standard DEFRA emission factors were used and a RFI of 2.7 was applied



3.2 Comparing SSA FFV air freight emissions

DFID is particularly interested in comparing emissions from SSA FFV exports, especially air-freighted exports, with produce from other sources and other transportation modes. While it has not been possible to compare emissions from the entire export market, it is possible to compare air-transport emissions from a product, such as a packet of green beans, with other modes of transport and activities. The following comparisons again are based on DEFRA's emission factors and all incorporate the IPCC's RFI of 2.7.

City Break in Barcelona[11,12]
A return flight from London to Barcelona compares with 420 packs of air-freighted Kenyan green beans (250g)

Week in the Big Apple[13]
A return flight from Liverpool to New York compares with 1,200 packs of air-freighted Kenyan green beans (250g)

The school run[14]
A 250g pack of air-freighted Kenyan beans compares with 12 school runs in the car

Using your laptop[15]
A 250g pack of air-freighted Kenyan beans compares with using a large laptop every week day for a month

Sea-Freighting compared to Air-Freighting[16]
A 250g pack of air-freighted Kenyan beans compares with 177 250g packs of sea-shipped Kenyan beans (beans are not usually sea-shipped - this has been used to illustrate the difference)

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[11] Assumptions: Green beans from Kenya were flown 6840km. These comparisons are limited to greenhouse gas emissions from transportation, except in the comparison with a laptop where emissions from transportation are compared against those from electricity generation (see below). None of the comparisons have included emissions from other stages in the product life cycle, for example, fuel refining, production of equipment, etc. and no other environmental effects are considered in these comparisons, such as loss of ecosystems from port expansions, etc.

[12] Distance from London to Barcelona is 1,137km

[13] Distance from Liverpool to New York is 5,560km

[14] The school run was made in a mid-size car (1.4-2.1 litre) which made one return journey totalling 1.9308 km (0.6 miles each way).

[15] The laptop uses 36w, 5w and 3w of electricity in on-mode, standby-mode and off-mode respectively. The laptop is on 5 days a week for 7hours, 3hours and 14 hours in each of the modes. The electricity used produces 0.45kg CO_2 per kWh. The total annual electricity consumption was generated using the Energy Calculator for PC Equipment provided by EU Energy Star (http://www.eu-energystar.org/en/en_008.htm#equipment)

[16] Green beans from Kenya were shipped 9921km from Mombassa to Liverpool. The sea-shipped produce are calculated using DEFRA's Guidelines for Company Reporting on Greenhouse Gas Emissions, using the emission factor for a large bulk carrier (14,201 deadweight tonnes, max speed 11.2 knots)

4 Conclusions and recommendations

Research reviewed for this briefing found that air-freight has the highest global warming potential of all modes of transport, and that the air-transportation of FFVs has high positive climate impacts (warming) relative to other life cycle stages in FFV production and consumption. There may be cases, such as for cut flowers, where energy consumption is lower for air-freighted SSA imports than regionally or locally grown produce, but rather than generate support for air-freighted produce, this is likely to raise concerns about the use of non-renewable energy in greenhouse production.

A conclusion emerging from the research reviewed for this report is that FFV imports, which are sea-transported, have comparable emissions to regional open-air produce. Emissions from sea transportation can be offset by favourable climate conditions and a less mechanised production system in exporting countries (Fuentes & Carlsson-Kanyama, 2006) as was found to be true for South American frozen broccoli. Sea transportation of New Zealand lamb was found to use less energy than that used during the transportation of lamb produced regionally in Germany, and beneficial climatic conditions in New Zealand were found to result in less energy use than German operations (Fleissner and Schlich, 2005). Furthermore, due to developments in shipping technology, some fresh produce previously only flown can now be shipped, as is the case for Latin American asparagus. The author recommends that DFID examine the possibilities and effects of supporting a gradual shift away from export produce reliant on air transport to produce that can be sea-freighted. Our research shows that transport of produce from Kenya to the UK by ship (1.7 MJ/kg produce) rather than by plane (57.8 MJ/kg produce) would result in a significant energy saving of 56 MJ/kg produce

There is scope to better communicate the benefits of the FFV export market to low-income producers in SSA. Criticisms of air-freighted FFVs are often discussed along with support for buying food locally. This latter debate goes beyond environmental concerns to encompass a myriad of social, environmental, cultural and economic issues. Support for local food reflects such concerns as the protection of rural communities, the connection between the public and food and farming, and the concentration of trade in the hands of fewer businesses. Criticisms of FFV imports can be weighed against their development benefits, if it can be established and illustrated that the trade really benefits those living in poverty whilst having a relatively neutral or even positive environmental impact. Connections made between SSA small-holders and the British public could also facilitate future DFID development objectives.

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Appendix 1: Summary of reviewed studies

The studies reviewed for this report were selected because they were the most relevant found during a literature search and through consultations with the authors' networks. The literature search was done within a very short period of time and as such there is a strong probability that relevant studies have been overlooked.

With one exception, the criteria for selecting a study for this review were that it calculates the energy used, carbon emissions and/or greenhouse gas emissions from one or more life cycle stages of a fresh or processed horticultural product. We reviewed the objectives, methodological approaches, and results and evaluated the relevance to this project of each of the studies. At the end of this section we provide an overview of all of the studies.

The following studies were reviewed:

Reference	Study
1.	Fleissner and Schlich (2005). 'The Ecology of Scale: Assessment of Regional Energy Turnover and Comparison with Global Food'. *International Journal of Life Cycle Assessment* 10 (3): 219 – 223
2.	Anne Van Hauwermeiren, Hannelore Coene, Chris Claes, Erik Mathijs (2006). 'Energy life cycle inputs in food systems: a comparison of local versus conventional cases'. Submitted to *Journal of Environmental Policy and Planning.*
3.	Hatirli, S.A., Ozkan, B., Fert, C., (2006). 'Energy inputs and crop yield relationship in greenhouse tomato production'. *Renewable Energy*31 (4): 427-438
4.	Vringer, K., and Block, K. (2000). 'The energy requirement of cut flowers and consumer options to reduce it'. *Resources, conservation and recycling* 28 (2000): 3-28
5.	Fuentes C. & Carlsson-Kanyama (Eds) (2006). *Environmental Information in the Food Supply System.* Swedish Defence Research Agency. Stockholm, Sweden
6.	Carlsson-Kanyama, Ekstrom, Shanahan (2003). 'Food and life cycle energy inputs: consequences of diet and ways to increase efficiency'. *Ecological Economics* 44 (2003): 293-307
7.	Mason, R., Simons, D., Peckham, C. and Wakeman, T. (2002). *Life Cycle Modelling CO2 Emission for Lettuce, Apples and Cherries*. DfT commissioned Transport 2000 study, part of Transport 2000's Wise Moves project
8.	Jones (2002). Environmental Assessment of Food Supply Chains: A Case Study on Dessert Apples. *Environmental Management* 30 (4).

1. Fleissner and Schlich (2005)

Relevance for this project: The authors conclude that energy used in long-distance sea transport can be easily be off-set by efficiencies gained in large-scale processing and transportation, and to a lesser extent by climatic conditions which require less energy use during the production stage.
Objective: Two-fold: to calculate the direct energy use in kWh per kilogram for two example products from either regional or global supply chains; and to research the relevance of operation size to direct energy use.
Products: Orange juice (concentrate from Brazil and shipped to diluting companies in Belgium and Holland) and apple juice (both concentrated and pressed from Germany, Poland, Britain and Italy) and frozen New Zealand and fresh German lamb – all sold in Germany.

Methodology: Calculates direct energy use within the manufacturing, transportation and distribution stages, obtaining data via in-person interviews with operations staff and from energy bills.

System boundary: Primary energy consumption only. Juices: manufacturing, transportation and distribution. The study omits the agricultural production stage for juice. The authors' work has been criticised (Jungbluth and Demmeler, 2005) for omitting energy use in orange plantations. Lamb: energy use up to farm gate, transportation, processing, distribution. This study does not explicitly state which elements of these stages are being included or omitted.

Unit of measurement: kWh per kilogram or litre of produce

Results and conclusions: The authors emphasise that despite the differences in distances transported, the size of operations represented a greater environmental hotspot than transport; small squeezers were found to need more energy to produce and distribute their produce. For lamb, again smaller producers were found to use more energy. Sea transportation from New Zealand was found to use less energy than that used during the transportation of lamb produced regionally. Overall climatic conditions in New Zealand resulted in less total energy use than by the German operations reviewed. Juice produced by companies squeezing up to 100 tonnes of fruit per year consumed 1.5–3.2 kWh/l, while juice produced by companies squeezing more than 2000 tonnes per year consumed 0.4–0.7 kWh/l. Both include transportation. There was no data provided on mid-size operations although Jungbluth and Demmeler (2005), stated that mid-size companies did exist.

2. Anne Van Hauwermeiren, Hannelore Coene, Chris Claes, Erik Mathijs (2006)

Relevance for this project: the authors found that air-transportation (Kenya to Belgium) was the single most significant stage of the life cycle. Emissions from a kilogram of tomatoes ranged by two orders of magnitude: from approx. 100g to 10kg of CO_2e. Heated greenhouse production added approximately 1.5kg CO_2 per kilogram of produce while air freight added approximately 8kg CO_2e per kilogram. This compared with 78-199g for processing and storage.

Objective: compare Belgium local and mainstream (i.e. supermarket) food distribution systems

Products: Items from a typical Belgian meal available in both systems: beef, potatoes, cabbage lettuce, tomatoes (Kenyan, Belgium and Spanish), carrots, apples and Gouda cheese

Methodology: Calculates energy use and CO_2 emissions drawing on data collected during interviews with producers and supplemented with assumptions on transportation distances, emission factors and other parameters

System boundary: transport from farm to retailers (not loading), processing, and storage within Belgium, supplemented with calculations based on data from literature for energy /CO_2 emissions from heating greenhouses, transporting produce from overseas and transporting food from the retail outlet to the consumer's home

Unit of measurement: MJ and CO_2 per kilogram produce

Results and conclusions: Greenhouse gas emissions for all stages covered in this research range from 0.094kg CO_2 per kilogram (regional open-air fresh tomatoes purchased on foot) to 9.361kg CO_2e per kilogram (imported air-freighted Kenyan tomatoes purchased by car). The smallest emission was 0.0473kg CO_2e per kilogram for storing and processing tomatoes, and the largest 8.510kg CO_2e per kilogram for air freighting tomatoes from Kenya. The authors found that local food distribution systems resulted in slightly more energy use and CO_2 than supermarket distribution systems. This was because supermarkets had higher load factors and more energy efficient vehicles and storage facilities and faster turnover (less time in storage). They also found that:

- In almost all cases, data was lower for processing and storage than transport
- There was a large variation in energy use and CO2 between products
- The most significant factors in the life cycle were air transportation, energy used in heating greenhouses and private car use for shopping

3. Hatirli, S.A., Ozkan, B., Fert, C., (2006)

Relevance for this project: The authors present evidence that small farms are more efficient than large farms. They also quantify the range of energy used in different stages of Antalyan tomato production (to farm gate).
Objective: To examine energy inputs and yields for different greenhouse farm sizes
Products: Antalyan tomatoes
Methodology: The authors selected a representative region, the Antalya province of Turkey, and randomly selected 40 greenhouse operators in two villages where greenhouse farming is a central economic activity. Farmers' responses were collected via in-person interviews using a structured questionnaire.
System boundary: All on-farm energy inputs (and outputs):
Unit of measurement: MJ per hectare and kilogram per hectare
Results and conclusions: On average, the energy consumed by all inputs on the sample farms was 0.835 MJ per kilogram of tomatoes. The authors conclude that Turkish tomato production is heavily dependent on fossil fuels, and 88 per cent of energy used in production was from non-renewable sources. The largest three inputs in MJ per hectare were: diesel oil, fertiliser (foremost nitrogen) and electricity. Smaller sized farms, run as a family business, are more efficient than larger farms. This is hypothesised to be because small farms are family business providing the sole source of family income thereby incentivising efficient production.

4. Vringer, K., and Blok, K. (2000)

Relevance for this project: This compares the energy required to produce a rose in Holland in a heated greenhouse with that required to produce and air transport a Kenyan rose.
Objective: to look for options for householders to reduce energy consumption resulting from the purchase of cut flowers, without reducing their consumption of flowers.
Products: 37 most common types of Dutch flower
Methodology: Data provided by the Information and Knowledge Centre for Agriculture and Horticulture, calculations made via EAP computer programme. No more information on methodology given.
System boundary: decontamination, herbicides, water, packaging, transport to the auction, auction, natural gas and electricity requirements, with data from literature for energy requirements of Kenyan, Israel, Spain and Morocco.
Unit of measurement: MJ/Dfl and MJ per flower (stem).
Results and conclusions: Dutch flowers were found to be extremely energy intensive, consuming between 3MJ to 195MJ per stem. Flowers cultivated in warmer climates do not consume energy in the heating of greenhouses and as a result consume significantly less energy. This, report the authors, is true even when factoring in the energy consumed during air transportation. Kenyan flowers are calculated at 2-3MJ (single rose), including air transport while the Dutch rose is calculated at 9.5MJ (single rose), three times the energy requirement. Within Holland, flowers grown in heated greenhouses consume four times the amount of energy as those grown outside, and flowers grown in winter consume more energy than those produced in summer. The authors do note, however, that energy consumed in Kenyan production is set to rise while the energy consumed in Dutch production systems is set to decrease.

5. Fuentes C. & Carlsson-Kanyama (Eds) (2006)

Relevance for this project: Quantifies energy use and greenhouse gas emissions, in carbon dioxide equivalents, for almost the entire life cycle of a range of fresh and frozen food products of various origins. Countries of origin include distant low-income countries. As other studies, the authors find that emissions from sea-transportation can be off-set by favourable climatic conditions and less energy intensive production systems in the exporting countries

Objective: To produce data on all parts of the food supply chain for food purchasing managers seeking to reduce overall environmental impact of food consumption

Products: Group 1: carrots, onions, tomatoes. Group 2: broccoli, legumes, chicken from various countries of origin

Methodology: Group 1 – data collected on site via interviews. Group 2 – 'case-specific data complemented by literature studies'

System boundary: This is the most comprehensive study of those detailed in this report. The study researches energy use and emissions from production (on-farm), production and distribution of raw materials and energy carrier, storage, processing, packaging and delivery, in the case of Group 1 – to the wholesaler or caterer, and for Group 2 - to the private household. It omits only embodied energy in machinery and vehicles, home food storage and processing and waste handling (except on-farm and in processing plants)

Unit of measurement: MJ and GWP per kilogram of produce. Water use, use of chemical agents and land use are also covered in this study but not reported here.

Results and conclusions: Greenhouse gas emissions for all stages covered in this research range from 0.069kg CO2e per kilogram (regional open-air fresh carrots) to 3.65kg CO2e per kilogram (imported Danish hothouse tomatoes). This compares with 0.90kg CO2e per kilogram for South and Central American frozen broccoli or 1.4kg CO2e for canned imported cooked beans. These examples highlight the energy intensity of heated greenhouse production. Emissions from imported broccoli (South/Central America) can be in range with European and domestic counterparts because of the lack of mechanisation in the exporting countries and partly due to the relatively low transport emissions per kilogram of food transported generated by bulk sea carriers

6. Carlsson-Kanyama, Ekstrom, Shanahan (2003)

Relevance to this project: examined and compared the life cycle inputs for 150 'everyday foodstuffs', including tropical air-freighted fruits

Objective: To provide information to those interested in supporting more sustainable food production and consumption

Products: 150 'everyday foodstuffs'

Methodology: Collated data from existing studies

System boundary: crop production (fertilisers, tractor fuel, crop drying, etc.), animal husbandry, food processing and preparation, storage, transportation, home transportation, home preparation and cooking.

Unit of measurement: MJ per kilogram

Results and conclusions: Found that energy inputs in food life cycles vary from 2 (cooked Swedish barley) to 220 MJ (cooked shelled shrimps) per kilogram. Significant factors: animal or vegetable origin, degree of processing and choice of processing, preparation technology, transportation mode and distance. The authors found that fresh tropical fruits from overseas transported by plane have energy inputs of 115 MJ per kilogram

7. Mason, R., Simons, D., Peckham, C. and Wakeman, T. (2002)

Relevance for this project: Another quantification of transport emissions from various modes of fresh fruit and vegetable transport, including air transportation, this time with a smaller system boundary; emissions from consumer and waste transportation was not included.

Objective: As part as a DfT commissioned project, to provide information to support the move towards "less energy intensive goods sourcing and distribution".

Products: Cherries (USA, Turkey, UK and 'Southern Hemisphere', apples (UK, New Zealand, Europe), lettuce (Spain, UK).

Methodology: Questionnaire to selected commercial food businesses

System boundary: Overseas transport, transport to UK processor, distribution centre and retailer. Transport of primary and agricultural inputs, packaging, waste and consumer transport were not included.

Unit of measurement: CO2 ratio

Results and conclusions: 'Southern Hemisphere' cherries had the largest carbon dioxide ratio (11.43) and UK lettuce the smallest (0.0147). This reflects both the distance travelled and mode of transport. As a product group, cherries were found to have the greatest emissions (3.128 kg CO2 per kg), reflecting the proportion of American cherries arriving in air-transport. Again reflecting the findings of other studies, whilst apples were found to have travelled further than cherries, they had lower CO2 emissions (0.109 kg CO2 per kilogram) as they almost entirely arrived on surface transport. Lettuce travelled the least and was responsible for the smallest emissions, reflected in both mode of transport and distance (0.0436 kg CO2 per kilogram). The authors highlighted the role of transport refrigeration in transport emissions and the need to reduce refrigerant CO2.

8. Jones (2002)

Relevance for this project: Compares the contribution of long-distance transportation to overall environmental impacts (in CO2 emissions and MJs per kilogram) with home-grown, locally and nationally produced apples and with energy used in apple cultivation.

Objective: To assess the environmental impacts of the predominant fresh apple supply chains; to determine the most environmentally benign option; to share this work with policy-makers and consumers; and to evaluate the effectiveness of the methodology employed.

Products: Apples – imported from the USA, home-grown, UK or locally sourced (40km), combined with three variables for outlets (supermarket, street market or home delivery service) and two variables for customer transportation (2 or 3 miles)

Methodology: Means /end analysis which models and compares all possible transport life cycles for fresh apples

System boundary: Transportation stages to the home (excluding transportation of packaging raw materials, packaging to wholesalers, agricultural raw materials, and agricultural inputs to farm).

Unit(s) of measurement: CO2 emissions and MJs per kilogram

Results and conclusions: In the case of imported fresh apples, the transport energy consumption is greater than the energy consumed in intensive commercial cultivation, which is calculated at 0.5MJ/kg apples. This compares with 0.514 – 4.866 MJ/kg apples used in transportation. Home-grown production and local sourcing were found to be the most benign options, followed by national sourcing, with imported produce having the greatest environmental impact. The transport emissions ranged from 0.401 kg CO2 emissions per kilogram (imported from USA, purchased during a shopping trip of 3km in a medium size car) to 0.016 CO2 emissions per kilogram (locally sourced, home delivered). The most significant transport stages are private car use, long-distance shipping and domestic road freight.

Comments

- Private car use, air freight and heated greenhouse production were found to be the most significant contributors to emissions and energy consumption.
- Emissions from sea-transportation of frozen FFVs can be off-set by favourable climate conditions and less energy mechanised production systems in export countries (Fuentes & Carlsson-Kanyama (Eds), 2006).
- Sea transportation of New Zealand lamb was found to use less energy than that used during the transportation of lamb produced regionally. Furthermore, beneficial climatic conditions in New Zealand resulted in less total energy use than by the German operations reviewed (Fleissner and Schlich, 2005).
- Smallholders are more energy-efficient than large farms (Hatirli et al., 2006). This is hypothesised to be because small farms are family businesses providing the sole source of income thereby incentivising efficient production. But large processors are more energy-efficient than small processors (Fleissner and Schlich, 2005).
- Supermarket distribution systems were found to be more energy-efficient than local distribution systems (van Hauwermeiren et al., 2006)
- There is a disparity in the figures for energy consumption resulting from private car use given in Jones (2002) and van Hauwermeiren et al. (2006), with the latter providing figures many times larger.
- What is clear from the LCAs is that there are multitudes of ways in which system boundaries can be drawn. This can go as far as accounting for the embodied energy in the vehicles moving the goods. As well as its own system boundary, each study has its own set of assumptions, such as emission factors, average distance travelled for grocery shopping, size of vehicle, and so forth.
- Some studies account for radiative forcing (van Hauwermeiren et al., 2006) while others do not (Mason, et al., 2002)

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For more information contact:
contact@agrifoodstandards.net

agrifoodstandards.net

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