FRUIT AND VEGETABLES & UK GREENHOUSE GAS EMISSIONS:

EXPLORING THE RELATIONSHIP

WORKING PAPER PRODUCED AS PART OF THE WORK OF THE FOOD CLIMATE RESEARCH NETWORK

TARA GARNETT
CENTRE FOR ENVIRONMENTAL STRATEGY
UNIVERSITY OF SURREY

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GLOSSARY

1-MCP	1-methylcyclopropene
BMI	Body Mass Index
CA	Controlled Atmosphere (storage)
Cal/lb	Calories per pound
CCA	Climate Change Agreement
CHP	Combined Heat and Power
CHRP	Combined Heat, Refrigeration and Power
CO_2e	Carbon dioxide equivalent
CSDF	Cold Storage and Distribution Federation
Defra	(UK) Department for Environment Food and Rural Affairs
DTQ	Domestic Tradable Quota
DUKES	Digest of UK Energy Statistics
EMR	East Malling Research
EU	European Union
FAO	United Nations Food and Agriculture Organization
FCRN	Food Climate Research Network (University of Surrey)
FrPERC	Food refrigeration and Process Engineering Research Centre (University of Bristol)
FSA	(UK) Food Standards Agency
GHG	Greenhouse Gas
GW h	Gigawatt hours
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HGV	Heavy Goods Vehicle
HRI	Horticultural Research Institute
IGD	Institute of Grocery Distribution
INCPEN	Industry Council for Packaging and the Environment
IPCC	Inter-governmental Panel on Climate Change
IPM	Integrated Pest Management
kW h	Kilowatt hours
LCA	Life Cycle Analysis
LDPE	Low density polyethylene
MAP	Modified Atmosphere Packaging
NDNS	National Diet and Nutrition Survey
NFC	Not From Concentrate
NOP	National Opinion Polls (polling organization)
PSL	Practical Storage Life
RDC	Regional Distribution Centre
TJ	Tera Joules
USDA	United States Department of Agriculture
WHO	World Health Organization
WRAP	Waste Resources and Action Programme

SUMMARY

1. Consumption of fruit and vegetables accounts for around 2.5% of the UK's greenhouse gas emissions.

2. The trends suggest that consumer demand for the more greenhouse gas intensive fruits and vegetables is growing.

3. The most greenhouse gas intensive stages of the fruit and vegetable supply chain are transport and refrigeration. Waste is also highly significant since food that is produced but not eaten represents a waste of the energy used in its production, processing and distribution.

4. GHG intensive fruits and vegetables include:

- Air freighted produce: Typical examples include US berries and cherries, African green beans and peas, and pre-prepared salads produced outside Europe;
- Unseasonal Mediterranean style produce: Grown either in heated greenhouses in the UK or under protection (sometimes heated) overseas. Examples include tomatoes, courgettes, aubergines, peppers and salads;
- Pre-prepared, trimmed or chopped produce: Examples include salad bags and bowls, fruit salads and cut pineapple
- Fragile or highly perishable foods: These foods are prone to spoilage, which represents a waste of the energy embedded in their production, transport and storage

5. The least greenhouse gas intensive fruits and vegetables are seasonal field grown UK produce cultivated without additional heating or protection, which are not fragile or easily spoiled. Overseas grown produce which is reasonably robust, cultivated without heating or other protection and which is transported by sea or short distances by road are also fairly low in their greenhouse gas intensity. A GHG reduction strategy for fruit and vegetables is one which promotes the production and consumption of these kinds of foods.

6. Total self sufficiency (even if this were possible) is unlikely to be 'the' optimal answer since there are trade offs between import-related transport and mobile cold storage emissions on the one hand and waste and stationary cold storage emissions through the storage of indigenous food on the other.

7. Air freight is an area of particular concern. Around 1.5% of imported fruits and vegetables travel by air but this 1.5% accounts for around half of all emissions associated with fruit and vegetable transport, excluding travel to the shops. Including shopping trips, the air freighting stage accounts for two fifths of transport emissions.

8. Nothing is being done to tackle the problem of air freight and the sector is growing at 6% a year. If unchecked, air freighting of fruits and vegetables is set to grow. Little is being done to address transport emissions (and other environmental impacts) from roads and shipping even though here too trends suggest that imports are set to grow.

9. Refrigeration is another life cycle 'hotspot.' Key areas of concern include refrigeration in transit, excessive time spent in cold storage and in supermarkets. Food which is

transported long distances or stored for long periods of time will be refrigeration-intensive.

10. Wasted food represents a waste of the energy used and emissions produced during the course of growing, refrigerating and transporting food. Around 25% of all harvested fruits and vegetables are never consumed. Waste levels are highest in the home and in the food service sector. A reduction in food waste means a reduction in 'unnecessary' greenhouse gas emissions.

11. Improvements in energy efficiency at all stages in the supply chain are necessary. However action to address consumer behaviour is also vital both as regards people's choice of certain products and their treatment of those products - how they travel to buy them, how they store and cook them, whether they waste them.

12. Consumers cannot voluntarily be expected to change their behaviours. The political, economic and social context in which they choose and consume food needs to change.

RECOMMENDATIONS

Headline recommendations:
- **Reduce the air freighting of food**
- **Promote cleaner and renewable technologies in the protected horticulture sector**
- **Improve refrigeration efficiency**
- **Tackle waste particularly at the household and catering stages**
- **Foster behaviour change**

Air and other freight transport: Tackle the growth in air freight; improve efficiency in road and sea transport.
RELEVANT PARTNERS: Supermarkets, freight forwarding industry, DfID

Horticultural production: More support and promotion of renewable technology and combined heat and power for commercial glasshouses.
RELEVANT PARTNERS: Horticultural Development Council, Horticultural Research Institute, Farm Energy Centre, produce trade associations.

Refrigeration: Further efforts to improve refrigeration efficiency at all stages in the supply chain and particularly in mobile units. Examine relationship between refrigeration, transport and waste in more detail.
RELEVANT PARTNERS: Universities (eg. Brunel and Bristol), consultancy, Cold Storage and Distribution Federation and other trade associations, supermarkets, Freight Transport Association, Market Transformation Programme.

Household: Promote energy efficient cooking and refrigeration appliances; promote energy conserving cooking and storing techniques
RELEVANT PARTNERS: Market Transformation Programme, UK Energy Research Centre, Energy Saving Trust; retailers; appliance manufacturers, media.

Waste: Reduce household and food service stages

RELEVANT PARTNERS: Waste Resources Action Programme, Biffa, supermarkets, hospitality trade associations, local authorities; the media.

Behavioural change

- Develop the concept of the Domestic Tradeable Quota further. Consider how food and drink might eventually be incorporated into such a scheme.
- Retailers should routinely report on the tonnage of produce they import by air each year and make that information clearly available to the public.
- Increase consumers' awareness of the connection between their food consumption behaviours and climate change. The focus should be wider than food miles alone.
- Increase consumers' awareness of the environmental implications of food waste.
- Seek to combine healthy eating and environmental messages

RELEVANT PARTNERS: Retailers, UK Energy Research Centre, WRAP, media.

INTRODUCTION

a. Purpose

The purpose of this paper is twofold. It considers what we know about the contribution that the fruit and vegetable sector makes to the UK's greenhouse gas emissions. It also looks at what we know about the options for achieving emissions reductions.

As regards the sector's contribution to emissions, an attempt is made to identify where the significant emissions hotspots lie along the life cycle, taking into account agricultural production, transport, processing, cold storage, cooking and waste; the relationship and interactions among these different life stages are also considered. Complementing this approach, the paper also considers particular categories of produce - field vegetables, glass house produce, tree fruit, soft fruit and so forth – and asks whether we can usefully categorise energy intensity by category.

When considering the options for reducing emissions, both the technological possibilities and approaches which focus on the need to change consumers' behaviour are explored. An attempt is also made to examine more closely the relationship between technological change and what and how we consume.

The paper also looks at the emissions reduction issue in relation to government's stated public health policy of encouraging us to eat more fruit and vegetables. It asks what the implications for fruit and vegetable greenhouse gas emissions might be were this goal to be fulfilled and whether there might be more or less carbon-intensive ways for nutritional goals to be achieved.

It is important to note that the focus here is on greenhouse gas emissions (largely, although not entirely, on carbon dioxide). There are of course other important areas of environmental concern for the fruit and vegetable sector including pesticide and water use, as well as social issues such as trade with, and economic development in, developing countries. These have been considered by others and it is beyond the scope of this paper to incorporate these other dimensions.

It is also important to emphasise a key inconsistency in this paper: much of the discussion on *production* focuses on UK horticulture while for our consumption patterns the full range of fruits and vegetables we consume are considered. Evidently we eat both domestically grown and imported produce. The inconsistency arises simply because very little information has been found concerning production methods in other countries. This said, some mention is made of Spanish tomato production and there is also a discussion of transport involved in the imports of fruit and vegetables. The picture presented in the paper is thus unavoidably skewed; on the other hand it highlights the need for a more international approach to quantifying and tackling emissions from this sector.

In conclusion, the paper represents a first step in the research process. It is hoped that the data gaps it identifies and the questions it raises will be addressed in future work.

b. Structure

The report is structured as follows:

Section one provides a brief overview of fruit and vegetable production and consumption: how much we grow, how much we import, and how much, and in what forms, we consume our fruit and vegetables.

Section two seeks to set out what we know about the impact that the fruit and vegetable sector has on the UK's greenhouse gas emissions. This section takes a life cycle approach - in other words it explores what the impacts might be at the production stage, from transport, during cooling and cold storage, in the home, and as a result of the waste that is generated.

Section three is complementary to section two. Rather than looking at each life stage in turn it considers whether there are particular types of fruit and vegetables which we can class as being particularly energy intensive.

Section four looks at government policies with a bearing on the fruit and vegetable sector and considers what influence these have had on the energy intensity and greenhouse gas impacts of this sector. The main focus of discussion is on government health policy where there is a strong emphasis on encouraging us to consume more fruit and vegetables. In addition, other non-health related government policies affecting the fruit and vegetable sector are very briefly highlighted.

Section five explores some of the technological options for reducing greenhouse gas emissions from the fruit and vegetable sector and assesses their potential for achieving reductions.

Section six looks at how changes in consumer behaviour might affect greenhouse gas emissions and what is known about effective strategies to influence behaviour in less energy intensive directions.

Section seven: attempts to summarise some of the findings in this document and to offer some conclusions. It tries to set out what we know about the greenhouse gas intensity of the fruit and vegetable sector and where the hotspots lie, both along the life cycle and by product type. It also tries to assess how far technological improvements can help reduce emissions from this sector and how far changes in people's behaviour will also be achievable and necessary. Finally, it highlights some of the gaps in our knowledge.

c. A note on data and terminology

Data have been compiled from a variety of sources and sometimes slightly different figures are cited for production and consumption, for transport and so on. For example Defra itself gives different figures for fruit and vegetable supplies in two of its own publications – *Agriculture in the UK* and *Basic Horticultural Statistics*. These discrepancies are a result of factors such as different methods of, and different time periods for, data collection. The figures below give – it is hoped – a fair sense of quantities, trends and impacts but should not be considered totally accurate.

Finally, a word about terminology. The focus of the discussion here is on fruit, vegetables and potatoes. Sometimes for clarity the phrase 'fresh fruit, vegetables and potatoes' is used but where the term 'fruit and vegetables' appears this should also be taken to include potatoes, except where it is stated that they have been explicitly excluded. When the term 'vegetables' is used, it includes salads (except when salads are separately specified) but does not include potatoes. Fresh produce should also be taken to mean fresh fruit, vegetables and potatoes. Processed foods include those which have been frozen or canned or which form parts of ready meals and so forth, while 'prepared fresh foods' include ready-to-eat salad bags, pre-cut fruit, ready-to-cook stir fry bags and other foods which are familiar sights on supermarket shelves. Processed potatoes are those which have been frozen such as chips, waffles, croquettes, textured 'smileys' and so forth as well as crisps and their variants.

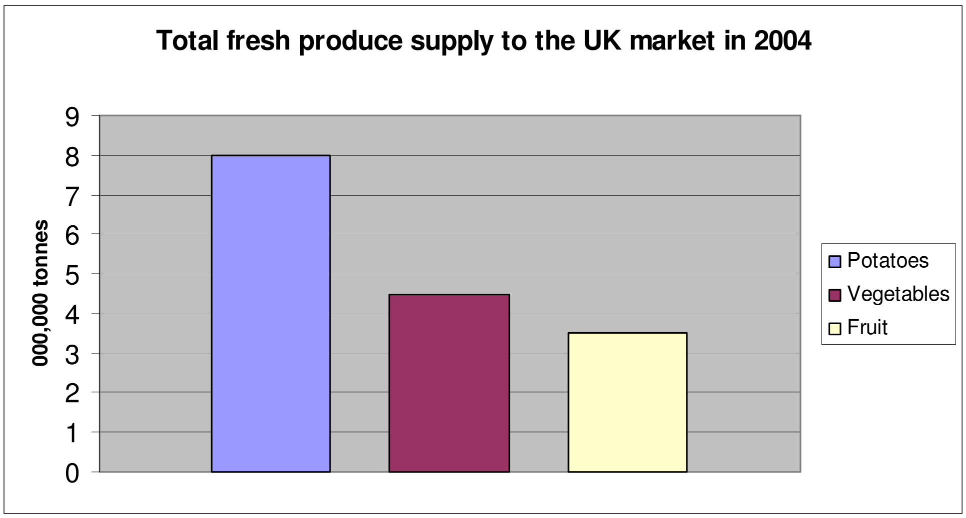
A distinction is also made between field and protected produce. Field produce is a term referring to the cultivation of produce in the soil in open air. Protected crops are those which are grown under protective structures, such as glasshouses, which may be heated.

SECTION ONE: OVERVIEW OF FRUIT AND VEGETABLE PRODUCTION AND CONSUMPTION

1a. Sector overview

In 2004 the supply of fruits, vegetables and potatoes to the UK market totalled 16 million tonnes.[1] Potatoes accounted for 8 million of these, fruit for 3.5 million and vegetables for 4.5 million. Just over a quarter of all this fresh produce went for processing[2] while the remaining three quarters entered the market in unprocessed form (Figure 1). These figures include both home grown and imported produce. However the volume of imported produce which enters the UK already processed (tinned, frozen, pickled, dried and so forth) will be additional to these 16 million tonnes.

Figure 1



Around 60% of all the fresh produce on the UK market is sold through the supermarkets. The remaining 40% is channelled via wholesalers and is either sold on to greengrocers, street-markets and independent stores, or is bought by the food service sector.[3] [4] While the latter in fact purchase the bulk of that 40%, a disproportionate quantity of what caterers buy is potatoes (for turning into chips); relatively few fruit and vegetables reach the end consumer by this route.[5]

The total market value of the fruit and vegetable sector (including potatoes) in 2003 was just over £4 billion, a figure which includes both domestically grown and imported produce.[6] Vegetables (including potatoes) account for just over half of the market value.

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[1] For the potatoes: Agriculture in the UK, Defra, 2005 (2004 provisional figures) and for fruit and vegetables: Basic Horticultural Statistics 2005, (2004 provisional figures)
[2] *United Kingdom Food and Drink Processing Mass Balance*, Biffaward/C-Tech Innovation, 2004 http://www.biffaward.org/downloads/projectfiles/2182-00335.pdf
[3] Fresh Produce Consortium estimate, personal communication, February 2006
[4] restaurants, pubs, hotels and so forth as well as public sector catering services and staff canteens
[5] *Re-fresh directory 2005*, Fresh Produce Journal, London, 2005
[6] *Re-fresh directory 2005*, Fresh Produce Journal, London, 2005

Retail sales of fruit and vegetables were, however, double the farm gate price at over £8 billion (2004 figures).[7]

The processing of fruit and vegetables adds further value. Prepared fruit and salads account for 1% and 13%[8] respectively of the chilled foods sector,[9] which is worth £7.19 billion as a whole and has a 10% share of the UK retail market. Other chilled food categories such as soups, ready meals and sandwiches will also have some form of vegetable component.

As for frozen and canned fruit and vegetables, these were valued at £1.41 billion in 2004.[10]

1b. Self sufficiency

Fruit

At only 9%, UK self sufficiency in fruit is particularly low. Between 1994 and 2004 UK fruit production declined by 24% by volume while imports grew by 38%. Much of this growth can be explained by our overwhelming enthusiasm for bananas, which now rank as the UK's most popular fruit. While our low self sufficiency levels can partly be explained by our taste for fruit not growable in this country, the data show that self sufficiency even in fruits indigenous to the UK, such as apples, pears and plums is still very low, at 16%. This can largely be attributed to the massive decline in UK apple production which almost halved between 1989 and 2003.[11] Self sufficiency in soft fruit is somewhat higher as is discussed below.

Note that figures for UK fruit production do not distinguish between fruits which are sold as fresh and fruits which go on for further processing. For imported fruit, fruits which are imported in the form of jams, jellies and in other preserved states are not included in and will be additional to the figures given above. For simplicity these do not feature in the discussions below.

Vegetables and potatoes

For vegetables, the trends are similar if less extreme. Between 1994-6 and 2004, UK field vegetable production (excluding potatoes) fell by 14%[12] and protected glasshouse vegetable production for the home market fell by 25%.[13] Imports, on the other hand, rose by about 65%[14] Whilst our self sufficiency in vegetables, at 62%, is higher than for fruit, this overall figure masks huge variation within the sector. For example, we are well

[7] Mintel, Fresh Fruit and Vegetables UK, May 2005
[8] prepared salads and stir fry
[9] Chilled Food Association, 2004 *UK retail prepared chilled food market*, http://www.chilledfood.org/Content/Market_Data.asp
[10] Mintel, Frozen and Canned Fruit and Vegetables, June 2005
[11] *re:fresh directory: 2005*, Fresh Produce Journal, London
[12] *Agriculture in the United Kingdom*, Defra 2005, table 5.9
[13] Basic Horticultural Statistics, Defra, 2005, table 14 http://statistics.defra.gov.uk/esg/publications/bhs/2005/veg.pdf
[14] The growth figure is only 16% according to Agriculture in the United Kingdom but this is due to discrepancies in the data for 1994-5. From 1996 onwards figures shown in AUK and BHS are more or less in agreement.

over 96% self sufficient in carrots[15] and 94% self sufficient in fresh potatoes[16] respectively but only 17.1% self sufficient in fresh tomatoes.[17]

Tomatoes are protected crops and our increasing reliance on imports reflects a general decline in the UK protected horticulture sector. Between 1994-2004, the total area under glasshouses declined by 61%. Increased productivity has meant that the decline in output has, at 25%, been less extreme but since our consumption of these glass-house type foods has been growing very rapidly indeed the end result is that we are now relying on imports more than ever. For example while in 2004 the UK production of glasshouse vegetables was 259,000 tonnes, imports came to 948,000 tonnes. In other words, UK self sufficiency in these crops averages just over 20%.

As with fruit, UK grown vegetables which go for further processing are included in the figures given whereas vegetables entering the UK in ready processed form (such as canned tomatoes) will be additional to the data given here.

Organic produce

Most of the fruit and vegetables eaten in the UK are grown using conventional or Integrated Pest Management (IPM) methods. A very small quantity of organic fruit and vegetables however are also consumed – compare the 8,500 tonnes of organic fruit produced in this country[18] with the 329,000 tonnes of fruit the UK produces as a whole and the *3.5 million tonnes* of fruit we actually consume. Self sufficiency in organic fruit at 6.6%[19] is lower even than our self sufficiency in conventionally grown fruit.

The total volume of organic vegetables consumed in the UK was 123,500 tonnes, again very small indeed compared with the 2.65 million tonnes of vegetables we produce as a whole in this country and the 4.5 million tonnes (including imports) that we eat in total. UK self sufficiency in organic vegetables (including potatoes and salads) is similar to that for conventional produce – around 64%.[20]

Self sufficiency in organic fruit and vegetables will of course vary by produce type. For example sufficiency in carrots, parsnips and potatoes are 83%, 86% and 76% respectively[21] whereas for onions they are (bizarrely) only 35%, for cucumbers 43%[22] and for apples 12%.[23]

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[15] Basic Horticultural Statistics, Defra, 2005, table 20 http://statistics.defra.gov.uk/esg/publications/bhs/2005/veg.pdf

[16] *Annual Balance Sheet of Potato Supplies and Disposals 1988-2004*, British Potato Council, 2005

[17] Basic Horticultural Statistics, Defra, 2005, table 20 http://statistics.defra.gov.uk/esg/publications/bhs/2005/veg.pdf

[18] *Organic Market Report 2005*, Soil Association, Bristol, 2005

[19] Organic Fruit Market 2005 (based on 2004 Defra and Organic Monitor data); information supplied by Chris Firth, Henry Doubleday Research Association

[20] Geen N and Firth C. *The UK Organic Vegetable Market (2004-05 Season): Defra Project no. OF 0342*, HDRA *et al*, February 2006

[21] Geen N and Firth C. *The UK Organic Vegetable Market (2004-05 Season): Defra Project no. OF 0342*, HDRA *et al*, February 2006

[22] Geen N and Firth C. *The UK Organic Vegetable Market (2004-05 Season): Defra Project no. OF 0342*, HDRA *et al*, February 2006

[23] Organic Fruit Market 2005 (based on 2004 Defra and Organic Monitor data); information supplied by Chris Firth, Henry Doubleday Research Association

It is not known whether the countries of origin for imported organic differ from those for non-organic; it would be interesting to know how the average distances and mode of travel for organic produce compare with that of their non-organic counterparts.

The decline in self sufficiency is relevant to the discussion about energy use and greenhouse gas emissions within the fruit and vegetable sector; this is discussed more fully in sections two and three. Two reasons for the decline are perhaps most prominent. One is the industry's inability to compete with cheaper production costs overseas. The second is the shift in consumption patterns that have occurred over the last thirty or so years. This issue is discussed in the sub-section that follows.

1c. Consumption patterns

How much do we eat?

Quantifying what it is we actually eat (as opposed to what we buy) is notoriously difficult. The Defra Family Food Survey (2004)[24] calculates that we purchase on average 2.269 kg of fruit and vegetables a week (excluding potatoes) per person per week. This figure does not include purchases of food in restaurants and other catering outlets; including these adds on a tiny 0.033 kg, although vegetables will also probably feature in compound foods such as Indian curries.

Assuming, as the survey does, that 10% of this household food purchased is lost as waste,[25] in effect we actually eat about 2.042kg per person a week. (Section 2f gives an estimate of average domestic waste which in fact suggests that waste levels are a good deal higher than 10%).

Once parcelled up into the Department of Health's recommended 80g 'portions' this 2.042 kg divides into around 3.7 portions of fruit and vegetables per person a day – rather less than the recommended five. Defra calculates that in order to meet its recommended consumption levels we would need to purchase 3.08 kg per person (adults and children) per week.[26] It is important to emphasise again that the Family Food Survey is a record of what we *buy*, not what we *eat*. An alternative survey to consider is the National Diet and Nutrition Survey (NDNS) for England. This is arguably more accurate since it is based on interviews with a representative sample of the population and measurements of actual dietary intakes. This NDNS puts intakes at an even lower 2.8 portions per adult per week.[27]

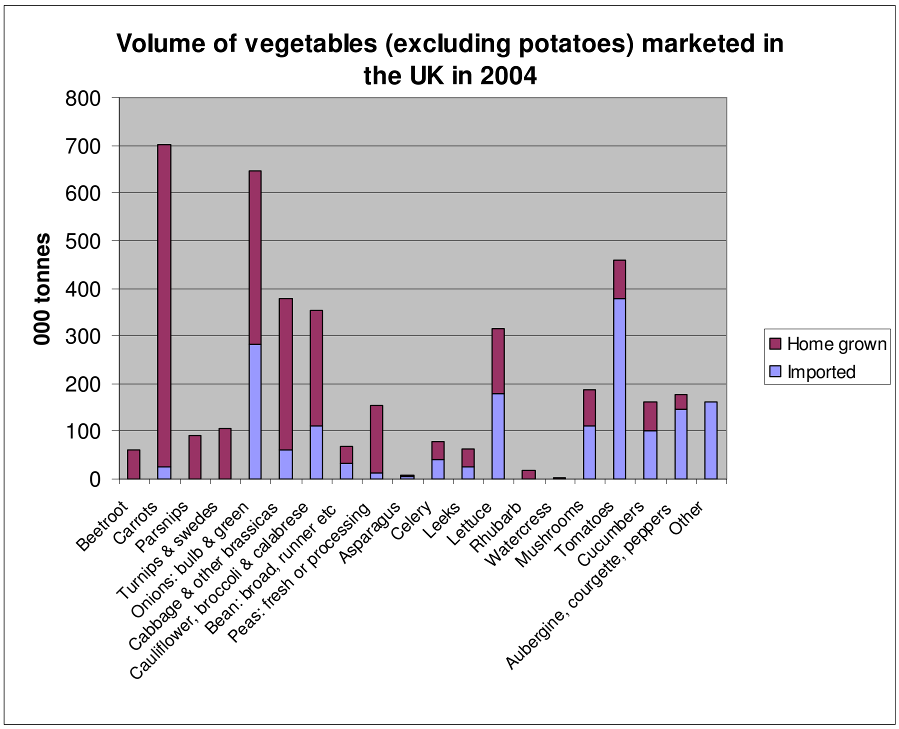
Since since 1974, vegetable consumption has slightly declined while fruit consumption has grown by 63%. Since 1997, our consumption of both fruits and vegetables has more or less stabilised.[28]

[24] *Family Food 2003/4*, Defra http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp
[25] Defra does not distinguish between peelings and food which is simply uneaten
[26] *Family Food 2003/4*, Defra http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp
[27] *The National Diet & Nutrition Survey*: adults aged 19 to 64 years Summary Report, ONS, 2004
[28] *Family Food 2003/4*, Defra http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp

Vegetables (excluding potatoes)

For vegetables (excluding potatoes) a closer look within the sector also reveals aspects of the way we consume which may have implications for GHG emissions. Figure 2 shows the volume of vegetables we purchased in the UK in 2003. The following crops account for 30% of our vegetable consumption: lettuce, tomatoes, mushrooms, aubergines, peppers, cucumber and capsicum. This is noteworthy since such vegetables tend either to be grown in heated greenhouses here in the UK or imported from overseas; issues which are discussed in later sections. The consumption of these vegetables (both home grown and imported) grew by 22% between 1994 and 2004 at a time when overall consumption of fruit and vegetables grew by only 5%. Another trend of note is the rise in popularity of salads and a shift in our buying habits towards pre-packed vegetables.[29]

Figure 2



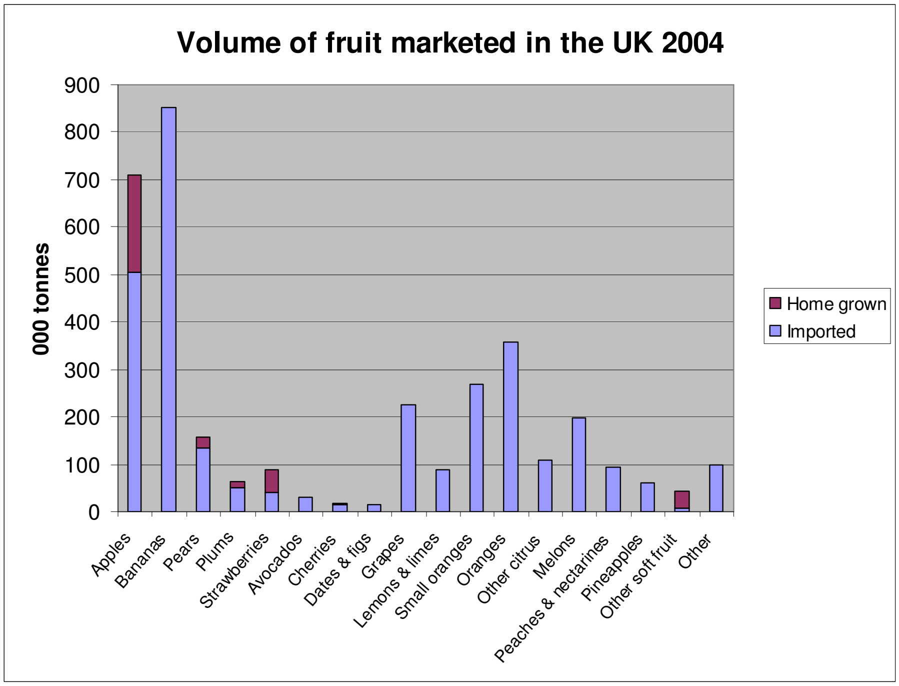
Source: Basic Horticultural Statistics, Defra 2005 The data for these tables can be found in appendix 1.
Note: Figures are obtained in two ways. Where possible, Defra figures for total supply in the UK and for the quantity which is produced and marketed domestically are used. This method takes into account the small proportion of UK grown produce that is exported or of imports that are re-exported. Where these data are not available, the volume of imports and UK production are added together. The latter method does not take into account exports and re-exports. However BHS shows that the total volume exported or re-exported is very small indeed and so this does not distort the figures presented here significantly. It is also important to note that various industry sources have recommended that Defra horticultural data be treated with some caution.

[29] *Fresh Fruit and Vegetables - UK - May 2005*, Mintel

Fruit

As regards fruit, it is clear from Figure 3 below that the most popular fruits consumed in the UK simply cannot be grown here. Even, however, where indigenous production is possible, self sufficiency is still very low.

Figure 3



Source: Basic Horticultural Statistics, Defra 2005. The data for these tables can be found in Appendix 1.
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The picture varies according to the type of produce. Note, for example, that the majority of soft fruit consumed in the UK is still grown in this country: compare 83,000 tonnes of UK grown soft fruit with 47,100 tonnes of imported produce. Following a decline in UK soft fruit consumption in the late 1990s, production has picked up again, especially for strawberries and now volumes are 14% above their 1994 levels. This said, there has also been a major growth in demand for soft fruit and much of this growth has been met with greater quantities of imports. The quantity of strawberries imported into the UK grew by 53% between 1994 and 2004.[30]

[30] Basis Horticultural Statistics 2005, Defra
http://statistics.defra.gov.uk/esg/publications/bhs/2005/default.asp

Interestingly, during 2005 43% of total soft fruit imports were brought in during the months of May through to October (inclusive), the period when the UK growing season is underway.[31] The peak importing months are March, April, May and June and these months together account for 48.5% of imports by volume. In other words most of our soft fruit imports (nearly three quarters) take place during, or just before, the UK growing season and not outside it. As such these imports do not so much complement UK production as compete with it.

Industry is also keen to erode whatever association we may still have of berries as summer and autumn fruits. Campaigns such as the Winter Berries campaign, for instance, have recently been set up with the backing of major winter berry importers, to promote soft berry fruits during the winter months. Supermarkets are also keen to further the growth in year-round demand through promotional offers.[32]

Frozen fruit and vegetables

Most fruit and vegetables are sold fresh, rather than frozen, the major exception being peas. According to the Family Food Survey[33] frozen fruit and vegetables (excluding potatoes) account for only 7% of the fruit and vegetables we consume. Of vegetables, peas account for 29% of sales; this will not be the same as volume but it does indicate how prominently they figure in the frozen vegetable sector. Fruit, vegetables and potatoes account for about 26% of total frozen food sales by value.[34] Again, while not the same as volume, this does perhaps give an indication of its importance; the implications for energy use are considered in more detail below.

The trends suggest that the frozen vegetable sector is likely to remain stagnant over the coming years, given our increasing preference for fresh chilled foods. However Mintel predicts that there will be strong growth in demand for frozen fruits such as berries.[35]

Potatoes

There have been substantial changes both in the overall quantity of potatoes we consume and in the form in which we eat them.

Half the potatoes we now eat are in processed form.[36] This represents a major change since 1988 when over 70% of our potatoes were bought fresh and unprocessed. Of the processed potatoes we eat nearly two thirds are frozen or chilled – in other words they are chips, or their manifold variants. It is also noteworthy that while our self sufficiency in *fresh* potatoes may be very high at around 94%[37] this is certainly not the case with *processed* potatoes. Nearly half (44%) the processed potatoes we eat are imported. This will have a bearing on emissions both from the transport and the cold storage

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[31] UK Trade Info, HMCR, 2005; data for soft fruits
[32] Somerfield focuses on soft fruit, Fresh Info news, 7 February 2006, www.freshinfo.com
[33] *Family Food 2003/4*, Defra http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp
[34] British Frozen Food Federation, 2005 data http://www.bfff.co.uk/RetailMarketBreakdown.pdf
[35] *Frozen and Canned Fruit and Vegetables* - UK – Mintel June 2005
[36] *Annual Balance Sheet of Potato Supplies and Disposals 1988-2004*, British Potato Council, 2005
[37] *Annual Balance Sheet of Potato Supplies and Disposals 1988-2004*, British Potato Council, 2005

stages.[38] Mintel notes that growth in frozen potatoes is likely to flounder over the next few years for a number of reasons including, interestingly, the decline in numbers of people aged 15 and under. Children are the major consumers of chips, frozen potato waffles and suchlike.

Chilled prepared produce

As noted earlier, fruit and vegetables also comprise around 14% of all chilled prepared foods, or perhaps a little more, since fruit and vegetables will also be a component of ready meals, pizzas, sandwiches and chilled deserts.[39]

Mintel predicts that the fresh fruit and vegetables sector is likely to grow by about 6% in real terms between 2005-10, and that most of this growth will come mainly from the value-added sector, with an increasing emphasis on pre-cut, ready to cook produce.[40] In a separate analysis of pre-packed and dressed salads Mintel predicts a growth of 10% in real terms.[41]

Canned fruit and vegetables

There are also canned foods to consider. It is difficult to look at the proportion of produce sold in this form since the weight of the can and the way in which the product is packed (in water or in solid form) will need to be taken into account. The Family Food survey indicates that processed vegetables (defined as processed tomatoes, peas, beans and ready meals – including canned) account for a quarter of our vegetable consumption and that canned tomatoes account for the biggest share of sales. Baked beans are also included in this category and these must take a considerable share of the total canned vegetable market. A market review published by the Fresh Produce Journal estimated the total volume of canned fruit and vegetables in 2002 to be 1.16 million tonnes, equivalent to 16% of our fresh consumption, and of course less of total consumption. It is not clear whether pulses and beans are included in this category.[42] Many canned fruits and vegetables will be imported – for instance in 2005 we imported 397,023 tonnes of canned tomatoes, slightly more than the 384,700 tonnes of *fresh* tomatoes we imported.[43]

Mintel predicts strong growth in the canned sector.

Juices

According to the National Diet and Nutrition Survey,[44] 45% of us drink juice regularly, the average for juice drinkers being around six glasses[45] a week.[46] When both consumers and non consumers are included, we drink around a third of a litre a week each. A

[38] Annual Balance Sheet of Potato Supplies and Disposals 1988-2004, British Potato Council, 2005
[39] http://www.chilledfood.org/Content/Market_Data.asp
[40] *Fresh Fruit and Vegetables - UK - May 2005*, Mintel
[41] *Prepacked and dressed salads*, Mintel, UK August 2005
[42] *Re-fresh directory 2005*, Fresh Produce Journal, London, 2005
[43] UK TradeInfo, HMRC, World Trade 2005 data
[44] *The National Diet & Nutrition Survey: adults aged 19 to 64 years: Summary Report*, volume 5, 2004 http://www.food.gov.uk/science/101717/ndnsdocuments/ndnsvol52004
[45] one glass is defined as 125 ml
[46] *The National Diet & Nutrition Survey: adults aged 19 to 64 years: Summary Report*, volume 5, 2004 http://www.food.gov.uk/science/101717/ndnsdocuments/ndnsvol52004

Mintel survey gives slightly different figures, estimating that 58% of adults drink juice and nearly one in five of us (17%) drink a glass or more a day.[47]

Whichever figures are used, clearly consumption is growing, and rapidly. In 2004, 2,15 million litres of juice were sold in the UK, a growth of 26% from five years previously. Of this more than half (54%) was in the form of pure fruit juice with the remainder accounted for by juice drinks – liquids containing a varying proportion of juice, sugar, water, sweeteners and other ingredients.[48] The latter are not considered here.

Recent years have seen growth in demand for chilled juices. Chilled juices (freshly squeezed, concentrated and Not from Concentrate or NFC)[49] now account for 34% by volume of all pure fruit juices sold, up from 28% in just two years. Orange and apple juices account for 82% of the market by volume.

It appears that fruit juice consumption is set to grow. Mintel predicts a 16% increase (in real terms) in the fruit juice market between 2004 and 2009.[50]The environmental implications of these trends are explored in more detail in Sections two and three below.

1d. Future trends

Overall, Mintel predicts that the value of vegetables is likely to grow faster than the value of fruit over the coming years. This may be because there is more scope for 'adding value' to vegetables than to fruit which are, in their natural form, already rather convenient. Much of the growth will come from the growth in the ready-prepared sector. Note that, while the growth in value is not the same as growth in volume, it is fair to say that the more value is 'added' to the product the more processing (usually requiring energy) will be involved. The possible environmental implications of this growth in value-added products are explored in sections 2 and 3 below.

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[47] *Fruit Juice and Juice Drinks* - UK - November 2004, Mintel

[48] *Fruit Juice and Juice Drinks* - UK - November 2004, Mintel

[49] Not from concentrate juice is taken from fruit which is squeezed in the country of origin and then lightly pasteurised and frozen or aseptically packed for shipment to the country where it will be sold. Freshly squeezed juice is taken from fruit which is shipped to the country of use and squeezed there for immediate use. It may be unpasteurised or lightly pasteurised. Source: British Soft Drinks Association http://www.britishsoftdrinks.com/htm/qa/FruitJuice.htm

[50] *Fruit Juice and Juice Drinks – UK,* Mintel, November 2004

SECTION TWO: QUANTIFYING GREENHOUSE GAS EMISSIONS FROM THE FRUIT AND VEGETABLE SECTOR BY LIFE STAGE

This section explores the contribution that the fruit and vegetables we eat make to the UK's emission of greenhouse gases. It takes a life cycle perspective, looking at the significance of emissions generated at each of the key stages: during the course of cultivation, during cooling and storage, transport, distribution, consumption and finally from the generation of waste and its disposal. This approach is, by definition, very general and somewhat simplistic given the diversity of fruits and vegetables we consume and of the different ways in which they are, stored, distributed, prepared and consumed. A more variety-specific approach is taken in section three.

It should be borne in mind that while this section is formally structured according to the basic life-cycle stages, in practice it is impossible to consider these stages in isolation from one another. One cannot, for example, talk about temperature control separately from waste, or transport separately from either. As a result there will be overlaps between and among the sections. It is hoped that the end result is not overly confusing; indeed it may be helpful to consider the areas where overlaps consistently occur as nodal points where the various life stages converge to energy-intensive effect.

2a. Agricultural production

Field grown vegetables

<u>Energy use</u>

The cultivation of field grown fruit and vegetables involves the consumption of energy in farm machinery as well as in the manufacture of the various agricultural inputs such as fertilisers and pesticides. Some field grown vegetables will also have undergone a period of initial growth (from seed to seedlings) in a heated glasshouse before being transplanted into a field, entailing an additional use of energy.

Before looking specifically at energy use for horticulture it may be helpful briefly to view the sector in the context of overall agricultural energy use.

The UK agricultural sector is, in fact, not a major user of *energy*. According to a calculation (based on derived figures) by Chris Plackett from the Farm Energy Centre, total UK agricultural energy use is about 27,600 TJ a year. [51] This, based on the agricultural fuel mix, works out at about 0.523 million tonnes of carbon or 0.33% of the UK's total carbon dioxide (not GHG) emissions, with most of the emissions arising from protected horticulture (see below) and intensive livestock production. Note that there are likely to be error margins of about 5-10% with the estimate given. This is a perhaps a surprisingly small figure but it should be emphasised that energy use by mobile machinery such as tractors and combine harvesters are not included, owing to problems with finding reliable data. As a very rough estimate one might double the figure to take transport into account, meaning that agriculture as a whole accounts for about 0.6% of the UK's carbon emissions.[52] Calculations based on DUKES (Digest of UK Energy

[51] Chris Plackett, Farm Energy Centre, personal communication, February 2006
[52] Chris Plackett, Farm Energy Centre, personal communication, May 2006

Statistics) [53] put total agriculture-related emissions at 612,762 tonnes of carbon, equivalent to 0.33% of the UK's greenhouse gas emissions. These, it appears, do include fuel used for mobile farm machinery

It is of course important to stress that while the agricultural sector as a whole is not a major user of fossil fuels (and hence emitter of carbon dioxide) it is nevertheless a major emitter of the other main greenhouse gases, nitrous oxides and methane which arise from livestock farming.[54]

What about field vegetables? What share of total emissions should be allocated to them? Probably very little because the area used for the cultivation of fruit, vegetables and potatoes is only 7% of the total area used for crops, or 1.7% of total agricultural land (including grazing). As such energy use for field grown fruit, vegetables and potatoes (see below for a discussion of protected crops) is, by virtue of the small land area allocated to it, very small.

Fertiliser applications

Rough estimates suggest that the manufacture of nitrogen accounts for approximately 1.0 - 1.5% of the UK's GHG emissions.[55] Not only is its manufacture an energy intensive process, leading to the generation of CO_2, but in addition nitrous oxides are also emitted. Once emissions from fertiliser production are taken into account then, one might estimate (using a combination of the figures given above) the total carbon dioxide emissions arising from UK agriculture to be about 1.5% of the UK's GHGs.

How much nitrogen does UK horticulture use? Rob Lillywhite at the Horticultural Research Institute cites provisional data from Defra showing that the horticultural sector (field and protected, edibles and ornamentals) used 3.55% of the total nitrogen applied to UK farmland.[56] This means that emissions resulting from the manufacture of fertiliser for UK horticulture works out at 0.035-0.050% of total UK GHG emissions.

To this very small figure should be added nitrous oxide emissions resulting from the de-nitrification processes in the soil. Lillywhite notes that during growth, most crops can recover only 50% of applied nitrogen, meaning that 50% is 'wasted'. However, before the crop reaches the retail sector, another 25% of the nitrogen is discarded as trimmings and crop residues. Of the nitrogen fertilizer applied to the growing crop only 25% is contained within the marketable product.[57]

A study by the Institute of Grassland and Environmental Research calculates that N_20 emissions resulting from the fruit and vegetable sector (including potatoes) accounts for

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[53] Aggregate Energy Balance 2004, DUKES 1.1http://www.dti.gov.uk/energy/statistics/stats-by-energy-source/Total%20Energy/page18424.html

[54] *UK Greenhouse Gas Inventory 1990-2003: Annual report for submission under the Framework Convention on Climate Change*, National Environmental Technology Centre, Harwell, Oxon, April 2005 section A3.6

[55] calculations made separately by Tara Garnett based on AIC Envtironment Agency declared chemical industry emissions 2003 website; and by Gundula Azeez, Soil Association.

[56] Rob Lillywhite, Nitrogen in horticulture - nutrient or pollutant? The Grower, London, 2nd September 2005; information based on British Survey of Fertiliser Practice and Defra statistics

[57] Rob Lillywhite, Nitrogen in horticulture - nutrient or pollutant? The Grower, London, 2nd September 2005; information based on British Survey of Fertiliser Practice and Defra statistics

about 4%[58] of the N_20 arising from soil-related N_20 emissions. Soil-related N_20 related emissions resulting from UK agriculture contribute in total about 4% of the UK's greenhouse gas emissions (expressed as CO_2e emissions)[59] and so one might calculate that the total N_20 contribution resulting from the de-nitrification processes associated with fruit and vegetable production is about 4% of this 4%, or 0.16% of the UK's total greenhouse gas emissions. Evidently, compared with the contribution from, say, ruminant livestock where the total impacts (from pasture and arable land used for feed production) are around 3.1% of the UK's total GHGs emissions, this figure is very minor. However, fertiliser application rates vary among crops - nitrogen application levels for potatoes and brassicas are particularly high whereas for carrots they can be around 80% lower. A more crop-specific approach might reveal particularly significant areas.

Protected cropping

Protected food production is an energy intensive activity. According to calculations by Chris Plackett at the Farm Energy Centre, the energy used to grow fruit and vegetables in heated greenhouses or in other spaces (such as those used for growing mushrooms) uses about 20,250TJ of energy a year, accounting for about 74% of the agricultural sector's total energy use. However in terms of its contribution to the agricultural sector's CO_2 emissions the figure is much smaller, at a third. This is because of differences in the energy mix used for protected horticulture (mainly gas with only 4% electricity) compared with agriculture as a whole (where electricity use accounts for approximately 30% of energy use).[60] In terms of its contribution to total UK carbon emissions, the figure is 0.1%.

Note that this figure does not take into account the substantial quantities of hothouse-type produce that we import. It has already been shown that imports of these foods by volume (and by economic value) far outweigh home production.

In the context of the food miles issue the relative energy merits of home grown hothoused versus field grown imported produce are hotly debated. A study by Carlsson[61] calculates that Dutch protected tomato growing emits around 16 times more CO_2 than Spanish tomato production - according to her figures Spanish systems generates 0.23 kg CO_2 / kg of produce, while the Dutch ones produce 3.6 kg CO_2 / kg produce. Even once transport and other life cycle impacts are taken into account Dutch production still entails the use of five times more energy than Spanish production. Note that this is a Swedish study and so the Dutch tomatoes still had to travel to Sweden, generating additional emissions. Interestingly, indigenously grown Swedish tomatoes were even more energy intensive than the Dutch ones (even allowing for the Dutch importing stage) reflecting, presumably, greater heating and lighting needs in Sweden.

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[58] *Estimation of Nitrous Oxide Emissions from UK Agriculture*, Lorna Brown and Steve Jarvis, IGER Innovations, Institute of Grassland and Environmental Research 2001
[59] based on data in *UK Greenhouse Gas Inventory 1990-2003: Annual report for submission under the Framework Convention on Climate Change*, National Environmental Technology Centre, Harwell, Oxon, April 2005
[60] Chris Plackett, Farm Energy Centre, personal communication, February 2006
[61] Carlsson A, Greenhouse Gas Emissions in the Life-Cycle of Carrots and Tomatoes: methods, data and results from a study of the types and amounts of carrots and tomatoes consumed in Sweden, IMES/EESS Report No. 24, Department of Environmental and Energy Systems Studies, Lund University, Sweden, March 1997

A comparison between Spanish and UK tomato production and distribution undertaken for Defra[62] found that the energy used to grow tomatoes in the UK significantly outweighs the energy used to import tomatoes from Spain by road, meaning that once both production and transport are taken into account the UK crop generates over three times more CO_2 than Spanish impacts. However this study was – as the authors stressed – not a full life cycle analysis. Factors such as refrigeration were not taken into account. In addition, it is possible that the tomatoes grown were not comparable. Most imported Spanish tomatoes tend to be the classic round type whereas increasingly UK growers are producing higher value cherry or vine tomatoes. While yields for the latter are lower than for the classic types, it is arguable that the quality is much higher.[63]

The studies highlighted so far do not, however, take into account the costs of the protective infrastructure. For Spanish tomatoes, which tend to be grown under relatively short-lived plastic structures, this additional embedded energy cost is considerable. Indeed one Spanish study found that the manufacture of the structures themselves required more energy and generated more GHG emissions than the actual tomato cultivation itself.[64] The life span of the structure is critical, as the study in question showed; two forms of cladding were examined and it was found that the relatively longer lived rigid polycarbonate (10 year life span) worked out better, from a carbon perspective, than the shorter lived LDPE (3 year life span). This fact is significant when comparing GHG emissions between UK and Spanish systems for two reasons. The first is that UK glasshouses tend to be permanent structures with long life spans[65] and so the energy required to manufacture them is discounted over a very long space of time. The second is that UK productivity in the protected crop sector is five times greater than productivity in Spanish systems.[66] This means that for every kilo of tomatoes produced, over five times more land area is needed in Spain and – crucially – five times more protective covering material is needed, compared with the UK system. How this affects the relative balance between UK and Spanish production would require a proper life cycle investigation but it could well be that the balance is less steeply tilted in favour of Spanish systems than the Defra comparison would suggest. The situation could change further too were Spanish growers to start heating their greenhouses (which is already starting to happen) or if UK tomato growers were to switch either to using renewable forms of fuel for heating their greenhouses or to extend their use of combined heat and power. This is a possibility that is examined more fully in section 5b below.

Of course not all our imported glasshouse produce comes from sunny countries. For example, Dutch imports will have been grown under protected conditions. One Dutch study finds that protected horticulture accounts for over 2.4% of Dutch GHG emissions[67]

[62] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp
[63] Adrian Williams, Cranfield University, personal communication, March 2006
[64] Antón, A.; Castells, F.; Montero, JI.; Muñoz, P. 2005. LCA and Tomato Production In Mediterranean Greenhouses. *Int. J. Agricultural Resources Governance and Ecology*. Vol.(2) Nº4: 102-112
[65] based on conversations with the horticultural industry
[66] Gerry Hayman, British Tomato Growers' Association, personal communication, December 2005
[67] *Effectiveness of energy conservation policy in the glasshouse horticulture industry* http://www.environmental-auditing.org/intosai/wgea.nsf/viewContainer2/nleng03ar_sm_effectenergysave.pdf/$file/nleng03ar_sm_effectenergysave.pdf

while another puts it at 3.4% of Dutch CO_2 emissions.[68] The Dutch industry is five times the size of the UK's[69 70] and is a major exporter to other countries, exporting 85% of its vegetables and 33% of its fruit..[71] The UK is a major customer, importing around 20% of Dutch salad crops. On the basis of these figures one might calculate that consumption in the UK is responsible for 0.4% of the total greenhouse gases emitted in Holland.[72] This amounts to around 0.23 million tonnes of carbon (0.86 million tonnes of CO_2), equivalent to 0.13 % of the UK's total greenhouse gas emissions.

This is noteworthy because at times the discussion as to whether it is 'better' to import tomatoes or grow them in greenhouses here in the UK assumes that the overseas tomatoes will have been grown without heating. We do in fact also import from countries where heating is used and for these imports there will be a double environmental downside. Finally, as noted above, some Spanish producers are now starting to heat their growing structures to minimise the impacts of frost.[73]

Production stage impacts and the importance of including imports

It is also essential to emphasise that when considering the total GHG emissions arising from the production of fruit and vegetables we consume in the UK we need to consider that the majority of them are imported. It has not been possible to calculate the N_20 and CO_2 emissions arising from their production since the specifics of the growing methods employed are not known. As a very crude rule of thumb one might however multiply the figures given for UK horticultural emissions by the greater quantity that is produced and imported from overseas. It would also be necessary to include emissions embedded in the production of canned, frozen and dried fruits, vegetables and potatoes. It has already been observed that we import slightly more tomatoes in tins than we do fresh and that nearly half of all the processed potatoes we eat (which themselves account for half of all our potato consumption) are imported.

Conclusions for this section

While production stage emissions for the fruit and vegetable sector appear, on the face of it, to be fairly modest, this observation masks two important points.

The first is that the protected crops sector is highly energy intensive relative to its level of output. Consumption of the sorts of crops grown under protection is rising steadily; the choice is then either to meet demand by growing more such crops in the UK or to import them from overseas. Overall production in the UK protected crops sector has declined over recent years (notwithstanding an increase in productivity) and so it seems that this increased demand is being met by overseas imports.

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[68] Spliet A. *H*orticulture under glass in the Netherlands: preliminary study for thesis about floating greenhouses, 2002, TU Delft / Duravermeer http://www.spliet.nl/Report%201%20screen%20optimized.pdf

[69] Basic Horticultural Statistics, Defra, 2005 and *Effectiveness of energy conservation policy in the glasshouse horticulture industry* http://www.environmental-auditing.org/intosai/wgea.nsf/viewContainer2/nleng03ar_sm_effectenergysave.pdf/$file/nleng03ar_sm_effectenergysave.pdf

[70] Hans Verwegen, The Greenery, personal communication January 2006

[71] Hans Verwegen, The Greenery, personal communication January 2006

[72] 20% of 85% of 2.4%.

[73] Chris Plackett, Farm Energy Services, personal communication, November 2005

Secondly – and perhaps even more importantly – overall emissions from the production stage appear low simply because we import so much and it has not been possible to quantify these overseas-generated production emissions with any degree of accuracy. Since around 90% of the fruit and 40% of the vegetables we eat are grown overseas, one could argue that any estimate of UK production stage emissions could be nearly doubled. To these would need to be added emissions generated during the course of producing canned, frozen and otherwise processed imports

As it stands production stage emissions attributable to UK-grown fresh produce are approximately 0.1-0.2% of the UK's total GHG emissions. If one were to double this figure to allow for imports it would come to about 0.2-0.4% of the UK's total. Adding the production of imported canned and other processed fruit and vegetables (including juices) would raise the figure still further. The figure is still of course very small but several points may be worth bearing in mind. The first is that the size of the figure is indicative of the very small quantities of fruit and vegetables that we consume, relative to other foods. If our consumption of fresh produce were to grow then the land area and the energy devoted to its cultivation (either here or overseas) would also grow. In the light of government health policy (discussed below) this situation could well arise.

Secondly, it is important to be mindful of the changing trends in what kinds of fruit and vegetable we eat. Mediterranean style, greenhouse grown produce is increasingly popular and, notwithstanding its very small output by volume (relative to the vast quantities of cereals and other crops we grow), the demand it makes on energy is very considerable. It is worth noting once again the significant contribution that the Dutch horticultural sector makes to Dutch greenhouse gas emissions – clearly if production and/or consumption of these products were to increase, the overall contribution from this sector to the UK's greenhouse gas emissions would also increase.

Finally, it is worth being mindful of the huge possible differences in the energy intensity of one particular type of fruit or vegetable. For example, a Defra-commissioned study by the University of Hertfordshire[74] finds a six fold variation in CO_2 equivalent emissions among different strawberry systems. These differences reflect the wide diversity of UK strawberry production methods. Indeed the study identifies around 20 different production systems, the variables including the use or otherwise of fumigants or of plastic mulches, whether the system is organic or non-organic, protected or field-based, the growing medium (soil or soil-free), and finally the duration of cropping - whether growers grew crops on the same plants for one or for three years.

A study of New Zealand apple production by Milà i Canals[75] also finds a wide variation in the GWP generated by different growing systems – the most energy intensive farm generated more than double the CO_2e emissions of the lowest energy user.

These studies highlight the difficulty of accurately quantifying emissions of fruit and vegetable cultivation. The difficulty is of course magnified when one considers the many different countries from which our produce is sourced.

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[74] *Sustainability of the UK strawberry crop*, Defra project HH3606, research undertaken by the University of Hertfordshire, January 2006

[75] Milà i Canals L (2003): *Contributions to LCA Methodology for Agricultural Systems. Site-dependency and soil degradation impact assessment*. PhD thesis. Available from http://www.tdx.cesca.es/TDX-1222103-154811/ (ISBN: 84-688-3285-5)

2b. Transport

The environmental impacts of our food system are often thought of in terms of their 'food miles' – the CO_2 and other costs associated with the long distance transport of food. The issue has received widespread media coverage and the concept is now frequently referred to by the media,[76] [77]by environmental groups[78] [79] and by the food industry itself. [80] In response, Defra commissioned research to examine whether food miles might serve as a useful indicator of sustainability. The report concluded that the issue is complex and that distance *per se* is not an especially helpful measure of anything.[81]

Transport within the UK

What contribution does the transport of fruit and vegetable make to the UK's emission of greenhouse gases? The Defra Food Miles study calculates that food transport related emissions *as a whole* (including both imported and indigenously produced food) account for 3.4% of the UK's total CO_2 emissions (or 2.9% of the UK's GHG emissions).[82] This figure does not include the CO_2 or other greenhouse gas generated as a result of mobile refrigeration, an issue which is discussed below in section 2c.

Data supplied by the Department for Transport shows that emissions generated during the course of transporting fruit and vegetables *within the UK* come to about 357,000 tonnes of CO_2. This works out at 0.06% of the UK's total CO_2 or 0.05% of the greenhouse gas total.[83]

The amount of food travelling within the UK by rail is insignificant.[84] [85]

Import related transport: road and sea

There are also transport emissions resulting from the import journey to consider. To calculate these, distinctions need to be drawn between modes of travel.

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[76] http://www.bbc.co.uk/food/food_matters/foodmiles.shtml
[77] Food study reveals hidden £9bn costs of transport, The Guardian, July 15 2005 http://www.guardian.co.uk/food/Story/0,2763,1528963,00.html
[78] Paxton A, 1994, *The Food Miles Report: the dangers of long distance transport of food*, SAFE Alliance
[79] *Eating Oil: Food supply in a changing climate* A Jones, 2001, Sustain, London, 2001
[80]http://www2.marksandspencer.com/thecompany/ourcommitmenttosociety/environment/food_miles.shtml
[81] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp
[82] for air freight it multiplies CO_2 figures by three to take account of the additional radiative forcing effects arising from transport at high altitude.
[83] Estimate based on figures provided by DfT from the Continuing Survey of Road Goods Transport and a formula from the Defra publication 'Guidelines for company reporting on Greenhouse Gas emissions; using the Defra food miles study the figures come out the same.
[84] Garnett T. 2003. *Wise Moves: exploring the relationship between food, transport and CO2*. Transport 2000, London
[85] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

Most of the food entering the UK does so by sea or road. In the year 2000, the UK imported 28 million tonnes of food and in that year also some 4 million tonnes of it, or one seventh of the total, were fruit and vegetables. A small proportion of these will, as is discussed below, travel by air but this makes very little difference to the total volumes moved by ship or road. Hence on might very roughly calculate that if overseas food transport accounts for 1.6% of the UK's total CO_2 emissions[86] then the importing of fruit and vegetables by road or sea accounts for a seventh of this. This works out at 0.23% of the UK's total CO_2 emissions or 0.2% of its total greenhouse gas emissions Note that additional energy use (and GHG emissions) arising from the need for temperature control would need to be added to the baseline transport energy use figure. According to several estimates an extra 14% should be added on top of transport emissions to take into account mobile refrigeration energy use.[87] [88] Mobile refrigeration is discussed further in section 2c.

It would be very helpful to know whether fruit and vegetables sourced from outside the EU (and therefore likely to make the greater part of their journey by ship) generate more or fewer emissions than EU-produce which will travel for the most part by road. Sea travel is less energy intensive, per tonne of goods carried than road. As highlighted above, most produce is sourced from within the EU but it is not clear whether from an environmental point of view this is preferable to sourcing from further afield. The Defra commissioned Food Miles study finds that sea travel of food as a whole (i.e. not just fruit and vegetables) accounts for only 12% of total food transport related CO_2. This 12% is the same, notwithstanding the far longer distances, as emissions generated by road vehicles to transport goods by road from the country of origin to the UK. The food miles study also states that 62% of our trade is with the EU, meaning that 38% is sourced from further afield. From this one might conclude that while relative to their overall weight, EU sourced products will emit less transport related CO_2 than their extra-EU counterparts, the difference is not actually that great. The difference is perhaps lower still when one takes into account that for imports from Spain, Portugal, Ireland and Russia the Food Miles study assumed that 50% of journeys were made by sea and 50% by road.

From Marriott's analysis[89] it appears that fruit and vegetable imports reflect the average food pattern - more come from within the EU than from outside.

In addition a further 14% of total food transport emissions are generated in overseas countries by road vehicles during the course of transporting the goods from their point of production to the port, airport or distribution hub before they makes their onward journey to the UK. These preliminary-stage transport emissions presumably need to be shared between road and sea transport.

[86] this figure takes into account the radiative forcing effect mentioned

[87] Ritchie K (forthcoming). *From Farm to Table: An energy consumption assessment of refrigerated, frozen and canned food delivery*. A report in draft prepared by Scientific Certification Systems Inc. on behalf of the Steel Recycling Institute, Pennsylvania, United States

[88] cite Sainsbury ref too

[89] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

Import-related transport: air

Many studies have highlighted the very intensive environmental damage caused by air travel. [90] [91] [92]

For food as a whole, less than one percent travels by air but the impacts of flown foods are disproportionately high, accounting for 11% of total food transport related greenhouse gas emissions.[93]

How far does the picture for food in general reflect the situation for fruit and vegetables in particular? Most of our fresh produce comes from within the EU and as such is unlikely to travel by air.[94] Air freighting is expensive and since most European produce is able to reach its destination sufficiently rapidly by sea and road, it is not necessary. One cannot, however, be absolutely sure that no EU produce at all is air freighted since mode-of-travel information for EU-sourced produce is not freely available.

For non EU produce however the picture is different. Non-EU produce constitutes, on average, 25.5% of our total fruit and vegetable imports - 15% of vegetable imports and 62% of fruit imports. Marriott[95] calculates, using UK Customs and Excise data (now Revenue and Customs) that 2.7% of non-EU fruit travels by air, or 1.67% of all fruit imports.

For vegetables, a quarter of non-EU vegetables are air freighted, meaning that 3.75% of all our imported vegetables now travel by air – nearly four times higher than the average for the food sector as a whole. Only 15% of vegetables are imported from outside the EU so the total proportion of vegetables air freighted is lower, at 0.56% of total vegetable imports.

In total, Marriott calculates that 6% of non-EU produce is air freighted. Using these data one can therefore calculate that the total proportion of air freighted fruit and vegetable imports into the UK is 6% of 25.5% - or 1.53% of all fruit and vegetables imported.[96]

All the signs suggest that the proportion of fresh produce travelling by air is likely to increase.[97] [98] It may also be that a very small additional percentage of particularly

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[90] *Aviation and the Global Atmosphere*, Intergovernmental Panel on Climate Change, 1999 http://www.ipcc.ch/pub/reports.htm

[91] Bows A, Anderson K and Upham P *Contraction & Convergence: UK carbon emissions and the implications for UK air traffic*, Tyndall Centre for Climate Change Research, February 2006 http://www.tyndall.ac.uk/research/theme2/final_reports/t3_23.pdf

[92] Whitelegg, J. and Cambridge, H. *Aviation and Sustainability. A Policy Paper*. Stockholm Environment Institute. 2004

[93] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[94] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[95] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

[97] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from*

perishable EU produce is flown in.[99] More significantly perhaps, some non-EU produce destined for the UK is flown first into an airport in continental Europe before being offloaded onto a vehicle and making its final leg of the journey into the UK by road. For instance Egyptian strawberries can be air freighted to Frankfurt and then trucked to the UK.[100] Such produce is classed as being of EU-origin and, since it has been assumed that most EU produce travels by road or sea and since this non-EU produce is then re-classified as of EU-origin, the air-stage of the journey does not show up in the statistics. It could therefore be that the proportion of food that has undergone at least part of its journey by air has been underestimated.

It is difficult to quantify accurately the emissions resulting from the air transport of food because methods for calculating the global warming impact of transport at high altitudes vary[101] and there is not always sufficient information available to make accurate assumptions either about loading factors or as to whether the food travels in dedicated air-freighters or in the belly hold of passenger planes.[102] The Defra food miles study acknowledges these difficulties.[103] It also calculates that fruit and vegetables account for 61% of the air freighted food total (the report is unclear as to the unit of measurement used but the assumption made here is that this is a measure of weight). This means, roughly speaking, that fresh fruit and vegetables account for 61% of 11%, or 6.71% of food transport related emissions. This translates into 0.2% of the UK's greenhouse gas emissions total. The figure as a proportion of CO_2 would be slightly higher.

Interestingly, this 0.2% is almost the same as the contribution made by produce travelling by road and sea (according to the Defra study), despite the massive differences in volumes carried; this throws into sharp relief the greenhouse gas intensity of air travel.

At the moment over 60% of freight is carried in the bellyhold of passenger aircraft[104] [105] and it could be argued that food travelling in this way actually makes efficient use of space that would otherwise be unused. To some extent, however, bellyhold freight subsidises passenger transport and hence the relationship is somewhat symbiotic. It is also the case that the influx of bellyhold-shipped food into the UK and its subsequent availability in UK stores has whetted our appetite for such foods. In response the

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1996 to 2004, Clive Marriott, Msc dissertation, University of Surrey, 2005

[98] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[99] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

[100] *Freshinfo* news, Saturday 11 February. www.freshinfo.com

[101] point highlighted at FCRN fruit and vegetable seminar held in Manchester on 1st December 2006; usually CO_2 figures are simply multiplied by three but this could be an underestimate.

[102] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[103] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005, Annex 1: Data sources and assumptions, http://statistics.defra.gov.uk/esg/reports/foodmiles/annex1.pdf

[104] Airport Property Market Survey King Sturge 2003-4 http://www.logistique.com/image/2005/Airport_Property_2004.pdf

[105] *Review of the Impact of Aviation within the Greater London Area: Final Report*, London Sustainable Development Commission17/12/2003 http://mayor.london.gov.uk/mayor/sustainable-development/docs/lsdc_airtransportskm.pdf

importing industry has taken steps to increase sales by increasing supply. This in turn has led to the use of dedicated air freighters and it is now the case that the air freight sector is growing rapidly at about 6% a year.[106] In other words, bellyhold traffic has catalysed the development of a dedicated air freighting service for food.

It is important to emphasise here that if a food is air freighted its overall greenhouse gas emissions will always be very high, however low its emissions may be at other life cycle stages. Work by the University of Leuven[107] for example presents a range of production and distribution scenarios for a range of foods, including fruit and vegetables, whose CO_2 impacts vary according to the range of factors which make up those scenarios. They include: whether the food was produced organically; in a heated greenhouse; purchased by a car-driving shopper – and whether the product was freighted in by air. It found that air freight has significantly more of an impact on energy use and emissions than any of the other variables examined.

Food-related car travel

It is possible to calculate very roughly the total emissions attributable to fruit and vegetables at the shopping stage. One might, for example, allocate a share of total food car-shopping related emissions to fruit and vegetables in proportion to the average contribution by weight they make to our shopping. According to *Family Food*,[108] fruit, vegetables and potatoes constitute roughly 26% of total food purchased by weight (this is a crude estimate and does not take packaging into account). In the Defra food miles study, cars are calculated to account for 13% of total transport CO_2 (not GHG) emissions. This is eqivalent to, meaning 0.44% of the UK CO_2 total, or 0.38% of total GHGs. And if fruit and vegetable-related car travel accounts for 26% of this, then total fruit and vegetable related car travel emissions contribute 0.1% to the UK's total greenhouse gas emissions

Of course a shopping trip will go ahead regardless of what is being bought. Arguably disaggregating car-emissions by food type is of limited value from a policy making perspective since the emphasis should clearly be on reducing car-based travel for shopping *per se*.

This said, it is sometimes helpful to look at the breakdown of food bought in terms of its bulkiness and the frequency with which a certain type of food is purchased. Some foods, by their very nature, need to be bought more often than others. While rice, say, will keep for years and can be bought infrequently and in bulk, fruit and vegetables have a storage life measured in days. As such they need to be bought often and so where they are being bought from will have a critical bearing on how people travel to buy them. In practice most people buy the vast majority of their fruit and vegetables from

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[106] Boeing 2004 | 2005 World Air Cargo Forecast http://www.boeing.com/commercial/cargo/01_01.html

[107] Anne Van Hauwermeiren, *Energy life cycle inputs in food systems: a comparison of local versus conventional cases*, Centre for Agricultural & Food Economics, Katholieke Universiteit Leuven: presentation given at FCRN fruit and vegetable seminar in Manchester, 1 December 2005

[108] *Family Food in 2003-4 Defra*, http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp

supermarkets[109] and since we eat so few of them, the weekly shop suffices. However it may be that any rise we might see in fruit and vegetable consumption (spurred on by a growing awareness of the health benefits), could lead to the development of different shopping patterns. One possibility might be more frequent trips to the supermarket. Recent research however shows that in the past few years we have started to move away from the once-a-week-only shopping trip. Instead, while we are as dependent as ever upon a main store for the bulk of our shopping, we are increasingly supplementing this with additional purchases at more local stores. In other words, we are now shopping more frequently and as part of this we are also making more local purchases than has hitherto been the case.[110] [111]

A second possibility might be an increased reliance on fruit and vegetable delivery schemes. These are growing in popularity although of course uptake is still very low. Research into the environmental impacts of home delivery schemes indicates that home deliveries, on balance are environmentally beneficial, notwithstanding concerns that the avoided need to drive to the shops will free the car up for other, also CO_2 emitting purposes.[112] This does happen of course, but perhaps not sufficiently to counteract the benefits of more consolidated bulk deliveries. However when fruit and vegetables are bought through a home delivery scheme (such as an organic 'box' scheme) and in addition, the bulk shop is carried out (by car) at a supermarket, there will in fact be additional transport impacts.

Food miles and the possible trade offs

Fruit and vegetables have come under particular scrutiny in the food miles debate; the air-freighted Kenyan dwarf bean and Californian strawberry appear now to have acquired celebrity-villain status. However there have been various modifying voices in recent years. Many life cycle studies have found that transport makes a relatively small contribution to overall life cycle emissions and that there are other stages – particularly agricultural production – where impacts are greater (this is particularly true of meat and dairy products.[113] There are also suggestions that on occasion importing produce from overseas can make more environmental sense than growing the produce in energy-intensive conditions here in the UK (as discussed earlier), or storing domestically grown produce in energy-intensive cold storage units for lengthy periods.

Life cycle analysis takes the food miles trade-offs debate further still by comparing interactions not just *between* transport and production but *among* several different life cycle stages. In other words it highlights the fact that interactions are not bilateral but

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[109] *Fresh Fruit and Vegetables - UK - May 2005*, Mintel

[110] Clarke I, Jackson P, Hallsworth A, de Kervenoael R, Perez del Aguila R, Kirkup M. *Workshop on Retail Competition and Consumer Choice*, Tuesday 8 June 2004, London. Presenting the findings of a long-term study of the effects of local retail change and the impact on consumer choice at the household level. Workshop Briefing Note, June 2004, ESRC / Lancaster University Management School, http://www.lums.lancs.ac.uk/files/marketing/3401/download/

[111] Local shops can include both local independent stores and supermarket 'Express' and 'Local' formats.

[112] see Garnett T. 2003. *Wise Moves: exploring the relationship between food, transport and CO2*. Transport 2000, London for a discussion of home shopping and e-commerce.

[113] Sonesson U, Mattsson B, Nybrant T and Ohlsson T Industrial Processing versus Home Cooking: An Environmental Comparison between Three Ways to Prrepare a Meal. *Ambio: A Journal of the Human Environment*, vol. xxxiv number 4-5 June 2005.

multilateral, which complicates matters considerably. Some of these interactions are discussed in this section; others are explored elsewhere in this paper.

For fruit and vegetables it has already been noted that, while UK production stage emissions do not appear to be very great, since there is an absence of data on overseas production emissions, informed conclusions cannot really be drawn. The Defra case study comparing UK and Spanish tomatoes moreover shows that for both UK and Spanish tomatoes the production stage emissions are more significant than those arising from transport. This is true even for the Spanish tomatoes which travel all the way to the UK.[114]

It is worth noting however that things can change, as technology or other factors develop. Indeed it may be helpful to consider the potential 'solvability' of various life-cycle problems. It may on the whole be both easier and cheaper to improve the energy efficiency and the carbon intensity of stationary infrastructure than it is to do the same for moving vehicles. (Note that a distinction is made here between energy efficiency and carbon intensity. The former is a measure of energy use per unit of useful product and does not distinguish between types of fuels or their carbon intensity. Carbon intensity, on the other hand is a measure of the carbon emitted per unit of energy generated: compare a kW h of energy produced by solar power with that produced by coal. A third distinction is 'energy demand,' which is a measure of the extent to which people use energy-using products and services, such as cars or space heating.)

For example improved energy efficiency in the UK horticultural industry and/or a shift towards using CHP or renewable energy sources could help strengthen the position, environmentally speaking, of UK production. Section 5b considers some of the technological options for reducing emissions. Where substantial reductions have been achieved in glasshouse energy use, there will be synergies between reductions in production stage and transport emissions. 'Substantial' is taken here to mean more than the horticultural industry's commitment to reduce energy use by 12% by 2010 under the terms of the Climate Change Agreement.

However it is also the case that Southern European and Mediterranean horticulture is increasingly facing the prospect of serious water shortages, partly because of the changes in global climate. In the short term this does not appear to be affecting their production – Morocco for instance is emerging as a strong horticultural producer. But it does mean that this region will be increasing its demand for energy intensive irrigation. In the longer term it could spell the decline in Southern Europe's horticulture industry. One consequence could be that British retailers seek other sources of overseas supply which might be more transport intensive to import.

Adding up total fruit and vegetable emissions

A crude calculation for transport emissions from the fruit and vegetable sector are presented in table 1. Note that these figures include emissions generated during the course of transporting produce from overseas – in other words, they are consumption-related. By contrast the UK reports only its production-related emissions under the terms of the Kyoto Treaty.

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[114] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

Table 1 - Transport emissions from the fruit and vegetable sector

Transport stage	% UK greenhouse gas emissions
UK road transport	0.05
Overseas road and sea	0.2
Overseas air	0.2
UK car shopping travel	0.1
Contribution to UK GHG total	0.55 (approx)

One might argue that 14% to could be added on to the road and sea freight legs to take into account refrigeration related emissions in which case the contribution would a little higher at 0.59%.

Trends in food transport and their implications for emissions

The forecasts suggest that food transport, not just by air, but by all modes (measured in tonne kilometres), is set to grow in the future.[115]

Of particular concern is air freight. This is predicted to grow at about 6.2% over the next two decades, meaning that by the end of this period the volume transported by this mode will have tripled.[116] The freighter fleet is likely to nearly double over the next 20 years, and three quarters of these additions will be modified passenger and combi aircraft.[117] This will further encourage the shift towards the use of dedicated freight vehicles to transport food. In addition, since freight aeroplanes will continue to be less energy efficient than passenger aeroplanes (as they tend to be refurbished old passenger planes) so the impacts of this projected growth will be disproportionately great relative to growth in passenger air travel.

Conclusions for this section

From an emissions perspective, transport may be a significant life cycle stage for the fruit and vegetable sector, particularly if the produce comes by air. While 0.5-0.6% of the UK's total greenhouse gas emissions is not huge it is important to note that transport trends in this sector are unfavourable. With the UK declining in self sufficiency, and with an increase in the volume freighted in by air, the relative importance of transport both to overall life cycle fruit and vegetable emissions and of course to the UK's total GHG emissions is likely to grow. This is perhaps in contrast with other life cycle stages where efforts to reduce emissions in absolute terms, and not just relative to production volumes, have met with some success.

[115] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp
[116] *World Air Cargo Forecast*, 2004-2005, Boeing http://www.boeing.com/commercial/cargo/01_01.html
[117] Outlook 2005, Boeing, http://www.boeing.com/commercial/cmo/index.shtml

2c. Refrigeration and cold storage

More than 50% of food in developed countries is retailed under refrigerated conditions.[118] In-store refrigeration is only part of the story however, for temperature control is integral to the entire process of producing, transporting and selling food. Fruit and vegetables, as perishable foods, are particularly dependent on this technology.

The technology and management of cold storage are immensely complex issues, and this paper cannot hope to tackle them in any depth.[119] The purpose here is to try and provide a fairly basic overview of how the demands of the fruit and vegetable sector for temperature control contribute to climate changing emissions; where the critical impacts lie; what the trade offs might be with other life stages, and how current trends in the pattern of our fruit and vegetable consumption may affect refrigeration-related emissions in the future.

Before starting, a brief word on the terminology might be helpful. The terms temperature control, cold storage, the cold-chain and refrigeration are used here more or less interchangeably even though strictly speaking there are differences (for example a temperature controlled product might be kept warm). Where the word refrigeration is used it should be taken to mean temperature control in general. However there are times in what follows when refrigerated foods are referred to as distinct from frozen foods. The context should make the distinction plain.

Post-harvest temperature control

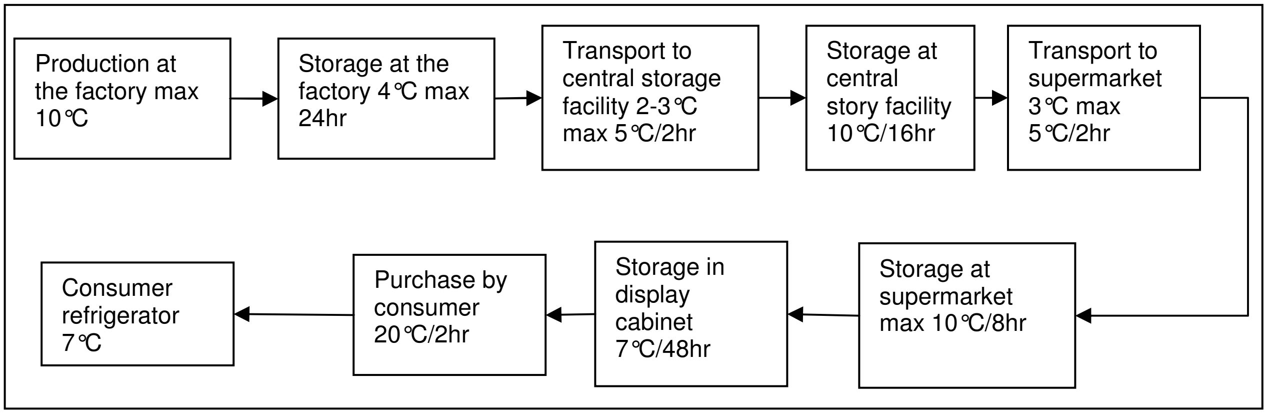
In the UK and elsewhere in the developed world, fruit and vegetables are cooled almost immediately they are harvested to slow the process of decay that begins as soon as they are picked. The produce is then transported under refrigerated conditions and it will continue to be stored in this way throughout the supply chain – in distribution centres, in the retail outlet and usually in people's homes. Figure 4 shows typical cold storage requirements for fresh cut fruit and vegetables.[120]

[118] François Billiard, *Food Safety and Refrigeration*, FAO/WHO Global Forum of Food Safety Regulators Marrakech, Morocco, 28 - 30 January 2002 http://www.fao.org/DOCREP/MEETING/004/AB435E.HTM

[119] cold storage will form the subject for a separate FCRN seminar and discussion paper

[120] *Refrigeration for Preserving the Quality and Enhancing the Safety of Plant Foods* by Francisco Artés Bulletin of the IIR - No 2004- International Institute of Refrigeration, http://www.iifiir.org/2enarticles_bull04_1.pdf

Figure 4



Source: *Refrigeration for Preserving the Quality and Enhancing the Safety of Plant Foods* by Francisco Artés Bulletin of the IIR - No 2004- International Institute of Refrigeration, http://www.iifiir.org/2enarticles_bull04_1.pdf

However, the temperatures at which fruit and vegetables are stored will vary by type. In general storage requirements for fruits and vegetables can be divided into three main bands as Table 2 below, based on Thompson and Kader's work[121] shows:

Table 2 – Storage temperatures by produce type

Storage 0°C – 2C	Storage 7°C – 10C	Storage 13°C – 18C
Apple	Avocado	Banana
Berries and cherries	Basil	Melon
Celery	Citrus fruits	Papaya
Cruciferous vegetables	Green beans	Potato
Cut vegetables	Mango	Pumpkin and squash
Fennel	Passion fruit	Sweet potato
Fig	Pepper	
Grapes	Pineapple	
Herbs (except basil)		
Kiwi fruit		
Lettuce and salads		
Lychee		
Mushrooms		
Peach		
Pear		
Peas		
Plum		
Pomegranate		
Root vegetables		
Spinach and greens		

[121] Thompson J F and Kader A A. Wholesale Distribution Center Storage, USDA Agricultural Research Service http://www.ba.ars.usda.gov/hb66/016wholesale.pdf

This is a general guide and the temperatures will vary not just by fruit and vegetable type but also by different varieties of the same fruit or vegetable. Take potatoes, for example. Their storage temperature ranges from 2℃ to 13℃, with the average at around 6℃. The temperature at which they are stored will depend on the variety, the intended storage time, the type of sprout suppression needed and the market for which it is destined – whether it is being sold fresh or whether it will go on to be processed (note that in the winter, heating rather than cooling will be needed to maintain the desired temperature). Potatoes can be stored for up to 11 months but the average tends to be about 5 months.[122]

Considerable energy is required to cool the fruit or vegetable to the required storage temperature. According to the British Leafy Salads Association,[123] to guarantee acceptable shelf-life in an iceberg lettuce, growers aim to cool the head to 3°C within 3 hours of leaving the field. On a hot day, the core temperature of the lettuce can reach 26°C, so evidently a great deal of energy is needed to get the temperature down to this level.

What happens after harvest will depend on the type of produce in question. For fruits or vegetables with a long storage life they will be kept in a cold store for some time, before travelling on to the retailer or wholesaler. For produce with a very short shelf life the journey to the retailer or wholesaler will begin almost immediately after harvest. For many goods of non-European origin, much of their storage time will be spent in transit, in the hold of a ship.

All these variables will have an impact on storage energy requirements.

Processing stage cooling and temperature control

As section one showed, while most vegetables are sold whole and unprocessed, a large minority of fruits and potatoes will be processed in some way and as such the refrigeration aspects of the processing stage need to be examined.

Processed fruits and vegetables include canned, chilled-prepared and frozen products. These foods will either be sold individually (a bag of frozen peas, a ready-chopped pineapple) or end up as a constituent ingredient in another produce, such as a sandwich, a pizza or a ready meal.

With such diverse routes through the supply chain it is difficult to track and calculate the energy used in the refrigeration of processed fruits and vegetables. The figures provided here are only approximate and based on what industry observers[124] know about the fruit and vegetable sector's share of the food manufacturing industry.

One estimate suggests[125] that refrigeration energy accounts for about 27% of total energy use in the food manufacturing industry, or half its electricity use. Enviros, which

[122] Phil Bradshaw, British Potato Council, personal communication, November 2005
[123] British Leafy Salads Association http://www.britishleafysalads.co.uk/plough/harvesting.shtml
[124] much of the information has been provided by Ray Gluckman, Enviros, personal communications Nov – January 2005-6
[125] Enviros estimates, personal communication November 2005

undertake much Climate Change Agreement-related work for the food industry, calculates total refrigeration energy demand to be about 3,300 GW h of energy. To this is added an additional estimated 500 GW h for cold storage.[126] These, taken together and translated into carbon emissions, add up to about 0.28% of the UK's total carbon emissions.

This figure relates to all manufactured food and drink and not just to fruit and vegetables. Breaking the data down by food type is, as already mentioned, very difficult. It is possible, however, to make a few rough calculations. For instance energy used by poultry and meat processors, dairy processors, bakeries and breweries can be excluded since these record their data separately under the terms of their Climate Change Agreements. Excluding these, then, leaves a figure of 1,900 GW h (from the original 3,300 GW h). This, in terms of carbon emissions, is equivalent to 0.14% of the UK's total.

A very approximate estimate by Enviros, based on a rough estimate of the size of the fruit and vegetable sector relative to those other food industries which also use refrigeration suggests that around 280 GW h are used by the processed fruit and vegetable sector, which works out at a very tiny 0.02% of the UK's total CO_2.

However, as is discussed below, the impact of refrigeration for fruit and vegetables is fairly substantial lower down the supply chain and it can be argued that some of the need for this refrigeration arises because of the processing that occurs higher up the supply chain. In other words, it is the processing itself that dictates the degree of refrigeration needed.

Mobile temperature control

It is also necessary to consider the energy used to control temperature during transport. Influences on this energy use will include how well the container is insulated, the time spent in the unit, both at a standstill and in motion, and how fully the vehicle is loaded.

Mobile temperature controlled storage tends to be significantly less energy efficient than stationary cold storage. The reason for this is simple – a smaller container such as a mobile refrigeration unit has a larger surface area relative to the volume it can hold than a large cold store and it is not possible to insulate it to the same degree. As such the coolness tends to escape through the walls of the vehicle (or strictly speaking the heat comes in).

Estimates for energy use in mobile units vary, as do the units of measurement. Some measure fuel use per distance travelled, while others define energy in terms of kW h. For example, the US Steel Recycling Institute (SRI) report which is discussed more fully later estimates refrigeration to add an extra 14% on top of transport energy. Put another way, the efficiency of a vehicle drops from on average 3.4km/litre to 2.93km/litre.[127] While this is a US study, mobile storage units tend to be sold internationally and so these figures may well apply to the UK. Helpfully, Sainsbury's, in its 2005 Corporate

[126] Enviros estimates, personal communication November 2005

[127] Ritchie K (forthcoming). *From farm to table: An energy consumption assessment of refrigerated, frozen and canned food delivery*. A report in draft prepared by Scientific Certification Systems on behalf of the Steel Recycling Institute, California, United States

Social Responsibility report, sets out figures for CO_2 emissions generated by refrigeration units and depot vehicles separately from HGV transport emissions.[128] It reports that CO_2 emissions from the refrigeration units add 15% to baseline transport emissions, a figure similar to the SRI report.

Cambridge Refrigeration Technology uses a slightly different approach, estimating[129] that on average a refrigerated vehicle will consume about 6 kW h of energy per 100 tonne/km. Maintaining food under Controlled Atmosphere conditions[130] adds an extra 1.5 to 2 kW to the system power draw.[131] This figure is perhaps more accurate than the others highlighted since it factors in both the weight carried and the distance travelled. It is not, however possible however to make direct comparisons between this and the other figures since the units of measurement are different.

A fourth perspective is given by the Cold Storage and Distribution Federation (CSDF) for a study undertaken by Heriot-Watt University.[132] The CSDF calculates that on average a cold store requires the equivalent of approximately three litres of fuel to maintain a pallet of frozen food at the required temperature for five and a half weeks. By contrast, transporting it from factory to the regional distribution centre (RDC) using a refrigerated vehicle consumes on average a further 11 litres of fuel, given typical lengths of haul and vehicle load factors. Of these 11 litres, roughly 2.8 litres are consumed by the vehicle's refrigeration unit over the 12 or so hours that the average pallet spends in a trailer on the way to and from the cold store. In other words refrigeration energy use during transport uses almost the same energy as is consumed during the course of storing a pallet for seventy six times longer than it is kept in the vehicle. This is despite the fact that the temperature at the stationary store tends to be up to 10℃ colder than the temperature in transit.

It is important to emphasise that food is not being refrigerated just when it moving. For much of the time the vehicle is not going anywhere at all but the food still needs to stay cold. Figure 5 below, taken from another study by Heriot Watt University[133] shows that a refrigerated vehicle spends only around 28% of its time actually in motion. Importantly, the study highlights the close correlation between efficiencies of time and energy use.

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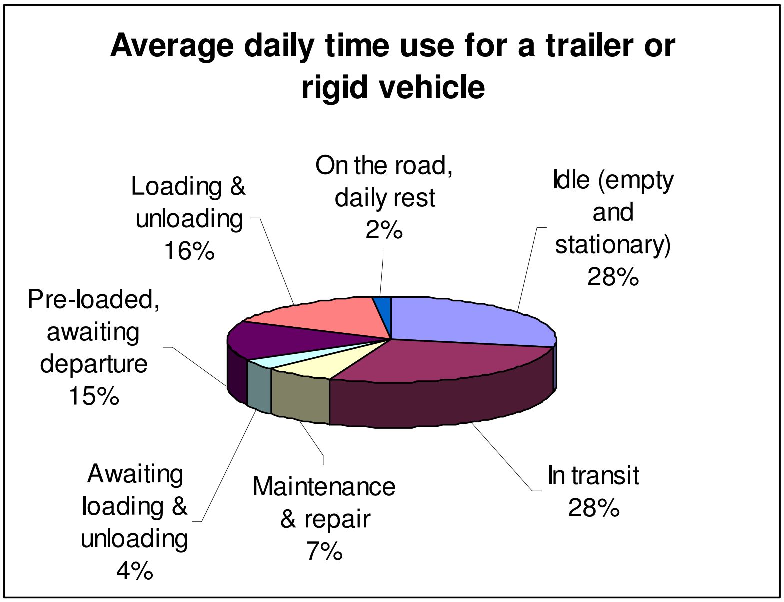
[128] http://www.jsainsburys.co.uk/files/reports/cr2005/index.asp?pageid=61
[129] Robert Heap, Cambridge Refrigeration Technology, personal communication, November 2005
[130] a storage method in which the proportions of oxygen, nitrogen and carbon dioxide, as well as temperature and humidity, are regulated in order to extend the product's life.
[131] Robert Heap, Cambridge Refrigeration Technology, personal communication, January 2006
[132] McKinnon A, Campbell J. *Quick-response in the Frozen Food Supply Chain: The Manufacturers' Perspective*, Christian Salvesen Logistics Research Paper no. 2, June 1998 http://www.sml.hw.ac.uk/logistics/pdf/cs2.pdf
[133] McKinnon A, Ge Y, Leuchars D. (2003). *Analysis of Transport Efficiency in the UK Food Supply Chain: Full Report of the 2002 Key Performance Indicator Survey*, Logistics Research Centre, Heriot Watt University http://www.sml.hw.ac.uk/logistics/pdf/Kpi2003.pdf

Figure 5



Source: McKinnon, Ge and Leuchars, 2003

Interestingly, the energy used to store frozen foods in transit is lower than that required for chilled foods.[134] [135] [136]This reflects the fact that maintaining a very specific temperature is vital for chilled foods if they are not to spoil or freeze and the constant temperature control that is therefore needed uses more energy than the simpler on-off systems which are used for frozen foods. More air circulation for chilled foods is also necessary, and the fans are energy intensive. For frozen foods, the specific temperature at which it is stored is not so critical once a certain threshold has been reached, although obviously storage at temperatures lower than necessary represents a waste of energy. One other reason for the greater energy requirements for storing chilled foods in transit is their lower density relative to frozen goods. Since more food can be stacked in a freezer unit than in a refrigerated container, fewer vehicles will be required to carry around the same amount of food. Note that US Steel Recycling Institute report only refers to mobile refrigeration energy use and uses the same figures for both frozen and fresh chilled goods.

Marine transport is also a major user of energy. In marine containers, refrigeration energy use is typically 48 kW h per tonne per day for frozen and 120 kW h per day for chilled foods. This is regardless of the quantity carried, but the figure will vary with the ambient temperature – evidently, more energy is needed to keep the containers cool in tropical than in Nordic climates. Most produce travels in specialist refrigerated ships which will use significantly less energy as their holds are larger, and therefore by definition, more efficient than marine containers.[137]

[134] Robert Heap, Cambridge Refrigeration Technology, personal communication, November 2005
[135] *Refrigerated transport: progress achieved and challenges to be met*, International Institute of Refrigeration, August 2003 http://www.iifiir.org/16NoteEN.pdf
[136] *Refrigerated transport: progress achieved and challenges to be met*. 16th Informatory Note on Refrigerating Technologies , International Institute of Refrigeration, August 2003
[137] Robert Heap, Cambridge Refrigeration Technology, personal communication, January 2006

It would be helpful to know more about the relative refrigeration energy intensity of particular fruits and vegetables, bearing in mind all the possible variables. For example as table 2 highlighted, some fruits and vegetables (mainly the tropical ones) are stored at far higher temperatures than others (such as the temperate ones). This may well mean that the temperate-zone fruits and vegetables are more energy intensive to store than tropical produce.

On the other hand, the tropical, high-storage temperature produce will be coming in from far away and as a result will spend much of their storage life in transit. As has already been shown, mobile refrigeration is far more energy intensive than stationary cold storage.

This said, many temperate products, such as apples, also come from far away. As such they may have the worst of both worlds – not only do they spend their time in energy intensive mobile cold storage but they also have to be stored at a lower temperature than some of the more tropical fruit. It is possible that, somewhat anti-intuitively, Brazilian pineapples and mangos may be less energy intensive overall than New Zealand apples. They could even, conceivably, be less energy intensive than, for example Italian apples, since the latter are more likely to travel by road (which is more carbon intensive per km travelled) and are stored at lower temperatures. While the difference between storing produce in transit at 2℃ compared with 13℃ is probably minor relative to the sheer energy intensity of mobile refrigeration,[138] when it comes to stationary storage (once the produce has arrived in the UK) the differences could be more significant.

Notwithstanding all these variables and uncertainties, it is clear that temperature control in transit represents an additional energy cost and one that is sometimes omitted in life cycle analyses as LCA databases do not usually contain data for mobile temperature control in transport records. At present the contribution made by mobile fruit and vegetable cold storage was estimated to be about 0.05% of the UK's greenhouse gas total in Table 1 above. This is an extremely crude calculation and is hoped that a forthcoming Defra-funded project will yield some more accurate figures.[139]

It is likely that energy use for temperature control in transit will increase as we see a continuing growth in the market for chilled foods and particularly for foods that require long journeys to reach these shores.

Temperature control in retail outlets

Refrigeration[140] accounts for at least half of the energy used by retail outlets. Waitrose for example calculates that over 65% of its energy is used to refrigerate food[141] while Sainsbury's says that refrigeration is the main use of energy in stores.[142]

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[138] Robert Heap, Cambridge Refrigeration Technology, personal communication, March 2006
[139] Fostering the Development of Technologies and Practices to Reduce the Energy Inputs into the Refrigeration of Food, Defra funded project
[140] taken here to mean maintaining both chilled and frozen foods at the right temperature
[141] http://www.johnlewispartnership.co.uk/TemplatePage.aspx?PageType=SCT&PageID=29
[142] http://www.jsainsburys.co.uk/files/reports/cr2005/index.asp?pageid=59

Provisional calculations supplied by the Market Transformation Programme show that energy use in food related cold storage at the retail stage and food service stages in the UK is very significant indeed, accounting nearly 1% of its carbon emissions. [143] This figure includes refrigeration used in all food and drink related retail outlets from supermarkets to off-licences, to refrigerated cabinets for sandwiches at Boots. It also includes refrigeration in pubs, hotels, restaurants, staff canteens and so forth.

The figure does not, however, take into account mobile refrigeration on vehicles or energy used during the course of transporting food from overseas, an issue which has been discussed above. Neither does it include additional greenhouse gases created by the refrigerant used, although this will have a much lower GHG impact than the energy used in the first place. The International Institute of Refrigeration estimates that greenhouse gases emitted from the refrigerants themselves add another 20% to total refrigeration emissions.[144] Adding this figure to the figures given above, one might calculate that the contribution of food related stationary storage to the UK's greenhouse gas (not just carbon) emissions is also 1%

It is very difficult to say how much of this should be allocated to fruit and vegetables. Supermarkets are not willing to give away this sort of information as it is considered to have commercial import. So, in the absence of more concrete information it is assumed here that 25% of total retail refrigeration use is devoted to fruit and vegetables (including a share of ready meals, frozen foods, sandwiches, and so forth). A quarter of 1.34 works out at 0.34. This is an arbitrary figure and one based purely on personal shopping experience. As such further research in this area would be welcomed.

Domestic refrigeration

The final stage of the cold chain is the domestic fridge-freezer. According to Market Transformation Programme figures[145] domestic refrigeration accounts for 1.1% of the UK's CO_2 emissions, and an equivalent contribution (taking the refrigerant emissions into account) to the UK's greenhouse gas emissions.

Recent years have seen major improvements in energy efficiency. Between 1995 and 2001 the energy consumption of an average 140 litre refrigerator in a UK home dropped by 25%; much of this improvement was achieved following the introduction of new EU legislation in 1999.[146] However the savings have been partly offset by the trend towards larger appliances. Research shows that appliances are now 15% bigger than they were in 1999 and so the net result has been a lower 19% reduction in average electricity consumption from fridge freezers. To this should be added the fact that recent years have also seen a growth in the number of households (often with single person

[143] Romano Pehar, Market Transformation Programme, work in progress, personal communication November 2005

[144] *The refrigeration sector's active role in the mitigation of global warming*, International Institute of Refrigeration, 2003 http://www.iifiir.org/COP9.en.pdf

[145] Sustainable Products 2005: Policy Analysis and Projections, Market Transformation Programme, Appendix F2
http://www.mtprog.com/ReferenceLibrary/MTP_Sustainable_Products_2005_updated_26_1_06.pdf

[146] Boardman, B (2004) *Achieving energy efficiency through product policy: the UK experience*. Environmental Science and Policy 7(3), 165-176

occupancy) and this has led to a 10% increase in the stock of appliances, both old and new, in British homes. The overall effect, then, is that total electricity consumption in the cold appliances sector has only decreased by 1% by 2001. [147] Boardman notes that an emphasis on energy efficiency on a relative basis can be misleading and can actually encourage manufacturers to make larger appliances since it is easier to achieve energy efficiencies in this way. She argues, as do others[148] that using absolute consumption as the basis for the energy label would help to encourage energy conservation.

As a final point it may be worth noting that refrigeration emissions may in fact be lower than they would be if we actually kept our fridges at the recommended 5℃. Most people do not know what temperature their refrigerator is set at and in most cases their fridges are not cold enough to meet food safety recommendations. A compilation of eight country surveys[149] which looked at people's fridge temperatures found that the majority of fridges run at over the recommended 5℃. In the UK 23% of people surveyed kept their temperature above 7℃ and the mean temperature was 6℃. Arguably if people did follow the 5℃ recommendation, energy use from refrigeration would go up. On the other hand we might see less food wasted through spoilage, and possibly fewer cases of food poisoning.

Comparing frozen and chilled foods in relation to temperature control

Frozen fruits and vegetables account for only 7% of all the fruits and vegetables (excluding potatoes) we eat[150] and, as already noted, it is unlikely that there will be much growth in the frozen fruit and vegetable sector in future years.[151] While frozen potatoes are of course by volume very significant – frozen and chilled make up half all potatoes by volume consumed (and two thirds of all processed potatoes) - [152] sales are likely to stay level or even decline in real terms for these foods.[153]

Since then, the frozen food (including fruit and vegetables) sector is fairly stagnant, what might the implications be for energy use from cold storage? Is a shift from eating frozen food to eating chilled food a 'good thing?'

Data used in a report commissioned by the US Steel Recycling Institute give some interesting insights into energy use in frozen foods as compared with refrigerated foods.[154] [155] It finds that energy use for freezing and storing frozen food is seven times

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[147] Boardman, B (2004) *Achieving energy efficiency through product policy: the UK experience*. Environmental Science and Policy 7(3), 165-176

[148] give ref

[149] James, S.J. *Developments in domestic refrigeration and consumer attitudes*, Bulletin of the IIR - No 2003-5, International Institute of Refrigeration the countries include the UK, Northern Ireland, France, Greece and elsewhere

[150] *Family Food in 2003-4 Defra*, http://statistics.defra.gov.uk/esg/publications/efs/2004/default.asp

[151] *Frozen and Canned Fruit and Vegetables* - UK – Mintel June 2005

[152] Annual Balance Sheet of Potato Supplies and Disposals 1988-2004, British Potato Council, 2005

[153] *Frozen and Canned Fruit and Vegetables* - UK – Mintel June 2005

[154] Ritchie K (forthcoming). *From farm to table: An energy consumption assessment of refrigerated, frozen and canned food delivery*. A report in draft prepared by Scientific Certification Systems on behalf of the Steel Recycling Institute, California, United States

[155] Note that the figures are ten years old and specific energy use will have declined since then.

greater than that required for cooling fresh food and maintaining it in chilled conditions. Note that the discussion here concerns *stationary* as opposed to mobile storage. Critical to its calculations are the assumptions it makes about the average storage life of chilled and frozen food. It assumes an average ten day cycle for the storage of chilled foods and an average 90 day cycle for frozen foods.

However, the contrast is modified somewhat when processing stage energy (the energy needed to cool the food down to the required storage temperature) is omitted and the storage stage only is considered. Here it is found that the difference between frozen and chilled foods is only threefold, despite the fact that the frozen food has assumed to have been stored for longer than the chilled food. Two conclusions would appear to follow: the first is that the energy required to freeze food in the first place constitutes a very significant chunk of overall cold chain energy use (more than 55%). Consequently an increase in frozen food production and consumption would lead to a disproportionate increase in energy use in this sector largely because of the amount of energy required in the first instance to bring the products down to the right temperature. As has already been noted, this is unlikely to happen, at least for vegetables (although an increase in consumption of frozen fruits such as berries is predicted).[156] A decline in the frozen food sector would lead to a disproportionate decline in emissions.

The second point to follow is that for chilled food, the reverse is true. The energy needed to store chilled food at the right temperature is vastly more significant than that required to cool it in the first place. Storage related emissions account for 96% of the total chilled food cold-chain emissions. (It is of course necessary to bear in mind that in absolute terms emissions from chilled foods will be lower than from frozen food when in cold storage. Which way the balance tips once mobile refrigeration is taken into account is not clear). The study also shows that of these storage related emissions more than four fifths (85%) occur during the time spent in the shop. This is largely due to the open display cabinets commonly used in supermarkets and other retail outlets. Clearly this is an area where major energy inefficiencies occur and section 5c below looks at what action is being taken to address this issue.

On the face of it then, a decline in frozen food and a growth in chilled food might be desirable from an energy saving perspective. If the infrastructure remains the same (the same number of cabinets and storage units), a shift from frozen to chilled could lead to a decline in overall emissions since so much of the energy use in frozen foods is embedded in the initial freezing stage.

However this on-the-face-of-it assumption may need modifying for several reasons. For a start, if growth in the chilled food sector leads to greater investment in storage infrastructure in retail outlets to accommodate the growth, then this could lead to an increase in emissions. Secondly, it may be that the growth in chilled fresh foods takes away not so much from the frozen food sector but from growth in the market for unprocessed, unprepared whole fruits and vegetables. Value-added ready prepared fruit salads, topped and tailed vegetables and so on tend to be stored in refrigerated display cabinets while their unmodified counterparts do not. The growth in, say, ready-to-eat chopped pineapple at the expense of the cut-your-own version is likely to generate an increase in refrigeration-stage emissions. The preparation of the food and the surrounding packaging will also have incurred the use of energy.

[156] *Frozen and Canned Fruit and Vegetables* - UK – Mintel June 2005

Finally the Steel Recycling Institute study did not distinguish between energy use in transit for frozen as opposed to chilled foods. As already discussed, the transport of chilled foods is the more energy intensive of the two.

How helpful is LCA when discussing refrigeration?

Clearly the cooling and storing of food under temperature controlled conditions is an energy intensive process. Most life cycle analysis allocates a share of refrigeration emissions to the product in question both on the basis of the space it takes up in the fridge or freezer and the length of time for which it is stored. The Steel Recycling Institute study highlighted above finds that frozen goods represent the most energy demanding food choice, once the whole life cycle of the product has been considered. Nearly half of the frozen food refrigeration emissions result from the assumed three months spent in the domestic freezer. Presumably if the foods were only stored for six weeks, the frozen food storage emissions would halve. Indeed, a life cycle assessment of frozen peas carried out by Unilever found a major difference in energy emissions depending on how long the peas were assumed to be kept stored.[157]

This does not really make sense. The fact is that almost all households have fridge-freezers and whether we choose to buy and store frozen peas or fresh spinach or not and how long we choose to store them for will make no difference to the overall energy that our cold appliances use. For example if I buy a packet of frozen peas and store it for four months, or whether I buy the same packet and store it for two months will in effect make no difference to my annual refrigeration energy use. The freezer will still be on. Indeed one might argue that a well stocked freezer runs more efficiently than a half empty one per unit of food stored.

However the question of refrigeration and its relationship with the fruit and vegetables we consume and the form in which we consume them is an interesting one. The development by food manufacturers and the selling by retailers of the types of foods we consume today is predicated on the assumption that we all have fridges and freezers. And as cook-chill, fresh, highly perishable or frozen foods take up increasing store space, we are buying them more often and in larger quantities. As a result, our fridges and freezers are getting bigger. In some cases we are buying second freezers. The issue here is not so much *what* we put in our fridge and for *how long* we store the food but how the size of the fridge is *determined* by how much food we put in and for how long we store it. In turn, larger average household fridge sizes support further growth in temperature controlled foods and perhaps in commercial cold storage infrastructure

2d. Energy intensive storage versus energy intensive transport: which is preferable?

When considering the energy impacts of cold storage in all its forms, it needs to be remembered that if food were not refrigerated, a proportion of it would rot or spoil. The loss of produce in this way represents a 'waste' of energy since the wasted food will embody the energy used in its production, processing and transport. Put simply, more

[157] Peter Shonfield, *Energy Consumption Across the Frozen Pea Supply Chain*, Unilever, presentation given at FCRN fruit and vegetable seminar, I December 2005

waste means that more food will have to be produced than is consumed, while less waste means the opposite. This is of course a very simplistic view because it does not take into account the complex interactions among production, demand and price which have at least as much impact on what 'needs' to be grown as do waste levels.

Nevertheless the relationship between storage and waste is worth closer investigation. One Brazilian study[158] compared two food stores; one without a refrigerated unit (store A) and one with (store B). The authors found waste in the un-refrigerated Store A to be as high as 28% while for refrigerated Store B waste levels were about a third of this, at 10%.

Apart from minimising waste, the cold chain also enables food which is indigenous to the UK to be stored for longer than would otherwise be possible, thereby reducing the need to import food. The storage of UK potatoes, white cabbage and Bramley apples from one season to the next, are examples.

On the other hand, the availability of such technology has not led to greater self sufficiency. On the contrary, the cold chain has in fact been core to the development of international food supply chains. Were it not for the existence of sophisticated cold chain technology we would not have such ready access to foods from distant countries – the food would simply spoil before reaching us. Thus, while refrigeration can act as an aid to self sufficiency it is perhaps more the case that cold storage has reduced the need for such self sufficiency by facilitating the development of long supply chains.

One might nevertheless hypothetically envisage a UK scenario of greater self sufficiency made possible by the use of cold storage for long periods to extend availability. Would this be, in energy terms, preferable as compared with the situation which we have today, where indigenously growable produce are imported outside the UK growing season? Of course in the case of many fruits and vegetables (particularly apples and pears) imported produce is offered even during the British growing season but to keep things simple this is ignored here. Nor are comparisons between glass house versus field grown produce considered here because this sort of produce cannot in any case be stored for long.

Presented with these two scenarios the question to consider is: does the energy used to store indigenous produce beyond its growing season outweigh the energy used to transport imported foods into the UK?

A comparison between energy used for food transport and energy used for refrigeration might be helpful here although the only figures available (and used here) are for *all* foods and not just fruit and vegetables. The Defra-sponsored Food Miles study calculates that in 2002 food transport within the UK produce 10 million tonnes of CO_2,[159] around 1.5% of the UK's total greenhouse gas emissions.

As noted above, retail-stage refrigeration (for all foods) accounts for 1.35% of the UK's total greenhouse gas emissions (2004) to which should be added refrigeration emissions

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[158] Fehr M., Calçado M.D.R., Romão, D.C. The basis of a policy for minimizing and recycling food waste, Environmental Science & Policy 5 (2002) 247–253

[159] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

during the manufacturing and domestic stages. These, added together, work out as about 2.7% of the UK's total greenhouse gas emissions.[160] Somewhat unsatisfactorily, two different years are being compared here.

But for imported food this is not the whole story. For a start imported food needs to travel to reach the UK and, as such, it is responsible for an additional 1.4% of the UK's total emissions, according to the Defra study. As with UK-produced food it will also travel around the UK from depot to retail outlet and will therefore be responsible for some of the 1.5% of the UK's domestic food transport GHG emissions. It is also the case that imported food will need to be transported in a temperature controlled environment. No accurate data here are available but the transport section above has added 14% percentage on top of transport emissions to allow for mobile temperature control. This could be an underestimate for produce coming in from hot countries where the refrigeration burden may be considerably greater than average mobile storage energy requirements in the UK.

What might one conclude then? It is difficult to give categorical answers. It is likely that a decision as to the 'optimum' GHG balance between growing and storing more food in the UK versus importing it from overseas will depend on very specific issues such as the length of the journey, the length of storage, the storage temperature needed as well as the difference in the relative energy intensity of the cultivation process itself. As highlighted above there are likely to be huge variations among different fruit and vegetable types.

One life cycle assessment has attempted to grapple with the storage versus transport figure in relation to a particular product; apples. The study [161] compares the primary energy requirement for Braeburn apples grown locally (to the study) in Germany with energy embodied in Braeburn apples imported from New Zealand. Note that the study looks only at energy use; without knowing the specific energy mixes used for New Zealand versus German production, these figures cannot be translated into CO_2 or GHGs.

New Zealand apples are picked at the end of March, transported for 28 days by sea and sold in Germany in April. German-grown apples are picked in mid-October and stored for five months before being sold in mid-March. The authors assume on the one hand higher yields for New Zealand production relative to energy use[162] and on the other additional transport energy use to allow for the importing stage. The study authors find that primary energy use for German apples is nearly 6 MJ per kg of fruit, of which 0.8 MJ, or 13% of the total energy used, is for storing the apples at 1°C during the winter months. By contrast the overall energy requirements for the New Zealand apples are

[160] This figure is actually energy use translated into carbon emissions but since one needs also to add around 20% for the global warming effect of the refrigerant gases, and since at the national scale the other greenhouse gases contribute an extra 20% on top of carbon, the figure also stands as a reasonable approximation of the contribution to the UK's total greenhouse gases.
[161] Blanke M.M and Burdick B. Food (miles) for Thought: Energy Balance for Locally-grown versus Imported Apple Fruit *Environmental Science & Pollution Research* 12 (3) 125 – 127 (2005)
[162] although it is argued (among other things) that the data they use is out dated in Cowell,S.J.,.Milà i Canals L, and S.Sim. 2006. Considerations in a comparison of local versus imported apples. *Environmental Science and Pollution Research*. Submitted.

found to be 7.5 MJ per kg or 25% higher. The study did not consider waste – apples spoiled in storage or during transit.

Several points are worth noting. For a start, the figures the authors used for production-stage energy use are very old[163] and much higher than more recent studies indicate, as is discussed in section three, below. Second, they do not look at waste which needs to be considered before making conclusions as to the environmental balance between the two sources.

A commentary on the paper by Milà i Canals *et al*[164] reworks the figures using more recent production stage energy data and factoring in a certain level of waste (which they vary by time of year). The authors conclude that the picture is not quite as clear cut as the original study suggests. The balance between local and imported apples very much depends on the length of time for which the produce is stored. They suggest it is preferable from a primary energy consumption perspective to eat local apples when they are in season and stored for shorter periods of time (4 months or less). At other times of the year (the European spring and summer), domestically produced apples may or may not be less carbon intensive, depending on a number of factors including production practices at the originating orchard, storage waste levels and the distances travelled.

It is easy, when discussing an issue such as transport versus storage to fall into the either-or trap. In reality, the choices available are likely to be more nuanced than between refrigeration and no-refrigeration. For example, while temperature control may indeed be necessary for most if not all fruit and vegetables, does food need to be stored at quite such low temperatures as those specified by the food industry? Storing apples, for instance at a few degrees higher than what is considered optimum (currently about 1-3℃) will result, at the end of the standard five or six month storage period, in a softer-textured apple. These are perfectly edible and nutritious (see below for a discussion of storage and nutrition) and waste levels will still be low. The industry however has repeatedly stated that what consumers want are very crisp, sweet apples. Hence the greater popularity, it is argued, of imported varieties over the softer indigenous Coxs and Russets. Apples stored for longer than the 'optimum' time or at higher than the 'optimum' temperature tend to soften. The food industry argues that consumers will not accept this perceived decline in quality, and as such the specified low storage temperatures are deemed to be appropriate and necessary.[165]

This of course raises the classic question as to the extent to which consumers drive trends in our food system and how far the trends are inevitable. This is discussed further in section six below.

On the other hand it is also very probable that a greater emphasis on eating indigenous field grown food *when in season* will lead both to lower and transport energy use. The emphasis on field-grown produce is also important because this way energy for heating the greenhouse structures is avoided. There is also the waste issue to consider, an area which is explored further in section 2f.

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[163] Milà i Canals L, Cowell SJ, Sim S. 2006. Considerations in a comparison of local versus imported apples. *Environmental Science and Pollution Research*. Submitted
[164] Milà i Canals L, Cowell SJ, Sim S. 2006. Considerations in a comparison of local versus imported apples. *Environmental Science and Pollution Research*. Submitted
[165] personal communications with supermarkets and fruit suppliers to supermarkets, ongoing

Cold storage and health

The cold chain plays a vital role in keeping food safe to eat, in inhibiting bacterial growth and in stopping it from rotting. Beyond a certain standard of basic health and safety however, the main function of cold storage lies in preserving the food's nutritional value; this mainly means its vitamin content. It may be helpful here to classify the vitamins into three categories: first, those that are generally unaffected by storage temperature; second, those that are affected by temperature in some foods and not in others and third, those that are highly sensitive to storage temperatures.[166]

Most of the research in this area has looked at the last of these categories. While vitamin C is the most temperature-sensitive nutrient, particularly in non-acid foods, and in the presence of air, thiamin (vitamin B1) is similarly thermally sensitive. Other nutrients that may be affected by extended storage are riboflavin (vitamin B2), folic acid, pantothenic acid and biotin. Levels of vitamin A are affected in some foods, but not others; in fact, levels in carrots and sweet potatoes seem to increase during storage. Minerals appear to be largely unaffected by storage.[167]

Lowering the storage temperature of a food can reduce the rate of vitamin loss. For example it has been shown that a reduction from 20℃ to 4℃ can reduce the loss of vitamin C during 24-hour storage by about 40 to 80 %, depending on the product and harvest date.[168]

Research has shown that, when held post-harvest at temperatures above freezing, fruit is less susceptible to the loss of vitamins than vegetables.[169] Freezing food straight after harvest is the most effective means of preserving nutrients and is considered to be the best commercially available method for long-term preservation. For example, at temperatures of -20 to -25℃ there will be on average only a 10% loss in vitamin C content over the course of one year. However at temperatures of -10℃ losses of up to 80 or 90% can occur after storage for the same period. The discussion above has already considered the merits and demerits of raising the storage temperature slightly from an energy saving perspective. Clearly in such a situation, there would be greater nutritional losses but in theory this could be compensated for by more rapid progress through the supply chain. In other words foods would be consumed, say within three to six months.

However, it is very important to note that, while losses can and do occur during storage, there will also be losses at other stages in the fruit or vegetable's life cycle. Nutrients are lost during processing and of course as they are being cooked, whether in a factory or in the home. Indeed there is some evidence that the maximum damage to nutrient levels in foods actually occurs during the domestic handling and preparation stages, with the storage of food post-harvest being less important in this respect.[170]

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[166] Elizabeth Rippon, Food Standards Agency, January 2006
[167] Elizabeth Rippon, Food Standards Agency, January 2006
[168] Fennema, O. (1977) Loss of Vitamins in Fresh and frozen foods, Food Technology, December, p32-38.
[169] Elizabeth Rippon, Food Standards Agency, Nutrition Division, personal communication, December 2005
[170] Kramer, A. (1977) Effect of Storage on Nutritive Value of Food, *Journal of Food Quality 1*

It is also the case that the most temperature- and light-sensitive vitamin, vitamin C, is absolutely not a limiting nutrient in the British diet. It can be obtained very easily; average intakes are more than 50% higher than the recommended 40mg a day and a standard small packet of crisps or a small helping of oven chips - those mainstays of the British diet - contain about a quarter the recommended intake.[171]

The vitamins of the B group are more stable than vitamin C during the storage process; the exception is folic acid which has been found to show similar sensitivity to degradation as vitamin C.[172]

While temperature and cooking method are important, the most significant variation in nutritional content occurs between fruit and vegetable types (e.g. broccoli versus fennel versus banana). There are also often major differences between specific varieties of a particular fruit and vegetable (Jonagolds versus Russets versus Golden Delicious).[173] Some would argue that the optimum approach for increasing the nutritional content of our diet lies in developing breeding programmes that select fruit and vegetable genotypes with the highest nutritional content.[174] Obviously such a strategy would need to be balanced against other goals including those relating to taste and to the environment.

One might infer then that while a particular storage method may impair the nutritional quality of, say, a Comice pear, the effect may be less significant than, say, the inherent nutritional difference between that Comice compared with, say, a Conference or a William.

Adding it up

Table 3 gives a very crude assessment of total cold storage related emissions from the food supply chain

Table 3 - Cold storage related emissions from the food supply chain

Refrigeration life stage	% total UK GHG emissions
Post-harvest	not known
Domestic	1.24
Processing	0.14
Retail	0. 97
Total	**2.39**

Note that emissions from mobile refrigeration are not included here since these have been added (for the fruit and vegetable sector at least) to transport emissions in the previous section.

[171] *Manual of Nutrition*, Food Standards Agency, tenth edition, 1995
[172] *Recommendations for the processing and handling of frozen foods*, 3rd Edition, 1986, International Institute of Refrigeration, Paris, France
[173] Kalt, W. Effects of Production and Processing Factors on Major Fruit and Vegetable Antioxidants, *Journal of Food Science*, Vol. 70, Nr. 1, 2005
[174] Kader A.A. (2002) Pre- and Postharvest factors affecting Fresh Produce Quality, Nutritional Value and Implications for Human Health, *Proceedings of the International Congress Food Production and the Quality of Life*, Sassari, Italy, September 4-8 (2000), Volume 1 pp109-119

For fruit and vegetables the total in Table 3 should be divided by four, meaning that fruit and vegetable related greenhouse gas emissions contribute 0.65% to the UK total. This allocation is considered to be reasonable since, while fresh fruit and vegetables (excluding bananas) account for only 17% by weight of total food and drink purchases[175] they are (with the exception of bananas and some other fruits) likely to account for a much higher proportion foods which are stored using refrigeration.

Trends

Will future years bring ever greater reliance on the cold chain? And what might be the implications for energy use?

The influences here are likely to include the legislative context, developments and innovations in the food industry itself and changes in our patterns of consumption which will of course be affected by the food industry and other bodies. The discussion here looks not just at fruit and vegetables, but at the issue of refrigeration in general, since it is difficult to separate them out and since the issues are relevant to all food products.

The key legislative concern at present is the use of HCFC refrigerants which have a very high global warming potential. New EU legislation will mean that as from 2008 the use of HCFCs will start to be phased out, leading to a total ban by 2015. From that date on, the main refrigerants used will be ammonia, with carbon dioxide as a secondary refrigerant. At present, around a quarter of cold storage sites in the UK use the HCFC R22. With the uncertainties in the industry (and presumably uncertainties as to how technologies will develop over the next few years) there has been a notable lack of new infrastructure development in the cold storage sector and this has led to a shortage of available cold storage space in the UK. According to the industry itself, the situation in the UK and indeed in Europe will remain uncertain over the next few years.[176]

It is likely, however, that following the introduction of the ban, future years will see investment in new, far more energy efficient and less GHG intensive cold storage facilities. Old sites may well be pulled down, new sites put in their place or additional ones built. Savings will be achieved partly by the use of non HCFC refrigerant gases (carbon dioxide has a lower global warming potential than do HCFCs and ammonia is not a GHG) but mainly because the stores will be far better insulated and will make use of the most energy efficient technology.[177]

In the view of the CSDF,[178] the overall supply of foods requiring cold storage is unlikely to change very much. Growth in the frozen foods sector has been very slow for some years. While growth in chilled foods (ready meals, prepared salads and so forth) has been far more rapid, these foods by their very nature do not stay long in storage – they

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[175] *UK Purchased quantities of household food & drink 1974 to 2004-05*, Family Food datasets, Defra, http://statistics.defra.gov.uk/esg/publications/efs/default.asp

[176] John Hutchings, Cold Storage and Distribution Federation, personal communication, November 2005

[177] John Hutchings, Cold Storage and Distribution Federation, personal communication, November 2005

[178] John Hutchings, Cold Storage and Distribution Federation, personal communication, November 2005

move through the supply chain very quickly and do not 'clog' up facilities in the same way that frozen foods do. As such, while there will be some increase in the total volume of storage space available it will not be especially dramatic. As a result, the cold storage sector is expected to achieve not just relative (per unit area) but also absolute reductions in greenhouse gas emissions over the next five to ten years.

However as already highlighted above, the commercial cold storage sector is not in itself the major hotspot in the cold chain. Refrigeration in store and in the home is far more significant and here the trends are more uncertain.

A report by the Market Transformation Programme[179] looks at (among other things) trends in domestic and retail refrigeration use. The study estimates current product energy use in both and then sets out a range of possible projections for energy use by these products in 2020.

The different energy use projections are based on four different possible policy scenarios. At worst, the 'reference scenario' shows what could happen if no new policy interventions are introduced. At best, the 'earliest best practice' scenario shows what energy savings could be achieved if consumers bought the most efficient appliances, manufacturers put the best known technologies on the market in a fairly rapid timescale, and Government took all reasonable (but somewhat ambitious) policy steps to improve energy efficiency. Interestingly, domestic cold appliance energy use is projected to decline according to all scenarios – between 23 and 34%. For commercial and industrial refrigeration energy use the reductions could be negligible at worst and up to around 23% at best.[180] However, while the Market Transformation Programme, in making its projections, takes into account factors such as possible policy developments and changing demographics, it does not take into account perhaps less quantifiable elements which could have a bearing on refrigeration energy use. One example might be new product innovations in the food industry which could lead to further dependence on the cold chain. Another might be the growth in minor cooling gadgets such as electrical cool boxes, work-top ice-cream makers and mini beer fridges.

It is interesting to note that as we demand fewer preservatives in our food, so the intrinsic perishability of our foods may increase; a product packed with salt or sugar will keep far better than one free from these age-old preservatives. In November 2005 Tesco announced[181] a 'Kitchen Cupboard' Guarantee' on its entire range of ready-meals; this, it appears, means that these foods will only contain ingredients found in a kitchen cupboard at home. Since ready meals are in any case always refrigerated there is unlikely to be an increase in cold-chain dependence but the trend itself may be worth highlighting.

It might also be questioned how far refrigerated goods are sold simply because, since the technology is there, they can be. Clearly there is a need for storage that helps

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[179] *Sustainable Products 2005: Policy Analysis and Projections*, Market Transformation Programme December 2005 http://www.mtprog.com/News.aspx?kintUniqueID=135
[180] *Sustainable Products 2005: Policy Analysis and Projections*, Market Transformation Programme December 2005 http://www.mtprog.com/News.aspx?kintUniqueID=135
[181] Tesco press release: *Tesco ready meals get 'kitchen cupboard' makeover* 18/11/2005 www.tescocorporate.com/page.aspx?pointerid=8AC658DBF05F4D1C95766DE050F9A2FB

maintain the safety and nutritional quality of foods. However, it is also clear that it is only because the technology is available that we have ready meals, pillow bags of prepared vegetables, composite salads, a thousand and one variants of frozen extruded potato and so forth. Technology breeds innovation in the food industry which in turn drives research into further innovative possibilities. The possibility of cold storage breeds not just innovation in the refrigeration sector but in packaging (with which there is a close relationship) and in the food processing sector (the development of novel manufacturing techniques). New foods are developed which would not otherwise be possible without the combined interaction of these technological forces. This is an obvious point but perhaps worth making. While these foods *need* to be stored chilled (or frozen) if they are to reach our mouths in the correct condition, it is very much open to question as to whether these foods are themselves *necessary*. Do they make a vital and un-substitutable contribution to the nutritional content of our diet? Of course we do not just eat food only for its nutritional value but because, among other things, we like it. This debate surrounding need versus demand is hardly new but there are growing attempts to find some form of satisfactory answer. It is discussed in more detail in section 6 below.

2e. Processing and packaging

It has already been emphasised that wasted food represents wasted greenhouse gas emissions. There is also of course the packaging to consider: whether or not the food is wasted, there will almost always be some form of packaging to be discarded, either in the bin for landfill or for reuse via recycling routes.

The packaging industry often argues that the energy used to produce packaging represents a very small proportion of the embodied energy in the food itself. It also points out that by preserving foods in edible condition, packaging helps minimise food waste and in this sense serves a valuable energy-saving function.[182]

This section takes a look at some of the packaging that is used for fruit and vegetables and considers what the environmental implications might be. It also explores the interplay between packaging and other parts of the life cycle. For example, what is the relationship between food waste and packaging waste? To what extent do packaging developments facilitate the development of longer supply chains? How do packaging developments affect dependence on refrigeration and the cold chain? And how do they influence the type of food we eat?

Unfortunately, it has not been possible to gain very much information about fruit and vegetable packaging. What follows here is sketchy and incomplete and really attempts only to scope out some of the issues that might need to be explored further in future research.

[182] *Environmental Impact of Packaging in the UK Food Supply System*, Incpen, Reading, November 1996
http://www.incpen.org/resource/userdata/ipu/FoodSupply.pdf

Fresh fruits and vegetables

Fresh fruit and vegetables can be sold either loose, or pre-packed in containers. These could include: bags (e.g. potatoes); trays (mushrooms); punnets (berries); plastic wrap (broccoli), or modified atmosphere packages (salads).

Most of the fruits and vegetable we buy are in fact pre-packed and judging from past trends, its share is set to grow. In 2004/5, 69.3% of the fruit and vegetables we bought were pre-packed, compared with only 30.7% sold loose. This is up nearly 2% from only 2 years before where the pre-packed:loose ratio was 67.6% to 32.4%.[183]

It has been argued many times by the food industry that less pre-packed produce is wasted than its loose equivalents. One environmental manager for example has pointed out that pre-packed apples tend to be sold and very few packs wasted, whereas for loose apples, waste levels are higher.[184] This is likely to be for a number of reasons – with pre-packed produce it is less easy to rummage, drop produce and select the best fruits, leaving the less attractive behind.

The supermarket industry also points out that with loose produce there is a great deal of additional 'hidden' packaging to consider. According to the packaging industry body INCPEN, loose produce tends to require more secondary and transport-related packaging to protect them during transit and storage.[185]

A full life cycle analysis would however be required to ascertain whether the saving on wasted food actually compensates for the additional energy used to package the food. It also may also be worth investigating whether losses in the loose produce category are inevitable or whether better store layout and management might reduce them.

Canned versus fresh and frozen food

As highlighted above, most of the fruits and vegetables we eat are bought fresh rather than in processed form. The proportions do vary; around 50% of the potatoes we eat are processed and 44% of the fruit while a far lower 14% of vegetables are processed.[186] The term processed here is taken to include not just ready meals and composite foods but also frozen, prepared, and canned products.

Foods that have been processed in some way will have required some form of energy input during the processing stage. Canning is perhaps an obvious example. It may be assumed that canned fruit and vegetables are more energy intensive per kg, or per portion consumed, than their fresh equivalents and that it is therefore preferable to buy fresh food.

[183] TNS data supplied by Fresh Produce Consortium, personal communication February 2006
[184] James McKechnie, waste manager, Sainsbury's, personal communication, December 2005
[185] *Environmental Impact of Packaging in the UK Food Supply System*, INCPEN, 1996 http://www.incpen.org/resource/userdata/ipu/FoodSupply.pdf
[186] *United Kingdom Food and Drink Processing Mass Balance*, Biffaward/C-Tech Innovation, 2004 http://www.biffaward.org/downloads/projectfiles/2182-00335.pdf

But is it true? Several studies have suggested that the picture is somewhat mixed. One Swedish study by Carlsson-Kanyama et al.[187] found that in the case of tinned tomatoes, for example, canned tomatoes were indeed nearly three times more energy intensive than tomatoes imported from Southern Europe but around five times *less* energy-intensive than Swedish glass-house grown tomatoes. Note that some of the assumptions made by Kanyama (about the relatively low intensity of Spanish cultivation) may be open to question, as discussed in section 2a above.

Another life cycle assessment, commissioned by the US Steel Recycling Institute found canned food to be more or less equivalent in its energy intensity to fresh food. Frozen food by contrast was between one and a half and two times more energy intensive. The study assumes a 60% recycled content for cans which is too high for the UK (new cans have a 25% recycled content)[188] although since this is theoretically achievable (and in keeping with recycling objectives) this need not undermine the findings. The study also makes assumptions about storage times and so forth which, as highlighted above, can be problematic.

Another possible problem with the study was that it assumed similar production stage emissions and similar transport distances. In practice these could vary between canned, fresh and frozen foods. For example, if canned and fresh blueberries both travel by road from 500 miles away the overall life cycle impacts will be similar. But if indigenously grown blueberries are canned for consumption later on while the fresh blueberries are imported by air from overseas, overall emissions are likely to be very different. Equally, there will be differences in locally produced blueberries compared with imported canned blueberries. Furthermore it is important also to consider the possibility of providing 'acceptable substitutes.' From a nutritional point of view it may be perfectly acceptable to consume indigenous apples instead of, say, pineapple imported in cans, from overseas. When need rather than demand (which is of course influenced by a variety of factors) is considered then of course the impacts and possibilities look very different.

Hence while these life cycle comparisons are helpful in showing that that 'common sense' assumptions are not always correct, as with all life cycle analyses it is very important to be fully aware of the assumptions underpinning the research.

The nutritional dimension has already been touched upon. The canned food industry argues that canned fruit and vegetables are as nutritious as their fresh or frozen equivalents[189] and on the whole academic research (albeit funded by the canned food industry) backs this claim up.[190] Vitamin C levels tend to be lower but on the whole levels of other nutrients are fairly well maintained or may even (as in the case of vitamin A), increase.[191] According to the government's Food Standards Agency canned fruits

[187] Carlsson-Kanyama A, Pipping Ekström M, Shanahan H. Food and life cycle energy inputs: consequences of diet and ways to increase efficiency, *Ecological Economics*, Volume 44, Issues 2-3, March 2003

[188] Canned Food UK http://www.cannedfood.co.uk/ accessed 20/1/06

[189] Canned Food UK http://www.cannedfood.co.uk/ accessed 20/1/06

[190] University of Illinois, Department of Food and Human Nutrition http://www.aces.uiuc.edu/~nutrican/findings.html

[191] Ligthart T, Ansems A M M, Jetten J. *Eco-efficiency and nutritional aspects of different product-packaging systems: an integrated approach towards sustainability*, Association of European Producers of Steel for Packaging, August 2005 http://www.apeal.org/emc.asp?pageId=212

and vegetables count towards the recommended five a day[192] although it recommends products without added brines or syrups.

When discussing various options for processing and storing food it is also necessary to compare the energy used to process and prepare the food in the factory with that required to prepare or cook it in the home. This is discussed further below in section 2e.

Juices

Juices are commonly packed in Tetra Briks, or aseptic block shaped packages, which are made of a combination of paper, polyethylene (LDPE) and aluminium. No attempt is made here to examine the environmental impact of such packaging, nor to compare this packaging form with other alternatives; this issue has been researched in some detail elsewhere.[193] [194]

The purpose instead is to look at trends in the size of containers used and in shifts in demand for certain types of juice.

As regards packaging size, most fruit juice (76%) is sold in one litre cartons. However for juice drinks (which contain juice plus other ingredients), which are popular in lunchboxes and with children, smaller packaging formats predominate. These smaller cartons account for only 18% of the volume sold but their environmental impact will of course be disproportionately high.

In the pure fruit juice sector, there has been particularly strong growth in sales of 'not from concentrate' and 'freshly squeezed' juices.

The environmental implications of these trends could be significant. For a start, transporting concentrated is more efficient than moving larger volumes of juice. In addition, the concentrate is shipped in frozen form and this, as was seen earlier, is less energy demanding than the transport of chilled goods. Moreover, once reconstituted and packed into cartons, the long life fruit juice does not need to be refrigerated until it is opened (although in practice at home it may often be put straight into the fridge).

On the other hand, the process of concentrating the orange juice – driving off water in a high vacuum evaporator – *is* energy intensive.

Most juices tend to be pasteurised, a process by which the juice is heated with steam or hot water to the about 85-94°C for about 30 seconds.[195]

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[192] http://www.eatwell.gov.uk/asksam/healthydiet/fruitandvegq/ accessed 20/1/06

[193] Rydberg T, Frankenhaeuser M, Lundahl L, Otto T, Swan G, Tanner T and Hanssen OJ (1995). LCA of the Tetra Brik milk packaging system. Product and process development options for improved environmental performance. Case study. Gothenburg (Sweden): Chalmers Industriteknik.

[194] Svenskmjölk (2003). Milk and the Environment. Available at: http://www.svensmjolk.se/pdf/Milk_and_the_Environment_booklet.pdf

[195] http://www.madehow.com/Volume-4/Orange-Juice.html

No studies comparing the energy intensity of concentrated versus non concentrated juice were found. In the light of our apparent growing demand for juice, this is an area which could benefit from further research.

Newer technologies

It is not possible here to examine the full breadth of packaging technologies available. The following paragraphs merely give a brief overview of one of the newer technologies, modified atmosphere packaging (MAP), as a starting point for exploring the relationship between packaging innovation and other life cycle environmental impacts.

MAP can perhaps be seen as a sister technology to controlled atmosphere (CA) storage. Whereas CA is used in store rooms and storage containers where the produce is loose, MAP technology is applied to ready prepared produce such as salad bags and ready chopped vegetables. For both, their function is to substitute a modified or controlled atmosphere for the normal mix of gases that are found in the air all around us, so as to inhibit the inevitable processes of decay. Although there are differences between modified and controlled atmosphere storage conditions, with both the atmosphere is altered by elevating CO_2 concentrations and limiting oxygen, while 'filling in' the remaining space with nitrogen. The lower oxygen levels slow down the processes of browning, ripening and spoiling of fruit and vegetables.

On the one hand, it is possible to argue that technologies such as MAP which extend a product's shelf life and hence reduce spoilage are environmentally beneficial. It is clear however that were the MAP technology not available, the production and marketing of ready prepared fruits and vegetables would not even be considered. And it is clear too that MAP aids the development of long supply chains; watercress from the US being a case in point here. MAP foods also tend to displayed in chiller cabinets whereas their un-chopped equivalents are stacked on un-refrigerated shelves. Finally, foods packaged in this way are bulky meaning that they make less efficient use of vehicle and stationary storage space than foods not packaged in this way.

In short, the growth in MAP packaging technology is predicated on the existence of a fast moving, temperature controlled supply chain. In its turn the success of the logistics and cold storage industries depend on packaging innovations that will withstand the conditions in which they are moved around. And of course as more fresh, precisely packaged, rapidly transported and properly chilled foods enter the market, consumers come to expect and indeed to rely on these foods when carrying out their weekly shop. In this way technology shapes behaviour and technology develops in anticipation of future consumer norms.

It is also interesting to note that the move towards processed and pre-prepared foods affects the availability of different varieties of fresh produce on our shelves. It is already the case that for many fruits and vegetables, varieties cultivated for fresh consumption will not be suited for use by the food processing industry and vice versa.[196]

For instance, the popularity of ready-chopped salads in pillow bags has prompted industry to undertake research into new or different breeds and varieties of salads. The

[196] Comment made at Food Climate Research Network fruit and vegetable seminar, held at the University of Manchester, 1st December 2005

aim is to find varieties of lettuce that do not discolour easily after they have been chopped, and to market more robust leaves (such as mizuna, radicchio, spinach and so forth) which better withstand the rigours of processing. The environmental implications of this are unclear. What is clear however is that the wrap surrounding the content to some extent dictates the nature of the content itself. Packaging helps determine what we do and what we do not eat.

Processing stage emissions

As highlighted in 2d above, procesing stage refrigeration accounts for 0.02% of the UK's greenhouse gas emissions. since, as stated, refrigeration energy accounts for about half (48%) of total electrical energy non-refrigeration related processing electrical energy accounts for another 0.02%.

As regards non electrical energy, data by Enviros[197] show that total energy use by the food and drink manufacturing industry (excluding bakers, brewers and others) is 7409 GWh. Fruit and vegetable processing is estimated (again by Enviros) to account for about 15% of this. On the assumption that the energy source is largely gas, this results in the emission of 57568 tonnes of carbon, equivalent to 0.03% of the UK's GHG (not just carbon) emissions.

All in then, emissions associated with the fruit and veg processing sector (excluding refrigeration in processing) come to 0.05% of the UK total. Note that this is simply energy used during the manufacture of the foods. Emissions associated with the production of cans and other containers will not be included.

2f. Domestic cooking

Little research has been undertaken into domestic cooking energy. Data in the Market Transformation Programme report[198] show that cooking[199] accounts for 1.1% of the UK's total greenhouse gas emissions. This figure includes energy use for electric and gas cookers and ovens and for microwaves and kettles. Other small cooking appliances are not included. Fruit and vegetables will be implicated in emissions from this sector but it is probably not very helpful – even if it were possible – to calculate the share that should be attributed to these foods. It is unlikely in any case that they will make a major contribution simply because we eat so few of them and because fruits tend to be eaten raw.

Method of cooking

Clearly the energy intensity of cooking varies by energy source (gas versus electric hob), by cooking technique (stir-frying versus baking), the quantity cooked (food for one or food for four) and personal variations in cooking behaviour (how full the kettle is, whether the pans have lids on). While the oven is probably the most energy intensive method of

[197] Enviros estimates, personal communication November 2005
[198] *Sustainable Products 2005: Policy Analysis and Projections*, Market Transformation Programme December 2005 http://www.mtprog.com/News.aspx?kintUniqueID=135
[199] hobs, ovens, microwaves and kettles

cooking[200] oven related energy use is likely to decline, partly due to a decline in usage and partly due to improved efficiencies in new stock[201] according to the Market Transformation Programme study.[202] The study anticipates a slight increase in levels of microwave ownership and a fairly substantial increase overall energy use[203] largely because newer models use energy on standby to power clocks and digital displays.[204]

There is also a relationship between cooking (the appliance type, method and length of cooking time needed) and the degree of processing it has undergone earlier in its life. A Swedish study,[205] for example, compares a range of different starchy foods with regard to their energy intensity along the whole of the life cycle up to and including the cooking stage. Products include potatoes, instant mashed potato, couscous, whole wheat grains and so forth. Note that the study looked just at electricity-based cooking appliances and not at gas hobs or ovens (in the UK most hobs run on gas). The study finds that there is huge variation in the energy intensity of the cooking stage – figures range from 0.11 MJ to 5.1 MJ per portion depending on the quantity cooked and the cooking technique used.

For a single food – such as a potato – energy use during the cooking stage can vary by a factor of nine – compare energy used to cook a single portion of boiled potatoes (cooked using an 'energy saving' method)[206] with that needed to bake a single potato in the oven. The study also finds – unsurprisingly – that foods which have been processed at an earlier stage in the life cycle such as couscous and instant mashed potato use less energy at the cooking stage. However when the energy use along the total life cycle is considered they are not necessarily less energy intensive than unprocessed foods cooked for a longer period of time; the specifics will vary according to the various factors noted above.

As a final point it is worth mentioning that for some foods such as potatoes, the energy used to cook them is significantly higher than the energy used to grow them. In the Carlsson study the energy used to bake a single 300g potato is 5 MJ. To grow it, the energy used is just 0.3-0.4 MJ - a twelve-fold difference - while total embodied emissions (including transport, packaging and so forth but excluding cooking) come to a little under

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[200] Carlsson-Kanyama A. and Boström-Carlsson K. (2001) *Energy Use for Cooking and Other Stages in the Life Cycle of Food A study of wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes*, fms Report No 160, Stockholm, Sweden

[201] *BNCK01: Assumptions underlying the energy projections of Cooking Appliances*, Market Transformation Programme, 21/9/2005, http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=204

[202] *Sustainable Products 2005: Policy Analysis and Projections*, Market Transformation Programme December 2005 http://www.mtprog.com/News.aspx?kintUniqueID=135

[203] BNCK05: Microwave oven energy use Market Transformation Programme, February 2006 http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=417

[204] BNCK05: Microwave oven energy use, Market Transformation Programme, 9/2/2006, http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=417

[205] Carlsson-Kanyama A. and Boström-Carlsson K. (2001) Energy Use for Cooking and Other Stages in the Life Cycle of Food A study of wheat, spaghetti, pasta, barley, rice, potatoes, couscous and mashed potatoes, fms Report No 160, Stockholm, Sweden

[206] The potatoes were cooked for twenty minutes then left to sit in the water, with the heat off for a further ten.

1 MJ. With more energy efficient methods the cooking energy is far lower but it still slightly outweighs the energy used for growing the food.

Cooking from scratch versus heating up a ready-meal

Recent years have seen much debate concerning the relative merits of cooking ready meals versus cooking from scratch.[207] [208] Recently, a full life cycle analysis was published,[209] comparing three possible ways of producing a meal of meatballs and mashed potatoes served with carrots and milk: an entirely home cooked version; a version using instant mashed potato powder and chilled meatballs and third, a ready to eat all-in-one meal. The study found, somewhat anti-climactically, there is little to choose between the three options. The home cooked meal used slightly less energy but generated slightly more GHG emissions (a result of different waste disposal assumptions).

Several points are, however, worth noting. Firstly it was assumed that the meal was consumed on the day of purchase and so energy for home storage was not included. Second, the study, being Swedish, quantified energy emissions based on the Swedish energy mix. 45% of Sweden's electricity is produced from hydro-electric power and 45% from nuclear with the remaining 10% from coal, oil and gas. This is of course different from the UK situation. This point is worth noting since slightly more electricity was used in the production of the ready meal than in the production of the home cooked equivalent; the balance might therefore be different (in favour of the home cooked version) if the UK electricity mix were factored in instead.

Third, single portion meals only were considered. No allowance was made for the fact that a home-cook might cook enough for two days, nor that they might cook enough for the whole family. This could affect the conclusions. Finally - and most significantly given the focus here on fruit and vegetables – the meat (pig and cattle) and dairy element of the meal contributed about 70% of the GHG emissions, with the remainder resulting from transport, processing, potato, carrot and wheat farming and the production of packaging. The implication of this finding might be that a focus on processing and other life cycle considerations can sometimes be less helpful than a focus on the actual type of food eaten. This is discussed in relation to fruit and vegetable types in more detail in the next section.

Of course it is also evident that the meal chosen was only one possible meal out of a huge number that could conceivably have been chosen. It was also a meat based meal. A focus on one which was largely vegetable-based might yield different conclusions.

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[207] Garnett T. 2003. *Wise Moves: exploring the relationship between food, transport and CO2*. Transport 2000, London

[208] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[209] Sonesson U, Mattsson B, Nybrant T and Ohlsson T Industrial Processing versus Home Cooking: An Environmental Comparison between Three Ways to Prrepare a Meal. *Ambio: A Journal of the Human Environment*, vol. xxxiv number 4-5 June 2005.

It is worth noting however that for vegetables as with all foods, the quicker the cooking time, the lower the emissions from this stage.

Finally, the home cooking and industrial processing discussions need to be viewed in the context of the waste that each of these two respective stages generates. This is the focus for the next sub-section.

2g. Waste

Waste overview

Wasted food represents a waste of energy used in the production and (sometimes) processing, storage and transport of the food in question, and as a result, a waste in greenhouse gas emissions. Various studies have commented on this.[210]

One UK study calculates[211] that nearly 9 million tonnes of food (of all types) are discarded as waste each year. This figure includes not just domestic but also commercial and industrial waste and it includes all types of discarded food. To this 9 million tonnes should also be added the 1 million tonnes of vegetable residues[212]) that are left in the field. Of course these residues cannot simply be classed as waste since they are usually ploughed back into the soil and so improve soil fertility. This said, anecdotal evidence[213] suggests that farmers do not always adjust their fertiliser inputs to take into account the additional nutrients supplied by these residues. Of the vegetable residues that arise, a small proportion will be made up of spoiled or substandard produce.

As regards more fruit and vegetable-specific information, one FAO study by Kader and Rolle[214] estimates that in developed countries around 12% of fruit and vegetables are lost from the point of harvest up to the retail stage. The figure will vary by product – compare 2% for potatoes and 23% for strawberries (and note that Kader has a US perspective). After this further losses will occur in the home or the food service outlet, as discussed below, comprising around 22% of the original harvest production figure. Taken together, Kader and Rolle calculate that in the developed world about one third of the horticultural crops grown are never consumed by humans.[215]

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210 *Reductions in the energy intensity of the UK food chain: where should they be made, and would consumers support them?* Rebecca White, 3 September 2004, Environmental Change and Management, University of Oxford, Masters Dissertation

211 *Nitrogen UK*, Biffaward/Horticultural Research Institute, 2005 http://www.massbalance.org/resource/reports.php

212 background data prepared for *Nitrogen UK*, Biffaward/Horticultural Research Institute, 2005 http://www.massbalance.org/resource/reports.php provided by Rob Lillywhite, Horticultural Research Institute, personal communication, January 2006

213 based on conversation with Rob Lillywhite, Horticultural Research Institute, March 2006

214 Kader A and Rolle R. *The role of post-harvest management in assuring the quality and safety of horticultural produce*, Food and Agriculture Organization of the United Nations, Rome, 2004 http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/007/y5431e/y5431e08.htm

215 Kader A and Rolle R. *The role of post-harvest management in assuring the quality and safety of horticultural produce*, Food and Agriculture Organization of the United Nations, Rome, 2004 http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/007/y5431e/y5431e08.htm

This section considers the generation of waste at each stage in the production and supply chain, and provides data where this is available.

Production stage waste

A study by Doug Warner *et al*[216] notes that around 10-30% of the strawberry crop can be defined as Class II and as such are usually left to rot in the field. Only a very small proportion is sold on for processing.

What produce is classed as waste depends very much on how the criteria are defined. For example, one case study by the Institute of Grocery Distribution[217] featuring an organic carrot grower supplying for Waitrose found that only 60% of the crop went on for supermarket sale. Nearly a fifth (19%) were rejected for being the wrong size – too big, too small, too wonky – and either went on for processing or for animal feed. Five percent had suffered some form of damage during harvesting and were similarly rejected. For potatoes a slightly higher 70% went on to supermarkets. These sorts of figures are comparable with waste levels for conventionally grown produce.[218]

Arguably, if the rejects go on to be used in other ways they are not actually wasted. It is the case though that many varieties of vegetables are grown specifically for the fresh market and are therefore not suited to processing. Examples here include potatoes which are grown very specifically with the end use in mind. Lower grade or rejected crops cannot go for processing but are simply fed to animals. While this is still a good use of wasted crops, for most livestock horticultural by-products account for a relatively small proportion of their diet – they are sustained mainly by dedicated feed crops such as cereals and oilseeds. As such while it may be convenient to feed horticultural by-products to livestock, given the minor contribution they make to the animals' diets it is hardly the case that these livestock depend on them for their sustenance. A stronger case could be made for the by-products issue were smaller numbers of livestock reared or larger proportions of by-products used.

What is perhaps most striking from the figures presented is that cosmetic appeal ranks as highly as wholesomeness, freshness or nutritional content in definitions of quality. How cosmetic appeal is defined and what or who drives standards further in the direction of extreme stringency is a matter for debate. It is likely however that industry will need to reassess and reconsider some of these definitions if substantial waste reductions are to be achieved.

Production and processing waste

A mass balance study of the food and drink processing sector[219] [220] found that 4.405 million tonnes of fruit, vegetables and potatoes entered the food processing sector in

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[216] Sustainability of the UK strawberry crop, forthcoming

[217] *Cutting Costs: adding value in organics*, Food Chain Centre, Institute of Grocery Distribution, January 2006

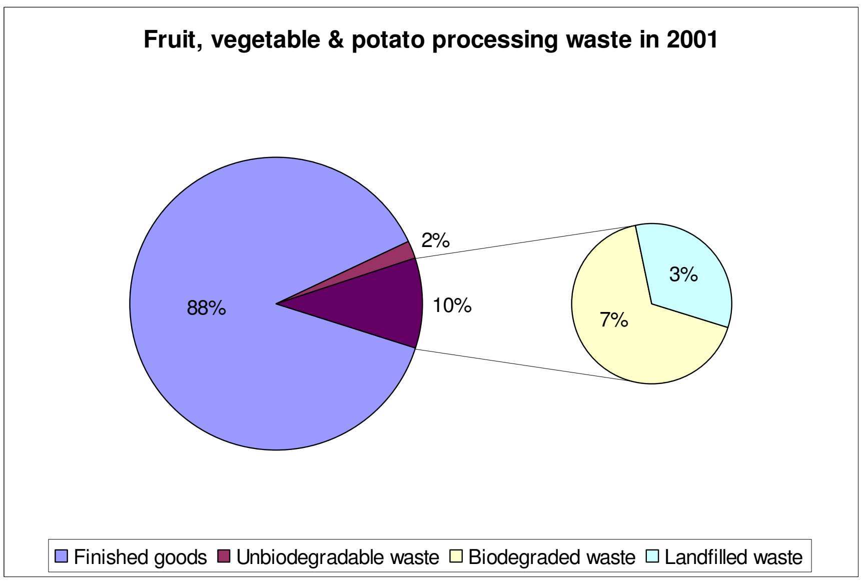
[218] Chris Firth, Economics, marketing and policy senior researcher, Henry Doubleday Research Association, personal communication, February 2006

[219] *United Kingdom Food and Drink Processing Mass Balance*, Biffaward/C-Tech Innovation, 2004 http://www.biffaward.org/downloads/projectfiles/2182-00335.pdf

2001, yielding 4.854 million tonnes of output at the other end.[221] [222] Most of this (4.26 million tonnes) was in the form of finished goods, while 624,000 tonnes or 12% of the total output was waste. Of this fruit and vegetable waste, the majority (84% or 522,000 tonnes) is biodegradable.

But is all biodegradable output put to use? The mass balance study did not follow this up. However a different study which looked at fruit and vegetable processing companies in the Yorkshire and the Humber region did.[223] The study found that 69% of the food waste produced was segregated and reused in some way – either as animal feed or for compost. However, the remaining 31% of biodegradable waste entered the general waste stream and was land filled. Taking the two studies together one might very roughly calculate then that a third of the 522,000 of biodegradable waste (84% of the 634,000 tonnes in the paragraph above) produced by the processed fruit and vegetable sector in the UK, or 16,000 tonnes of biodegradable waste is land filled. Figure 6 below illustrates this.

Figure 6



Sources: *United Kingdom Food and Drink Processing Mass Balance*, Biffaward/C-Tech Innovation, 2004 and *Food and drink waste in the Yorkshire and Humber Region*: Report prepared for Yorkshire Forward, SWAP Project No: 204/10 Save Waste and Prosper Ltd, Leeds, June 2005

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[220] Note that according to the study 14% vegetables, 44% of fruit and 40% of potatoes are processed – the rest continue through the chain in unprocessed from. Figures given earlier put the split between processed and unprocessed waste at 50:50

[221] United Kingdom food and drink processing mass balance,

[222] The greater volume of output relative to input is accounted for by the additional water that was also inputted into the system.

[223] *Food and drink waste in the Yorkshire and Humber Region*: Report prepared for Yorkshire Forward, SWAP Project No: 204/10 Save Waste and Prosper Ltd, Leeds, June 2005

There is also the associated packaging to consider. Most (82%) but not all paper and board packaging was segregated and all plastics were land filled.[224] Taking into account this inorganic waste, fruit and vegetable-associated waste comprised over 27% of the materials entering the food processing industry's waste stream. The Yorkshire and Humber food processing study concluded that there is considerable scope for improving current reuse and segregation rates.[225]

Retail waste

Fruit and vegetables take up a considerable share of total retail waste. Not only are they perishable and easily spoiled, but their purchase is also subject to the vagaries of the weather. More salad is bought in the summer, for instance. Hence supermarkets increase their supply during this period to meet anticipated demand. A few unexpectedly cold days during the summer months however can bring salad sales down and lead to waste, despite supermarkets' use of weather forecasting services.

In the financial year 2004/5, Sainsbury's disposed of 85,181 tonnes of food-related waste (a figure which includes plastics and packaging) and the fresh produce category (fruit, vegetables and salad) accounted for 25.5% of this, or 21,721 tonnes. This figure is net of packaging. [226] The store also calculates that around 9% of wasted food (of all types) was still perfectly edible. The remainder was damaged or otherwise inedible in some way. Unfortunately information showing the quantity of wasted food as a proportion of overall food is not available. All this wasted produce went to landfill.

Marks & Spencer estimates that about 4% of food displayed on the shelves ends up unsold. Although this food is classed as waste, far less than this figure is actually land filled since some of it will be sold off at a discount to employees or donated to food aid schemes.[227] Note that the Marks and Spencer and Sainsbury's figures are not directly comparable since one gives the tonnage of food wasted without stating what proportion this is of the overall quantity on display, while the other gives a percentage of the overall figure without a tonnage of actual waste.

A US study[228] estimates that retail losses stand at around 2%.

Figures in Waitrose's Corporate Social Responsibility report[229] show that of the company's total annual waste disposal of 17,269 tonnes, 60% is food waste. Again, as with Sainsbury's, it is not known how this figures as a proportion of the overall food on sale.

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[224] *Food and drink waste in the Yorkshire and Humber Region* Report prepared for Yorkshire Forward by Save Waste and Prosper Ltd, Project No: 204/10, June 2005

[225] *Food and drink waste in the Yorkshire and Humber Region* Report prepared for Yorkshire Forward by Save Waste and Prosper Ltd, Project No: 204/10, June 2005

[226] James McKechnie, Sainsbury's, personal communication November 2005

[227] Rowland Hill, Marks & Spencer, personal communication November 2005

[228] *Estimating and Addressing America's Food Losses*, Linda Scott Kantor, Kathryn Lipton, Alden Manchester, Victor Oliveira, Food Review, January-April 1997

[229] *The Partnership: Corporate Social Responsibility Annual Review 2005*, John Lewis Partnership http://www.johnlewispartnership.co.uk/assets/pdf/CSRAnnRev05.pdf

A very crude attempt here is made to calculate the total volume of fruit and vegetable waste resulting from the supermarket sector. Sainsbury's estimated 21,721 tonnes of fruit and vegetable waste (a quarter of 85,181 tonnes) is taken here to be representative of the fruit and vegetable sector as a whole relative to its market share. Sainsbury's share of the fruit and vegetable market stands at 18.3%.[230] Scaling the figure up proportionately to include all the major retailers brings the figure up to 118,694 tonnes. Of course fruit and vegetables are bought not just from supermarkets but from markets, greengrocers and other independent retailers. While non-supermarket outlets have only 14% of the fruit and vegetable market[231] it may be that waste levels are considerably higher because they will be taking in class II and other produce which is past its peak and therefore more susceptible to spoilage. Rounding the figure up to take this into account this works out at a very approximate 170,000 tonnes.

Food service waste

The food service sector comprises restaurants, fast food outlets, public sector catering outlets, staff canteens and so forth. Food service, greengrocers and street markets together have about 40% of the fruit and vegetable market. Most of this 40% (around 30% of the total market) is in fact taken by the food service sector.[232]

Very little research has been undertaken into food service waste. A Swedish study[233] however suggests that figures are high, at around 20%. If the sector uses 30% of 16 million tonnes and wastes 20% of this, then total fruit and vegetable waste from the food service sector comes to 0.96 million tonnes.

Consumer waste

The data suggest that as fruit and vegetables move along the supply chain towards the point of consumption, so the proportion lost as waste will increase.

A study by the USDA's Economic Research Service found that around 26% of all food waste produced occurs at the food service and domestic stages. Of that 26%, a fifth by weight is made up of fruit and vegetables (it is not clear whether this includes peelings). The Adel study noted above also cites estimates which put losses at the retail, food service and consumer stage in 1995 at 23% for fruits and 25% for vegetables. Fresh fruits and vegetables account for nearly 20% of consumer and foodservice losses, the reasons for such losses including food going off, too much being bought in the first place, and plate waste.[234]

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[230] *Re-fresh directory 2005*, Fresh Produce Journal, London, 2005

[231] *Fresh Fruit and Vegetables - UK - May 2005*, Mintel

[232] calculation based on fact that if supermarkets account for 84% of the retail market and if supermarkets take 60% of the fruit and vegetable supply then the share going to the greengrocers etc must be 16% of 60 or around 10%. Hence the food service sector has 30% (40-10) of fruit and vegetable supplies.

[233] Carlsson-Kanyama and Engstrom R Food losses in food service institutions: Examples from Sweden, *Food Policy*, Volume 29, Issue 3, Pages 203-294 (June 2004).

[234] Kantor, L.S., Lipton, K., Manchester, A., and Oliveira, V. 1997. Estimating and addressing America's food losses. *Food Review* 20:3-11.

A Swedish study of food waste in the home found that vegetables ranked as the second most wasted food group, after meat and dairy produce.[235] Most of the waste was not plate waste but consisted of vegetables thrown out after being stored, presumably because they had gone rotten. Indeed the study found that for every eight portions of vegetables prepared, nearly four portions worth of vegetables never even made it to the cooking stage, but were thrown away. Some of this will consist of peelings and other inedibles but the overall waste figure, at 50%, is still extremely high.

To what extent are these studies representative of the situation here in the UK? According to the Government-funded Waste Resources Action Programme, households generate around five million tonnes of food waste every year.[236] Fruit and vegetables account for about half, or 2.5 million tonnes. [237] This works out at over 40 kg per person a year.

This is a very considerable proportion of the total fruit, vegetable and potato tonnage available on the UK market. According to Defra the total supply of fruit, vegetables and potatoes stood at 16 million tonnes in 2004. Note that this is the supply available after harvest losses and so forth have been taken into account but before supermarket and other retail waste. If one deducts the estimated retail waste calculated above from the 16 million tonnes, and if householders waste 2.5 million tonnes of the 15.83 million tonnes remaining, this works out at around 16% of what they buy.

Interestingly the Kader study already cited[238] estimates that in the developing world significantly less food is wasted from food service outlets and homes – only 10 percent compared with the more than 20% he calculates for the developed world. Overall waste losses may, however, be higher in the developing world (one estimate puts it at 50%),[239] because of poor storage and handling at earlier stages in the chain.

In other words, the difference in waste levels between developed and developing countries result from differences in the causes of the waste. While in the developed world technological measures have helped reduce waste at the production and storage stages, a great deal of food is still thrown away, because, perhaps of a more blasé attitude by consumers to wasting food. The reverse is likely to be true in the developing world. The scope for reducing waste through technological means, in the light of these attitudes, is discussed further in 5e below.

[235] Sonesson U, Anteson F, Davis J and Sjödén. *Home Transport and Wastage: Environmentally Relevant Household Activities in the Life Cycle of Food*. Ambio volume XXXIV Number 4-5, June 2005

[236] based on data provided by the Waste Resources Action Programme estimating 200kg food waste per household per year and ONS data on the number of households in the UK

[237] Parfitt J. *Home consumption of fruit/vegetables and food waste*, presentation given at FCRN fruit and vegetable seminar held in Manchester, 1 December 2005

[238] Kader A. A. *Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce,* University of California, Department of Pomology http://ucce.ucdavis.edu/files/datastore/234-528.pdf

[239] Kader A. Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce, 2005 http://ucce.ucdavis.edu/datastore/datareport.cfm?reportnumber=204&catcol=1809&categorysearch=Postharvest%20Losses

Which are the most wasted fruits and vegetables? It would be interesting to know, for example, whether those fruits and vegetables that are most energy intensive in other respects (air freighted, or grown in glasshouses) are more or less likely to be wasted either at the retail stage or in the home. One might argue that 'luxury' fruits and vegetables such as raspberries or beans are considered nicer and hence end up being eaten. And of course since they are more expensive, more care is taken to eat them. Hence their environmental impact at earlier stages in the chain is balanced by lower losses later on. On the other hand a similar argument might be adopted for allowing children to eat sweets and chocolates instead of proper food – they're less likely to be wasted – hardly an approach to be recommended. Just as children habituated to eating 'proper' food tend to enjoy it, so, were 'luxury' foods not available (or prohibitively expensive) then the 'ordinary' fruits and vegetables might rank higher in people's esteem.

It is also the case that the waste hotspots occurring along the supply chain may vary by product type. For example it has been reported that waste levels for some imported fruit and vegetables are very high – some industry figures cite figures of 40% for waste in the air freighted foods sector.[240] As already indicated above, some 'luxury' foods often suffer high levels of waste post harvest – 23% in the case of strawberries.

It would be useful to know whether ready-prepared foods are more or less wasted than fresh unprocessed foods. Washed salads, ready to stir-fry vegetables and other pre-prepared produce require none of the preparation that may put people off cooking or eating the produce and as such they may be less likely to be wasted.

Unfortunately little or no research has been carried out on this subject. The only information available was the results of an NOP survey commissioned by the Chilled Food Association. The poll found that in response to the question *'Thinking about when you buy whole unprepared vegetables, how often, if at all, do you end up throwing away the leftovers at the end of the week because you haven't got round to using them up?'*[241] 53% of those interviewed said they ended up throwing away whole, unprepared vegetables. However since the poll did not go a step further and ask people how much they threw away or whether they also threw away salad bags or prepared vegetables this information is only of limited use. Anecdotal evidence suggests[242] [243] that 25% of the contents of bagged salads are thrown away.

Landfill

Most fruit and vegetable waste is landfilled. It is, however, very hard to know what the consequences of landfilling these foods are for greenhouse gas emissions. In 2002-3, the total amount of industrial, commercial and agricultural waste landfilled was 94.6 million tonnes.[244] A study undertaken by Oxford University[245] finds that waste in landfill

[240] Garnett T. 2003. *Wise Moves: exploring the relationship between food, transport and CO_2*. Transport 2000, London
[241] Chilled Food Association, personal communication, January 2006
[242] Julian Davies, Stockbridge Technology Centre, personal communication March 2006
[243] comment also heard at Waste Resources Action Programme seminar on food waste, Banbury, May 2006
[244] Defra, http://www.sustainable-development.gov.uk/progress/indicators/18.htm
[245]

generates around 0.46 MT CH_4, equivalent to about 1.6% of the UK's total greenhouse gas emissions. The main sources of these emissions are likely to be paper and board, timber (to a small extent) and animal and plant waste rather than construction or chemical waste. However, since the composition of that landfilled waste it is not known, the percentage of methane emissions attributable to fruit and vegetables cannot be calculated.

Trends in waste

Both the food waste and packaging waste issues are relevant as regards the government's aim of getting us to buy more fruits and vegetables. Growing awareness of the five a day message may in time translate into greater sales of fruit and vegetables and there are tentative signs that this may already be happening.[246] But will more buying lead to more eating? Or will there simply be more waste as good intentions are binned by the end of the week?

It is also necessary to consider changing demographics. Increasing numbers of the UK population are living alone. More and more of us are relying on ready meals or 'ready-to-prepare meals. In addition, eating out is on the increase.[247] According to the IGD this is likely to mean greater demand for smaller pack sizes (meaning proportionately more packaging). It may also mean more food waste overall as people end up not eating what they've bought. A more 'spontaneous' lifestyle approach may mean that people decide to go out to eat at the last minute, meaning that the food they have bought goes to waste. As highlighted restaurants and other food service outlets despite their attempts at planning for anticipated demand, do not produce less waste than we do in the home so the shift to more eating out is unlikely to be beneficial.

Finally it may also be that as incomes increase, as food becomes cheaper (relative to our overall incomes) and as the diversity of foods available grows, our somewhat casual attitude towards food waste may continue or become more exaggerated. In other words, if current trends continue we are likely to waste more, not less food.

The waste total

It is very difficult to give an accurate figure for the total amount of fruit and vegetable waste that occurs. Table 4 is based on some of the estimated figures that have been given in the paragraphs above (note that packaging waste is not considered in the calculations). These are very rough approximations and should be treated with caution. This said, the figure is in keeping with other estimates.

[246] Food Standards Agency, Consumer Attitudes to Food Standards 2005, Wave 6, England Regional Report, February 2006 http://www.food.gov.uk/multimedia/pdfs/casengreg05.pdf
[247] The Changing Consumer and Consumption Trends, IGD factsheet http://www.igd.com/CIR.asp?menuid=35&cirid=124

Table 4: Total estimated fruit and vegetable waste

Life cycle stage	Volume wasted (million tonnes)	Information source
Agricultural production	0.2?	Assuming 5% of 1 million tonnes total vegetable residues (source: HRI)
Food processing	0.16	Based on calculations above
Retail	0.17	Based on calculations above
Food service	0.96	Based on calculations above
Domestic	2.5	
Total fruit and vegetable waste	3.99	
Total fruit and vegetables marketed	16 million	
Fruit & vegetable waste as % of total supply	**25%**	

From a greenhouse gas perspective this finding suggests that the elimination of waste could reduce emissions by over a quarter. The food is not eaten – it is not needed – it need not therefore be grown, processed, transported and refrigerated. This is of course a simplistic view of the production-consumption supply chain since it does not take into account very strong economic determinants of how much food is produced. It does however indicate the level of unnecessary waste in our society.

Of course waste will never be eliminated and for some life cycle stages waste volumes are already fairly low. The greatest volumes occur at the household stages, and reflect our attitudes towards waste in general and fruit and vegetables in particular. Food service waste is also significant which is a management issue is, perhaps. As regards production-related waste, the figure presented here is a tentative guess at the quantity of field residues that are edible but left on the field to rot. The figure does not include rejected horticultural produce which is technically not 'wasted' since it goes to feed animals, but which is nevertheless perfectly edible.

2h. Relative versus absolute impacts

Many individual life cycle assessments highlight the significant 'hotspots' in a particular product's life cycle. Understanding where the hotspots lie can be very helpful if, as a result, something can be and is done to reduce those impacts.

However it is also essential to take the wider context and the overall *scale* of emissions into consideration. The hotspot of one particular foodstuff may be (say) transport but *overall* transport emissions may be relatively minor compared to transport emissions for another product where transport is not the key hotspot, simply because overall emissions for the second product are so very much greater.

This point is illustrated by research undertaken by Carlsson.[248] She looked at the separate elements contributing to energy use in the life cycles of tomatoes and carrots

[248] Carlsson A, *Greenhouse Gas Emissions in the Life-Cycle of Carrots and Tomatoes: methods, data and results from a study of the types and amounts of carrots and tomatoes consumed in*

consumed in Sweden but originating from a range of countries. These included Germany, Italy, the Netherlands, the UK, 'other countries' (including Israel) and Sweden itself. The study focused on four key impact areas: the production of fertilisers; the agricultural process; storage; and transport. For tomatoes, Carlsson looked at two cropping systems - the high input (heated, protected) cropping prevalent in Denmark, Sweden and the Netherlands and low input (unheated) systems such as those more likely to be practised in Spain and 'other countries'. Carlsson calculated the energy consumed and the emissions produced at each life stage for both products and for each country of origin.

Carlsson found that the relative importance of the various life cycle stages varied both by product and by its country of origin. With carrots, transport accounted for 21 - 43% of total emissions. Storage was more significant at 37–53%, while farm production contributed 14–28% and the production and transport of fertilisers, another 4–10%.

For tomatoes, the figures were quite different. She found that the farm production process accounted for 94–96% of total emissions generated during the life-cycle of tomatoes in high input cropping systems but only 28% for low input-cropping ones (a figure comparable to carrots, which are field grown and unheated). Transport's contribution to total life-cycle impacts was around 1–4% for highly input intensive systems, compared with 39% for low-input intensive ones (as are found in Spain and 'other countries'). These figures reflect the fact that the total quantity of emissions produced by the highly input-intensive system was, in absolute terms, very much greater than that of the low input-intensive systems. Since most of these emissions were generated during the production process, transport's contribution was, in relative (although not necessarily in absolute terms, as we discuss below) not so significant. Similarly, storage accounted for only 2% of emissions for high-input systems but 8% for low-input ones. Fertiliser emissions, by contrast, contributed greatly (24%) in high input systems but only slightly 1% in low-intensive ones.

It is of course important to distinguish between energy use at different times of year. New season strawberries and tomatoes, for instance, are likely to have been grown in well heated greenhouses. During the main growing season however, the heating will be turned down or even off. It is an obvious point, perhaps, but food grown during the season most favourable to its growth is likely to be less energy-intensive that food which is not.

Tomatoes and carrots are fresh products. For processed foods, life-cycle analysis yields a different set of results. Another Swedish analysis, found that in the case of tomato ketchup, transport accounted for only 2 - 3% of total energy use.[249] While 2 - 3% is low, it is nevertheless 2 – 3 % of rather a lot; the packaging and processing involved makes tomato ketchup a highly energy-intensive product, requiring 39 MJ per kilogram of product. Transport's contribution, at 2-3% amounts to 0.8 -1.2 MJ. By contrast the total energy used in the life-cycle of a kilogram of the fresh Spanish tomatoes in the previous study (where transport energy use was relatively far more important at 39% of the total) consumed 5 MJ of energy. Clearly this is more than transport energy use for tomato

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Sweden, IMES/EESS Report No. 24, Department of Environmental and Energy Systems Studies, Lund University, Sweden, March 1997

[249] Andersson K, Ohlsson T Olsson P. Screening life cycle assessment (LCA) of tomato ketchup: a case study, *Journal of Cleaner Production 6* (1998) 277–288

ketchup but the difference in absolute terms is not nearly as great as the difference in the relative importance of the transport stage for the two products. In other words, focussing solely on *relative* hotspots can lead one to overlook the fact that the less *relatively* significant life stages can still be worth addressing because of their absolute contribution to energy use and emissions.

The study referred to above, comparing frozen, canned and fresh food, contains information that leads to similar conclusions. It was found that the importance of transport to total life cycle energy use varied from 27% for some refrigerated products to around 6-7% for frozen food.[250] This is not an indication of the absolute transport-related contribution to GHGs but of the relative importance of other life stage impacts.

Another study, this time the preliminary findings of work in progress by Milà i Canals [251]- indicates that there can be a three-fold difference in the energy intensity of potatoes versus chicory taking into account all factors from the production up until the retail stage. That chicory is more energy intensive to produce is possibly a fairly intuitive finding. What is interesting about the result, however, is that while for potatoes energy use is fairly evenly distributed among production, storage and packing, and distribution and retailing, for chicory, the balance is very different. The largest use of energy is the electrical energy used to force the chicory under refrigerated conditions, closely followed by energy used for packaging.

Of course chicory and potatoes are very different foods, containing different nutrients and performing different functions in our diets and perhaps comparing them is of limited value. What is striking about the study however is how difficult it is to generalise across the fruit and vegetable sector as a whole as to where the key critical impact might lie.

2i. Comparing emissions by life cycle stage: what can we conclude?

The discussion above looked at how and why impacts occur at each life stage. A few very rough estimates of fruit and vegetable sector emissions as a proportion of total UK greenhouse gas emissions at the various life stages have been made. Adding all these figures together and making a few judgements where the information is not available (for instance overseas production and translating waste into emissions) one might guess that the fruit and vegetable sector contributes perhaps 2.5 - 3% to the UK's total greenhouse gas emissions.

It would be convenient if one could say that for fruit and vegetables one or two particular life stages are more important than any others and as such efforts to reduce impacts should focus on these. But the picture is far more nuanced than this. The two to three percent figure is comprised of relatively small quantities of emissions from many different life stages (a few parts of a percent to agriculture, to refrigeration and so forth) and given the 'bittiness' of the individual contributions, it is difficult to hone in on one particular impact. As is discussed below in sections five and six, this has implications for efforts to reduce emissions from this sector.

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[250] Ritchie K (forthcoming). *From Farm to Table: An energy consumption assessment of refrigerated, frozen and canned food delivery*. A report in draft prepared by Scientific Certification Systems Inc. on behalf of the Steel Recycling Institute, Pennsylvania, United States
[251] Llorenç Milà i Canals, University of Surrey, personal communication, January 2006

For some fruits and vegetables, such as those travelling by air, transport is clearly a critical impact. For others, even those sourced from far away, transport stage emissions will be less significant simply because of the mode of transport used. Again, while production stage emissions are fairly low for many crops, for protected crops the impacts here will feature very strongly. In absolute terms, however, these contribute very little to the UK's total GHG emissions simply because so few of them are grown and consumed relative to other non horticultural crops. Cooking related emissions will be almost nil for fruits but for some vegetables, and potatoes in particular, they may be high. And of course for many varieties of fruits and vegetables impacts will be fairly evenly distributed across life stages, meaning that efforts to reduce emissions will need to focus on all of them.

However, perhaps three fairly clear conclusions can be drawn from the analysis above and one hypothesis ventured.

The first conclusion is that the interactions among the different life cycle stages (such as transport, refrigeration, waste) are more important than the individual stages. Working together they are more than the sum of their parts and by increasing their interdependence; they tend to ratchet up the emissions.

The second is that waste is clearly a problem along the whole of the supply chain but particularly at the production and the domestic stages.

The third is that, environmentally speaking, air freighted foods will always rank as highly unsustainable, however minor their energy use (or indeed other environmental impacts) might be at other life stages. Any measures that shift food from air to other modes will lead to major reductions in the embodied energy of the food in question. For some foods, modal shift is impractical because of longer travel times involved and hence commercially unviable spoilage rates. For these foods the 'solution' from a climate change perspective is not to import then at all although this raises major questions both about consumer choice and about economic development in countries from where these foods are exported. The argument has often been put that supporting economic development in developing world countries such as Kenya contributes to other sustainable development objectives.[252] The pros and cons of this argument are not explored here since the focus is on greenhouse gas emissions. Evidently the climate change issue needs to be seen in the context of social sustainability and economic viability. However it is also the case that it is countries such as Kenya that are likely to bear the full brunt of climate change impacts and as such the sustainability of economic activities that meet short term objectives but perhaps undermine the essential viability of the planet may require a little challenging.

Perhaps one might suggest that a useful marker for the energy intensity of a particular fruit or vegetable is its fragility and perishability. Produce that is fragile and perishable tends to be easily spoiled, hence waste and wasted emissions are a problem. Fragile perishable produce also tends to require energy-intensive storage at low temperatures in order to minimise the decay process. Third, in order to minimise the time taken between point of harvest and point of retail, rapid modes of transport are desirable. In other words, perishable produce is more likely to be air freighted than produce which is not.

[252] Marks & Spencer, personal communication, ongoing

While the picture is clearly more subtle than this – air freighted strawberries and UK strawberries are equally perishable but their GHG burden is very different – this hypothesis, if it holds true, might provide a useful initial rule-of-thumb for assessing the GHG intensity of a particular fruit and vegetable.

The next section builds upon the analysis and the conclusions presented in this section.

SECTION THREE: ASSESSING GREENHOUSE GAS EMISSIONS BY PRODUCT TYPE

This part of the report takes a product perspective. It asks: are there any types of fruit and vegetable which we can say are particularly energy intensive? Where we can identify such products, is there a life stage which is particularly implicated in its energy intensity and if so is there anything we can do to reduce these impacts? Are trends in our fruit and vegetable consumption moving in more or less GHG intensive directions? Finally, are there some products that we simply should not – from an environmental perspective – be eating? This last will doubtless raise commercial and political eyebrows but it needs to be asked.

3a. Fruits versus vegetables?

One question that occurred during the course of writing this study was: are fruits more energy intensive to produce than vegetables? This question is worth asking since recent trends in our eating patterns show that the increase over the last twenty odd years in our overall consumption of fresh fruit and vegetables has come about because we are now eating more fruit. Our vegetable consumption levels have remained fairly static.

On the face of it, this is potentially cause for some environmental concern. The vast majority of fruit we eat in this country is imported, as section one has highlighted. It has also already been noted that transport represents a significant 'hotspot' in the life cycle of many fruit and vegetables, not so much because of the transport emissions involved but because of the combination of transport and mobile refrigeration requirements. And of course for the small but growing proportion of produce which is freighted in by air, the energy intensity will be very high indeed.

On the other hand, while more fruits are imported than vegetables, vegetables constitute the majority of produce imported by air.[253] As section 2b has already shown, the contribution of air freight to fruit and vegetable transport emissions is disproportionately great relative to the actually rather small quantity of produce carried in this way. It is also the case (as can be seen from table 2 above) that storage temperature requirements for vegetables tend to be lower for fruit and this may mean a greater energy requirement.

Moreover, most fruits are grown on trees whereas most vegetables are annuals, with new crops needing to be planted each season. This could mean potentially higher on-farm energy requirements for vegetables compared with fruits although we are not aware of studies that have considered this question. This said, one study of the UK strawberry crop (one of the fruits that has only a few growing seasons before it needs to be dug up) finds that growing strawberries on the same plants for two or even three years before replanting a new set results in lower emissions from the strawberry yield

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[253] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

averaged over three years.[254] If this finding were applied more generally to fruits and vegetables it might confirm the environmental merits of perennials (more likely to be fruit) over annuals (more likely to be vegetables).

Moreover, in contrast with vegetables, most fruits tend to be eaten uncooked. As such there will be an added environmental burden for vegetables from the cooking stage.

It is also worth considering the place that fruit and vegetables occupy in our diet. Vegetables tend to be eaten as part of a meal whereas fruit tends to be eaten as a snack (although of course they can also feature in a meal). As such there is the substitution effect to consider. It is conceivable that as we increase our consumption of fruit we might eat less of some other snack food – a bag of crisps or a chocolate bar, say. Increased consumption of vegetables may not on the other hand produce this effect, or at least not to such an extent. If this distinction holds then it could mean that fruit has, by virtue of displacing another food (which itself may require more energy to produce – see figure 8) a positive environmental impact relative to vegetables. This is, however, to assume that changes in our consumption of biscuits, cakes, chocolates and crisps have anything at all to do with our patterns of fruit consumption. We do not know of any research on this subject. What is very likely however, is that whether one finds a correlation or not, other trends in our socio-economic and cultural lives are likely to be at least as and indeed far more significant.

Finally it would be interesting to compare how waste levels differ between fruits and vegetables both during the course of growing, transporting and distributing the vegetables as well as in the home. Unfortunately no figures are available here.

3b. Differences in emissions between different types of fruits and vegetables

While there may be some use in comparing the energy intensity of fruit as a whole versus vegetables as a whole, a closer look at particular kinds of fruits and vegetables may be far more helpful in clarifying where the particular energy hotspots lie and as a result, what we might need to do to reduce these impacts.

Unfortunately no large scale comprehensive analysis comparing energy intensity across a range of fruit and vegetables has been undertaken. Individual studies of products such as apples,[255] [256] carrots and tomatoes,[257] chicory and potatoes,[258] strawberries,[259]

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[254] *Sustainability of the UK strawberry crop*, Defra project HH3606, research undertaken by the University of Hertfordshire, January 2006

[255] Milà i Canals L (2003): *Contributions to LCA Methodology for Agricultural Systems. Site-dependency and soil degradation impact assessment*. PhD thesis. Available from http://www.tdx.cesca.es/TDX-1222103-154811/ (ISBN: 84-688-3285-5)

[256] Stadig M (1998): *Life-cycle-assessment of apple production in Sweden, New Zealand and France*. The Swedish Institute for Food and Biotechnology, Göteborg

[257] Carlsson A, Greenhouse Gas Emissions in the Life-Cycle of Carrots and Tomatoes: methods, data and results from a study of the types and amounts of carrots and tomatoes consumed in Sweden, IMES/EESS Report No. 24, Department of Environmental and Energy Systems Studies, Lund University, Sweden, March 1997

[258] Milà i Canals L. Work undertaken for ESRC Rural Economy and Land Use Programme, forthcoming.

orange juice[260] and so forth have been carried out. However all these studies vary in their choice of system boundaries, their assumptions, the location of the study and in other ways; as such it is difficult to make sensible judgements across different studies. This said, in the absence of anything more consistent, all that can be done at this stage is to look at the findings of these individual studies and see if any general conclusions emerge.

Others of course have done this already. One Swedish study[261] carried out by Wallén, Brandt and Wennersten compiles data from a variety of sources to show the emissions (expressed in CO_2e) generated during the production, processing and distribution (not cooking) of a range of commonly eaten foods in Sweden. Some of the figures they use are presented in the chart below.

Figure 8

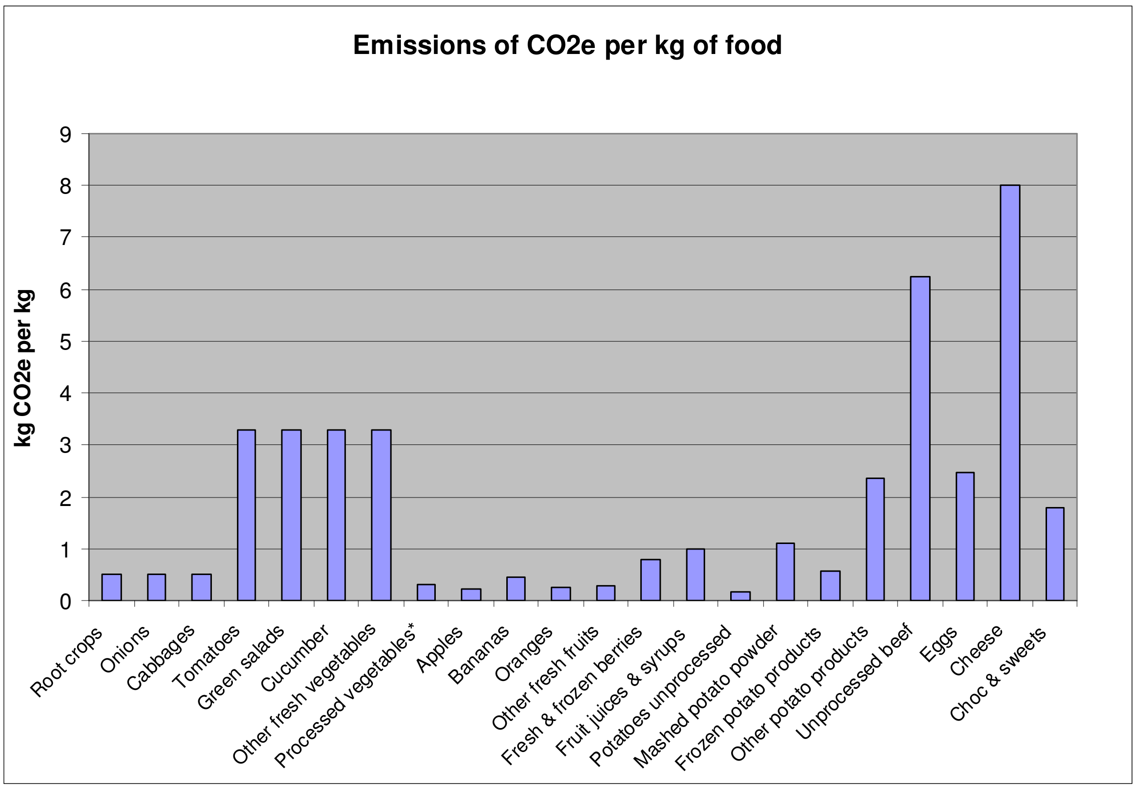

Table based on data provided in Wallén *et al* (2004)
∗ see discussion below for definition of 'processed vegetables'

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[259] *Sustainability of the UK strawberry crop*, Defra project HH3606, research undertaken by the University of Hertfordshire, January 2006
[260] Elmar H. Schlich and Ulla Fleissner, The Ecology of Scale: Assessment of Regional Energy Turnover and Comparison with Global Food, *Int J LCA* 2004
[261] Wallén A, Brandt N, Wennersten R. Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy 7* (2004) 525–535

The study shows that emissions from traditional indigenous vegetables such as root crops and cabbages are, perhaps predictably, fairly low. The 'other vegetables' category is not defined and may hide a multitude of variations.

Our staple fruits - apples, bananas and oranges – have similar impacts even though bananas and oranges, and often apples are imported. Note that the study assumes that 20% of apples are home grown and 80% imported, a figure that is not too dissimilar from the UK situation (29% home grown). This may be less surprising in the light of the discussion in 3a above about the relative impacts of fruit versus vegetables and about the different storage temperature requirements of different fruits highlighted in table 2, above.

What really leaps out from this table is the apparent energy intensity of salads and Mediterranean type vegetables. These are, in the UK as in Sweden, the vegetables that are either grown indigenously in heated greenhouses or else imported from overseas. These foods are increasingly popular in the UK and, together with mushrooms, make up about a third of the vegetables we eat.

However some of the data they show and the findings they present should perhaps be treated with caution. For a start, it has already been emphasised that comparing data from different studies, each with its own different methodology and set of assumptions (which is what the authors do), is less than satisfactory.

Second, the authors are unclear as to what they do and what they do not include in their calculations. The data table they provide is titled '*Energy use and emission of greenhouse gases for food production, processing, and distribution needed for food consumption per capita in Sweden in 1 year*' but the paper itself offers no detail beyond that. For example it is not clear whether any account is taken of different waste levels among different fruits, whether refrigerated storage energy is included or whether transport energy includes also energy used for temperature control.

Significantly, it is also the case that comparisons with other studies that do exist for some of the products shown yield different results. In order to gain a better understanding of the reliability of the various data sources, the following paragraphs take some of the fruit and vegetable categories shown in the table above and compare the data with what is presented in other studies.

Strawberries / berries

It is striking that the Swedish study's figures for fresh and frozen berries look rather modest – higher than the staple fruits but still quite low. Their figures apparently include freezing stage emissions, transport and distribution.

A study of the sustainability of the UK strawberry crop carried out by the University of Hertfordshire puts greenhouse gas emissions at about 50% lower than the Swedish study, at about 0.4 tonnes CO_2e/tonne strawberries.[262] However this looks just at *production* stage emissions for UK grown strawberries.

[262] Doug Warner, personal communication, January 2006 - background data used in the report *Sustainability of the UK strawberry crop*, Defra project HH3606, research undertaken by the University of Hertfordshire, January 2006

The Swedish study also assumes (in the absence of data) that all the berries consumed in Sweden are indigenously produced. While a study of UK production can sensibly give emission figures for UK grown produce, any study looking at *consumption*-related emissions can certainly not ignore imports. In the UK our self sufficiency in berry fruits is just over 50%.[263] The exclusion of imported berries will therefore skew the picture very considerably. For example, according to Marriott's air freight study[264] it appears that emissions generated during the course of air freighting strawberries work out, somewhat staggeringly, at around 3.6 tonnes CO_2 per tonne of product. This is around ten times the CO_2 generated from the production stage.

Of course, and as Marriott notes, not all imported strawberries are flown in. Only 11% of imported strawberries are sourced from outside the EU. Hence, of all imported strawberries only 11% are likely to travel by air, although as noted earlier this may be an underestimate since some produce classed as of EU origin may have been flown into Europe first before making its way to the UK by other modes. The vast majority of our imports come from within the EU and will therefore probably come by road and sea. As a result, transport emissions from Spanish, Italian and other EU strawberries which constitute the bulk of our emissions will be substantially lower. For example (and here we fall into the same trap of using different data from different studies) the Defra food miles report calculates that transporting tomatoes from Spain to the UK results in the emission of 0.1 tonne CO_2 per tonne of tomatoes.

It should also be remembered that waste levels for strawberries are very high indeed – the study mentioned above puts it as high as 23% (see section 2f). None of the studies discussed - the Hertfordshire, Swedish or air freight studies – look at refrigeration or waste rates in any detail. Were these to be included, overall life cycle emissions per unit of *delivered* produce would almost certainly rise quite considerably. Note that while the Swedish study does include 'frozen' berries it is somewhat unclear as to the assumptions made in the data it uses.

Tomatoes and greenhouse crops

For tomatoes and other such crops, the Swedish study uses data from Carlsson-Kanyama.[265] Her figures take a year-round average of emissions from Swedish tomato consumption and assume that 25% are indigenously grown and 75% imported. This is not too far off the UK situation (17% home grown and the rest imported).

However in the view of UK glasshouse energy specialists[266], UK production figures are probably only 60% of those used by Carlsson-Kanyama. This could reflect improvements in glasshouse efficiency here and our milder climate. In addition, figures

[263] *Basic Horticultural Statistics*, Defra, 2005 http://statistics.defra.gov.uk/esg/publications/bhs/2005/fruit.pdf

[264] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

[265] Carlsson-Kanyama A. Climate change and dietary choices - how can emissions of greenhouse gases from food consumption be reduced? *Food Policy*, Vol. 23, No. 3/4, pp. 277–293, 1998

[266] Rob Jacobson, Cucumber Growers' Association, personal communication, November 2005

published in the Defra-commissioned food miles study put emissions for tomatoes at about 2.4 kg CO_2 per kg of produce,[267] or about 25% lower than the figures presented in the Swedish study. Another figure from the Farm Energy Centre[268] puts glasshouse energy requirements at 10 kWh energy per kg of produce. This works out at about 2.2kg CO_2 / kg produce (note that this is an average for glasshouse production – energy use for tomatoes is likely to be slightly higher since they tend to require lighting as well as heating). To confuse matters further, the Swedish study takes imports into account in its calculations[269] while the UK figures given are just for UK production.

Clearly, notwithstanding the problems of accurately quantifying emissions, emissions from these types of vegetables are high.

Processed vegetables

The term used here in the Swedish report is misleading. The authors use data for pickled cucumbers as representative of processed vegetables; possibly not the most popular processed vegetable in the UK.

Perhaps for a more representative study of what we might define as processed one might take another look at the Steel Recycling Institute study discussed above which compares frozen, canned and fresh foods. For frozen foods the study calculates that energy use is around 2250-2406 ckal/lb. This, in less archaic units is about 4.3-4.5 MJ/kg - considerably more than fresh vegetables. For canned produce the range is between 2-3 MJ/kg. As highlighted, energy use for fresh produce is calculated in this study to be comparable with that for canned although some of the assumptions made in this study have been questioned, above.

Oranges

Only one study of Spanish orange production has been found.[270] This concludes that production-stage emissions work out at about 0.25kg CO_2e per kg of oranges, which is similar to the figure presented in the Swedish study above. However the Swedish study also includes the transport and distribution stages and as a result may be unrealistically low.

As regards transport, the main suppliers of oranges and citrus fruits in general to the UK include the US, Israel, South Africa, South America and Spain. Spain is the largest single source of citrus fruit for the UK, accounting, in 2005 for a quarter of all imports.[271]

Nevertheless, in 2005 59% of all citrus fruits came from outside the EU.[272] In addition to transport, storage related energy use will need to be added on. The storage

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[267] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp

[268] Chris Plackett, Farm Energy Centre, figures presented at FCRN fruit and vegetable seminar, Manchester, 1 December 2005

[269] this is not made clear in the text but is apparent in Carlson-Kanyama source material they use

[270] Sanjuán N, Úbeda L. Clemente G and Mulet A. LCA of integrated orange production in the Comunidad Valenciana (Spain) I*nt. J. Agricultural Resources Governance and Ecology*, Vol. 4, No. 2, 2005

[271] UK Trade Info 2005,

temperature requirements of citrus fruits fall into the average category (7-10℃) but there will be variations depending on the type of citrus fruit. Lemons for example can be stored for up to eight months[273] whereas mandarins last for just two to four weeks.[274] The storage time will also vary according to the temperature set - oranges can be stored from around three months at about 11.11º C, up to about five months if stored at between 2-4º C.[275] Storage related energy use will of course need to be added on to production stage energy use.

Apples

A life cycle assessment by Milà i Canals *et al* of New Zealand apple production[276] finds that CO_2e emissions range, according to the production system, between 0.04 and nearly 0.1 tonne CO_2e / tonne of class I and class II produce. In terms of energy this is 400 – 700 MJ per tonne (0.4-0.7 MJ/kg).[277] In other words there is wide variation in energy use in one country alone. When one considers the full spectrum of countries which provide the UK with apples, the diversity is wider still. For example a separate paper by Milà i Canals *et al*,[278] cites values ranging from 0.4 MJ/kg to 1.1 MJ/kg.

Other fruits and vegetables

There appear to be huge holes in our knowledge of the impacts of a range of commonly eaten fruits and vegetables. These include grapes, melons, kiwis, stone fruit (such as peaches, pears, nectarines and so forth), bananas and avocados. A proper impact assessment will, of course, need to take into account all their life stages. All we can do here is to point to where some of the critical impacts might lie for them.

Little is known about the production-related impacts of these products. Some of them have received attention on other environmental counts (bananas and pesticides, for example) but it would be helpful to know whether some were more or less energy intensive to produce than others. Factors affecting their intensity might include reliance on irrigation, on nitrate based fertilisers, or on harvesting machinery.

As regards storage, table 2, above, shows that there is wide variation in the temperatures at which they need to be stored. Grapes, kiwis and stone fruit for example require conditions of around 0℃ -2℃; for avocados and citrus fruits the storage temperature will be higher and for some of the tropical fruits, the ideal temperature is 13℃ or higher.

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[272] UK Trade info 2004

[273] http://www.hort.purdue.edu/newcrop/morton/mandarin_orange.html

[274] *Properties and Recommended Conditions for Storage of Fresh Fruits and Vegetables*, Postharvest Technology Research and Information Center, University of California http://postharvest.ucdavis.edu/Produce/Storage/prop_c.shtml

[275] http://www.hort.purdue.edu/newcrop/morton/orange.html#Keeping%20Quality

[276] Milà i Canals L, Burnip G M, Cowell S J. Evaluation of the environmental impacts of apple production using Life Cycle Assessment (LCA): Case study in New Zealand, Agriculture, Ecosystems and Environment 114 (2006) 226–238

[277] the reason for the greater variability in CO_2 is to do with differences in the types of energy used by the different farms

[278] Milà i Canals L, Cowell SJ, Sim S. 2006. Considerations in a comparison of local versus imported apples. *Environmental Science and Pollution Research*. Submitted

Thus, when in stationary cold storage it would seem that tropical fruits tend to be less energy demanding than temperate ones although when in transit the differences will be insignificant.

As regards transport, the study by Marriott which has already been discussed has shed light on some of their transport-related impacts.[279] It appears that for the most part these fruits and vegetables travel by sea. Avocados do fly in from some countries, as do mangoes from Pakistan. Grapes are also very occasionally flown in. In addition, there will be occasions when 'top ups' of many products that normally travel by sea are flown in to meet unplanned shortfalls in supply. These include every-day produce such as apples and onions.[280]

Finally, differences in levels of waste need to be looked at. Product-specific data are not available here. It may be that those fruits and vegetables with a longer storage life, or which are more robust in one way or another are likely to suffer less damage and be less wasted than softer, shorter shelf life produce. However there are likely to be other factors at play too, including the susceptibility of a particular product to blight and disease.

3c. An attempt at categorising produce according to their greenhouse gas intensity

Might it be possible to divide fruits and vegetables into categories of greenhouse gas intensity? Such an approach would need to take into account not just what the overall absolute life cycle emissions are for a particular fruit or vegetable but also where the critical 'hotspot' life stage or stages might lie.

The latter is important because it has a bearing on the 'solvability' of a particular problem (see section 2b for a discussion). If action can be taken to tackle the 'problem' life cycle stage (by for example using renewable energy for greenhouses) then the picture could look very different.

What follows, then, is a first and somewhat sketchy attempt at categorisation. While for the most part the categories are defined in terms of basic product type (salads, root vegetables), there is also a table which categorises certain products according to country of origin (e.g. Pakistani mangoes) where these have a bearing on travel mode.

The reason for this two-fold method of categorisation is because for some produce, the country of origin gives an indication of the likely mode of transport and where this mode is air, the impacts can be very significant. This is critical.

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[279] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

[280] *From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004*, Clive Marriott, Msc dissertation, University of Surrey, 2005

The tables below are based on some of the findings uncovered in the analysis above, allocating certain products to certain categories on the basis of what is known about the production, storage and waste impacts. Much of the required information is very partial or non-existent and so a fair number of guesses have had to be made. It has been assumed that an air freighted food automatically enters the ‘high greenhouse gas intensity’ category. The perishability of a product – and hence the likelihood of its reliance on rapid transport, cold storage and of a high wastage rate - has also been taken into account.

The point of the tables below is simply to put what is known or thought (at least by this author) down on paper in the hope of kick-starting further research and discussion. As such, what follows if very much open to question and criticism.

As a final note it is important to acknowledge the work of Clive Marriott here. His study of air freight in the non-EU fruit and vegetable sector included a highly useful table setting out a wide range of commonly eaten fruits and vegetables against their countries of origin. Marriott adopted a traffic light red-amber-green system, which indicated the likelihood of a product travelling by road and sea versus air.

Strikingly while for some foods it was almost always likely that the product travelled by a certain mode whatever the country of origin, for others the picture was far more varied and less clear. Some countries emerged as being more likely to send their goods by air than others.

The following tables (Tables 5 to 8) make extensive use of Marriott’s work for the transport aspect of the equation but builds upon it by factoring in other non transport related considerations. While for air freighted goods these non-transport related considerations are not really relevant (since air travel, from an energy perspective, ‘blacklists’ them instantly), for other produce travelling by other modes these non-transport related factors will be critically important.

Note that the tables are based on general principles; it does not for example take into account the small quantities here and there that are flown in as top-ups to meet shortfalls in supply, but ranks produce on the basis of whether in general they travel by road or sea. Excluding the top-ups issue may be a significant omission since there are indications that supermarkets are increasingly relying on air-freighted top ups in order to ensure the continuous availability of supply which is so key to their ‘brand value.’

Table 5 - Highly GHG intensive products, by produce type

Category	Examples	Reason	Exceptions / modifying comments	Information source
Mediterranean vegetables (except summer months):	Tomatoes, courgettes, peppers, aubergines, mushrooms	These foods will either have been produced in the UK or imported from overseas. If grown in the UK the production stage will be particularly energy intensive (heated greenhouses) and if imported from overseas the critical areas will be transport, refrigeration and the plastic protective structures under which they are grown.	The situation for UK produce could change were there to be greater uptake of combined heat and power or renewable energy. In the UK summer, UK produce will have had little or no heating and so their GHG intensity is likely to be lower than their imported equivalents	Farm Energy Centre, Defra Food Miles Study, Carlsson Kanyama
Salad vegetables (except summer months)	Lettuce, tomatoes, cucumbers	As above. In addition, salad crops are very perishable and waste levels along the supply chain could be higher than the average for the fresh produce sector as a whole	As above. Note that greenhouse tomatoes are more intensive than other protected crops because they have a greater light requirement British lettuces grown between mid- May and end-October are field grown	As above
Winter berries and cherries	Strawberries, blueberries, raspberries, cherries, blackcurrants etc	In the winter these are most likely to be air freighted.		Marriott
Miscellaneous exotic fruits	Lychees, papayas, passion fruit,	Almost always air freighted		Marriott

Table 5 (cont)

Category	Examples	Reason	Exceptions / modifying comments	Information source
Figs		Almost always air freighted	Turkish figs tend to travel by road. However since waste levels are likely to be high and storage temperatures low, figs from all country sources are likely to be GHG intensive.	Marriott, Kader,
Luxury vegetables	Non European asparagus	This is almost invariably air freighted		Marriott
Frozen vegetables	Peas, beans, sweetcorn, processed potato products, mange-tout, baby corn etc.	Freezing produce and storing it in a frozen state is energy intensive. However see section 2c above for a discussion of some of the issues surrounding cold storage		Steel Recycling Institute
Ready prepared chilled fruits and vegetables	Ready chopped fruit salads, bagged salads broccoli florets and other vegetables	Increased demands on the cold chain; high energy use for mobile refrigeration additional washing and processing energy use; energy requirement for modified atmosphere packaging	Waste levels may be lower at the consumer stage; i.e. people may (and this is speculative) be more likely to eat the food and not throw it away uneaten. Waste generated at the production stage is more likely to be reused in some way	Cambridge Refrigeration technology; Food and Drink Mass Balance

Table 6 - Highly GHG intensive products, by country of origin

Category	Examples	Reason	Exceptions / modifying comments	Information source
Africa (including Kenya, Zimbabwe, South Africa, Zambia**)**	Green and fragile vegetables such as dwarf beans, mange tout, fine beans, sugar snap peas, fresh peas, baby corn, herbs	African produce tends to be air freighted	Moroccan produce tends to come in by road[281]	Marriott
Pakistan	Mangoes	Pakistani produce most likely to be air freighted		Marriott
South Africa	Grapes (sometimes), pineapples	Often (not always) air freighted	Further information needed here	Marriott
USA perishable fruit and vegetables	Soft berry fruits, watercress	The perishables tend to be air freighted	Citrus fruit and apples mainly travel by sea	Marriott

The following produce are likely to be relatively low in their energy impacts. It should be born in mind however that some of the assumptions made here are based on judgement rather than on verifiable information.

Table 7 – Low GHG producing products, by produce type

Category	Examples	Reason	Exceptions / modifying comments	Source
Root vegetables and tubers	Carrots, parsnips, turnips, potatoes, celeriac etc	These are field grown vegetables largely indigenously produced	Cooking stage energy use can be high depending on the cooking method	Wallén *et al*, Llorenç Milà I Canals, Carlsson-Kanyama
Brassicas	**Cabbages, sprouts, broccoli, calabrese**	These tend to be indigenously grown field crops or else imported by road from Europe	Occasionally supplies will be sourced from outside Europe and here they will tend to be air freighted	Wallén *et al*, Marriott, Defra statistics
Staple indigenous type fruits	Apples, pears	Indigenous production is low (for apples) but production stage waste levels are low and produce tends to travel by road or (from the	Indigenously grown apples and pears likely to have lower emissions during UK growing season	Wallén *et al*.

281 Sarah Sim, Marks & Spencer, personal communication, March 2006

		new world) sea		
Non indigenous staple fruits	Bananas, oranges	Produce travels by sea at medium (not very low) storage temperatures	Little is known about production level impacts nor about waste levels	Marriott, Kader

Very little is known about the greenhouse gas intensity of the produce in the following category. The energy impacts have been ranked here as moderate but information on the different variables involved is needed before a sound judgement can be made.

Table 8 – Unknowns or moderate GHG producing products

Category	Examples	Reason	Exceptions / modifying comments	Information source
Summer stone fruit	Peaches, nectarines, plums, cherries	Usually these are sourced from Europe and travel by sea and road.	Storage temperatures are low. Waste levels may be high	Wallén *et al*; Marriott, Kader
Summer soft fruit	Strawberries, raspberries, etc	In the summer they are usually sourced either from the UK or within Europe but waste levels are very high and storage temperatures low so these cannot be classed as low GHG foods.		Kader; Warner
Winter stone fruit	Peaches, nectarines, plums (for cherries see table six)	In the winter months these are sourced from South America so they cannot be classed as low in GHG intensity	In the winter months peaches are very likely to be flown in by air from outside the EU; this is less true for nectarines. Sea-borne produce will combine long travelling times at low storage temperatures.	Kader
Other tropical	Melons and mangos	Usually these travel by sea and road but their production stage impacts are not known	Pakistani mangos travel by air	Marriott
Avocados		Sometimes air freighted so at times GHG intensity. Waste levels?		Marriott.

Table 8 (cont)

Category	Examples	Reason	Exceptions / modifying comments	Information source
Vine fruits	Grapes, kiwis	Usually these travel by sea and road but sometimes from far away e.g. South America or New Zealand so they cannot be classed as low intensity. Topping up grape supplies with air freighted imports is fairly common. Sea-borne produce have long journeys and storage temperatures are low.		Kader, Marriott

Perhaps, as has already been suggested, one useful 'rule of thumb' indicator of the likely GHG intensity of a particular fruit and vegetable is its perishability. Perishable produce is more likely to require low cold storage conditions. It will have a short life which means that if it comes from overseas it is more likely to need to travel by air. Perishable produce is more prone to spoilage and rotting and as such a relatively high proportion will be wasted. Foods that have been cut or prepared in some way will also be more perishable and prone to spoilage. As such they will need to be kept refrigerated at all life cycle stages. It would be interesting to know whether English strawberries eaten in summertime are more or less GHG intensive than imported apples once the waste issue has been factored in.

The information presented so far discusses the issue of fruit and vegetables in terms of the CO_2 impact they have on the environment.

However – and it is such an obvious point that it is sometimes forgotten in life cycle analysis - the point of growing the fruits and vegetables in the first place is so that we can eat them. Government thinks we should eat more of them. So do the WHO and many other health-related institutions. What the impact might be should their encouragements be successful, is the subject of the next section.

SECTION FOUR: GOVERNMENT POLICY AND THE FRUIT AND VEGETABLE SECTOR

4a. Health policy

The Government recommends we eat at least five portions of fruit or vegetables per person per day to help reduce the risk of some cancers, heart disease and many other chronic conditions. This works out as about 400g a day – a recommendation in line with that set by the World Health Organisation.[282] In general most countries urge their citizens to eat about this quantity, usually defining the quantities in terms of portions or frequencies of consumption.[283]

The UK government, via the relevant departments,[284] has put in place a number of initiatives and schemes to help us meet the desired goals. One such example is the School Fruit and Vegetable Scheme which provides one piece of fruit in school each day for all children aged 4-6.[285] Note that although this scheme is likely to be discontinued it is probable that fruit and vegetables will feature strongly in whatever new scheme is developed in its place. There is also the Department of Health's Five a Day logo which manufacturers are allowed to use (in accordance with certain terms and conditions) if their foods contain fruit and vegetables. In practice though, many of the supermarkets simply use their own logos.

The government does not, however, specify whether some fruit and vegetables should be consumed in preference to others, either from an environmental or a health perspective. The Food Standards Agency website encourages us to eat a variety of fruits and vegetables (and of other foods) since it says that in this way a wider range of essential nutrients is more likely to be supplied. Some of the suggestions the FSA makes as to how we might more conveniently and painlessly increase consumption, are likely to entail significant environmental expense. For example it suggests buying mini-corn (usually air freighted from Thailand) and freezing them – a double whammy, so to speak.

The supermarkets and the media in general have vigorously taken up the 'five a day' cry and recent years have also seen the promotion of certain 'superfoods.' These include certain fruits and vegetables such as blueberries (and indeed berries in general), avocados, pomegranates and brassicas, especially broccoli.

Notwithstanding the superfoods hype, the Food Standards Agency has not changed its line[286] and continues to advocate diversity of consumption rather than a nutrient-focused, variety-specific approach. From an environmental perspective, the emphasis on superfoods is likely to raise some environmental concerns since many of them are likely

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[282] *Diet, nutrition and the prevention of chronic diseases*, WHO Technical Report Series 916, Report of a Joint WHO/FAO Expert Consultation, Geneva 2003 http://whqlibdoc.who.int/trs/WHO_TRS_916.pdf

[283] http://www.who.int/dietphysicalactivity/fruit/en/index2.html

[284] DfES, DoH, FSA

[285] at the time of writing the effectiveness of this scheme has been a subject of much discussions

[286] Food Standards Agency, personal communication, January 20066

to have been transported by air into the UK; this is generally the case with berries for example except for during the short few months when they are in season.

A question that one might need to consider is whether a full balance of nutrients can be supplied from fruits and vegetables that are grown, stored or transported in less energy intensive ways. This in effect is likely to mean the consumption of field grown, predominantly indigenously grown, vegetables consumed within or around their natural growing season. If there is indeed a trade off between nutritional goals and those centering on GHG emissions reduction it will be necessary to frame policy that seeks to manage such contradictions.

A US paper[287] examines the nutritional quality of fruits and vegetables and the impact of storage, cooking and other factors on their nutritional content. The paper helpfully includes a table listing the various nutritional properties which fruit and vegetables provide, (various vitamins, minerals, phenolic compounds, carotenoids and sulphur compounds) and detailing those particular fruits and vegetables which are especially rich in these properties.

From their table it appears that we could indeed meet our nutritional needs from fruits and vegetables indigenous to the UK and available in combination all year round although of course UK production would need to increase to meet our needs. In other words, for each of the vitamin, mineral and other nutritional categories set out in the study, an indigenous field grown UK fruit or vegetable can be found to supply the nutrient. Examples of such fruits and vegetables include apples, berries, greens, brassicas, alliums, root vegetables and pumpkins and squashes. The only class of compounds which UK indigenous produce does not provide in abundance are flavanones which are abundantly present in citrus fruits. Since this is just one type of fruit and since such fruits as discussed above are unlikely to carry an excessively high energy burden, the inclusion of some citrus fruit in our diets does not seem to be overly problematic.

The point being made here is that theoretically we could meet our nutritional needs from indigenously growable produce. As it stands, however, the UK does not grow enough fruit and vegetables to meet existing demand let alone levels that would be needed were fruit and vegetable consumption to increase. A separate study is needed to look at whether higher levels of self sufficiency in horticulture are actually achievable bearing in mind other land use needs.

Another question to consider is, were fruit and vegetable consumption to increase in line with government and WHO recommendations, what might the impact be on our consumption of other foods? If government were successful in its attempts to cajole, direct and otherwise cause us to increase our consumption of fruit and vegetables, what then might the impact be, first on energy use and emissions from the fruit and vegetable sector and secondly, from the balance of foods as a whole that we consume?

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[287] *Nutritional Quality of Fruits, Nuts, and Vegetables and their Importance in Human Health* Adel A. Kader, Penelope Perkins-Veazie, and Gene E. Lester, http://www.ba.ars.usda.gov/hb66/025nutrition.pdf, undated and in Perishables Handling Quarterly, http://ucce.ucdavis.edu/files/datastore/234-104.pdf Issue no. 106, May 2001

Regarding the first question, it seems that if current trends in the types of produce we consume continue, emissions from the fruit and vegetable sector would rise. The five-a-day goal would be achieved through the greater consumption of air freighted, Mediterranean style and ready-prepared produce. On the other hand, it is conceivable that, were we to achieve our five a day by eating more indigenously growable produce, then seasonal emissions from the fruit and vegetable sector might decline; clearly a proper study is needed to examine this. It is also worth mentioning that if we actually ate some of the fruit and vegetables that we currently throw away, then production (and energy use) even on current consumption trends might not need to increase quite so much.

The second question asks: if we eat more fruit and vegetables, might we eat less of other foods? In other words do people who eat more fruit and vegetables have less of an environmental impact as a result of their non-consumption of other foods? This question was alluded to earlier in the section comparing fruits with vegetables.

This is a difficult question to answer. While, unsurprisingly, no research dealing specifically with this issue were found, there were a couple that were perhaps tangentially relevant and therefore worth highlighting.

The first is a review study which considered whether there might be a correlation between fruit and vegetable consumption and lower average weight (measured in terms of Body Mass Index or BMI). The relevance of this question to the food-greenhouse gas issue rests on the assumption that thinner people eat less food relative to their activity levels and that the greater consumption of fruit and vegetables to some extent substituted for consumption of other foods.

In fact the review finds that not only is there little evidence available that might enable one to answer the question, but that such evidence as does exist is somewhat equivocal. Some studies have found some correlation between higher fruit and vegetable consumption and a lower BMI, but equally many have not.[288] [289] Interestingly, in Greece where fruit and vegetable intake stands at around 500 grams per person a day (25% more than the minimum recommended UK intake) adult obesity levels are even higher than in the UK, whose population consumes a mere 200 grams or so a day.[290]

Of course if one were to eat dramatically more fruit and vegetables than the minimum recommendations, then one might see some substitution effect; people would eat less simply because the bulkiness of the fruits and vegetables would leave them with no room for anything else. However it is unlikely that consumption at current levels recommended by government would have that effect – adding a couple of hundred

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[288] Rolls, B.J., Ello-Martin, J.A., Carlton Tohill B. What Can Intervention Studies Tell Us about the Relationship between Fruit and Vegetable Consumption and Weight Management? *Nutrition Reviews*, Vol. 62, No. 1, January 2004

[289] Carlton Tohill B, Seymour, J, Serdula, M Kettel-Khan L, Rolls, B.J. What Epidemiologic Studies Tell Us about the Relationship between Fruit and Vegetable Consumption and Body Weight, *Nutrition Reviews*, October 2004

[290] World Health Organisation, various data
http://www.euro.who.int/eprise/main/WHO/Progs/CHHUNK/burden/20041123_18

grams to the one and a half to two kilos of food and drink that we consume each day[291] hardly adds much bulk.

The first study then gives no clear cut answers. An alternative way of approaching the question is to ask whether a vegetable based diet is more or less greenhouse gas intensive than one including foods of animal origin?

A great many studies have focused on the energy and greenhouse gas intensity of meat and dairy production and have argued that a key way of reducing our environmental burden on the planet would be to reduce our consumption of these foods.[292] [293] [294] [295] [296] [297] A separate FCRN study focuses specifically on the meat and dairy sector in relation to its greenhouse gas emissions and discusses their arguments in some detail.[298]

Many of these studies are indeed persuasive but as Annika Carlsson points out, just because meat is a highly greenhouse gas intensive type of food does not mean that vegetarian diets are always low in GHG intensity. In one paper,[299] Carlsson compares greenhouse gas emissions in four different meals, two vegetarian and two containing meat. She finds that the meal lowest in emissions is indeed vegetarian - comprising Swedish grown, non-hothoused vegetables – and that the meal highest in emissions (nine times higher) contains both meat and hot-house imported vegetables.

But she also finds that the meal which is the second lowest in emissions is one which contains both meat and indigenous vegetables; this is less greenhouse gas intensive than a fully vegetarian meal made up of 'exotic' (imported) vegetables.

The conclusion to draw from these studies may be that while fruit and vegetables have the *capacity* to act as substitutes for other foods, thereby delivering greenhouse gas reductions, there is no guarantee that a diet which provides the recommended five portions a day will actually deliver these benefits. It is perfectly possible to eat more fruit and vegetables with no substitution effects occurring. And it is possible to eat a largely vegetable based diet which is nevertheless highly greenhouse gas intensive.

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[291] *The National Diet & Nutrition Survey*: adults aged 19 to 64 years Summary Report, ONS, 2004
[292] Gold, M. (2004) *The global benefits of eating less meat*, Compassion in World Farming Trust, Petersfield, Hampshire.
[293] Goodland, R. (1997) Environmental sustainability in agriculture: diet matters, *Ecological Economics*, 23 (1997) 189-200
[294] Gerbens-Leenes, P.W.; Nonhebel, S. *Consumption Patterns and Their Effects on Land Required for Food* Ecological Economics 42 (2002), S. 185-199.
[295] M.A. Keyzer, M.A, Pavel I.F.P.W, van Wesenbeeck, C.F.A (2005) Diet shifts towards meat and the effects on cereal use: can we feed the animals in 2030? *Ecological Economics* (2005) forthcoming.
[296] Cohen J. 1995. *How many people can the earth support?* Norton, New York, p532.
[297] Brown L.R., Kane, H. 1994. *Full House: Reassessing the Earth's Population Carrying Capacity*. Norton, New York, p261.
[298] An exploration of the complexities of quantifying greenhouse gas emissions from the meat and dairy sector, FCRN working paper, forthcoming
[299] Carlsson-Kanyama A. Climate change and dietary choices - how can emissions of greenhouse gases from food consumption be reduced? *Food Policy*, Vol. 23, No. 3/4, pp. 277–293, 1998

This said, a diet rich in field grown, largely indigenous, seasonal fruits and vegetables – those listed as low intensive in table 8 – at levels perhaps significantly higher than the recommended five a day might indeed lead to a reduction in overall food related greenhouse gas emissions. It is worth noting that the five a day or 400g a day recommendation is somewhat arbitrary[300] and there is evidence to suggest that those consuming more than five a day enjoy additional health benefits, such as reduced risk of strokes[301] compared with those who ate between three and five portions.

4b. Other government policies affecting the fruit and vegetable sector

The paragraphs above have focused on government health policy as it relates to fruit and vegetables. However there are also other areas of government policy which affect the sector. A thorough review has not been possible and so the discussion here is limited simply to highlighting what some of these policies are without exploring what their implications as regards greenhouse gas emissions might be.

With fruit and vegetable production, a distinction tends to be made between the protected horticulture sector and the field-grown fruit and vegetables sector. Protected horticulture and potato growers are each represented by a levy board, the Horticulture Development Council and British Potato Council respectively, set up by Government to promote and protect the interests of their respective members through research, advocacy and other means. In return, growers registered as Council members (and all growers over a certain size or with a certain threshold of income) must make a small annual return on the value of their sales, by way of a levy due.

Since the protected horticulture sector is energy intensive, it has recently negotiated a Climate Change Agreement, came into force in spring 2006. Under the terms of the Agreement the protected horticultural sector is committed to achieving a 12% reduction in specific energy consumption (measured in terms of kW h/m^2), in return for which it receives an 80% rebate on the cost of the Climate Change Levy.

Other policies affecting the sector's environmental performance are common to the farming industry in general, including measures to reduce water pollution in nitrate sensitive zones. Defra also funds a number of research projects which are intended to improve the sustainability or viability of the sector; these are highlighted further below. These projects are either wholly funded by Defra or part-funded in conjunction with industry.

It should be noted too that the food industry has stated in its Food Industry Sustainability Strategy that the UK food industry should play its part in contributing to the UK's carbon reduction goals by reducing its own emissions by 20% (from a 1990 baseline) by 2010.[302] It does not specify whether some sectors should achieve greater cuts than

[300] Professor Tim Lang, Centre for Food Policy, City University, personal communication, February 2006

[301] He F J, Nowson C A, MacGregor G A. Fruit and vegetable consumption and stroke: meta-analysis of cohort studies, *The Lancet*, Volume 367, Issue 9507, 28 January 2006-3 February 2006, Pages 320-326

[302] Food Industry Sustainability Strategy, Defra, 2006, http://www.defra.gov.uk/farm/sustain/fiss/fiss2006.pdf

others and it should also be noted that the focus of the document is largely on the manufacturing and retailing stages, rather than on earlier stages in the food life cycle.

As a more distant target, the UK government as a whole has set itself the aspiration (not a firm target) of achieving a 60% cut in the UK's carbon dioxide emissions by 2050. The adequacy of this goal has been subject to much questioning of late[303] [304] [305] with some suggestion that a 90% cut in the UK, equivalent to stabilising concentrations of CO_2 at 450 ppm[306] will be necessary in order to keep the temperature rise to around 2°C and thereby avoid the worst impacts of climate change. This said, given current progress in meeting our targets, the 60% goal is still fairly ambitious. It might be logical to assume that the food industry would need to play a proportionate part in helping the UK reach this goal too.

It is important to note that, other than research funding, the industry receives no subsidy or other form of financial support either from government or through the Common Agricultural Policy. As has already been noted above, the industry faces severe competition from overseas and has been doing so for a number of years. This has led to an increase in cheaper imports and a decline in indigenous production. The consequences, in terms of greenhouse gas emissions, have already been explored in the transport section above.

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[303] *Government needs to keep carbon dioxide target under review to avoid dangerous climate change,* Royal Society Press Release, 30 January 2005

[304] *Scientific and technical aspects of climate change, including impacts and adaptation and associated costs*, Department for Environment, Food and Rural Affairs September 2004 http://www.defra.gov.uk/environment/climatechange/pubs/pdf/cc-science-0904.pd

[305] *Avoiding Dangerous Climate Change: International symposium on the stabilisation of greenhouse gas concentrations*, Hadley Centre, Met Office, Exeter, UK, 1-3 February 2005: Report of the International Scientific Steering Committee, May 2005 http://www.stabilisation2005.com/Steering_Commitee_Report.pdf

[306] parts per million

SECTION FIVE: STRATEGIES FOR REDUCING GHG EMISSIONS: THE TECHNOLOGICAL OPTIONS

This section looks at how technology might help us reduce greenhouse gas emissions from the fruit and vegetable sector. It considers the extent to which a technology focused approach can help us achieve the goal, as stated in the Food Industry Sustainability Strategy, of achieving a 20% reduction in carbon dioxide emissions by 2020.[307] This appropriateness of this target may reasonably be disputed but it serves as a starting point.

This section is by no means comprehensive. Each of the technological areas highlighted below is a massive research area in itself, populated by myriad research projects and enormous expertise. The purpose here is not to set out and detail all the technological options that are possible but rather to give a feel for the sort of work that is underway and the sorts of energy reductions that are thought to be achievable. The intention is also to gain a sense of where the technology is leading, of what sort of a dent it might make in greenhouse gas emissions and of whether by itself a technology-oriented approach to reducing emissions will be sufficient.

5a. Plant breeding

Defra's horticultural breeding strategy is guided by Defra's wider aims for food and farming.[308] For farming, these include the goals of providing safe, healthy products in a manner which is viable and economically sustainable for agricultural and other communities, that operates within natural resource limits and which minimises demands on energy.

There is however, no formal 'breeding strategy' as such; breeding-focused research projects are developed as and when breeding is perceived to have a role to play in achieving these wider aims.[309]

Any particular breeding research project is likely to have several end goals. Pest and disease resistance are clearly priorities; there is no point in breeding plants on any commercial scale that succumb easily to disease. Other goals may include flavour, drought resistance, nutritional content and the extent to which the produce is likely to take a hold in the market place. This last will be influenced not just by a product's tolerance to storage and shelf life conditions but also by retailers' views on whether people will actually buy the product in question. Supermarkets clearly act as gatekeepers here and have a major impact on the varieties of fruit and vegetables that are available in store and that we subsequently know about and eat. A variety which is good in many ways – pest resistance, good flavour, lower input requirements and so forth - may be rejected by the supermarkets simply because they feel consumers will not

[307] from a 1990 base line
[308] *Strategic Priority - Sustainable Farming and Food, Including Animal Health and Welfare* http://www.defra.gov.uk/science/how/documents/PDFs%20in%20Parts/Part%20II%20in%20sections/20.pdf
[309] Emma Hennessey, Defra, personal communication January 2006

like, say, the colour. The flavoursome but brownish-coloured Florence strawberry is a case in point here.[310]

Given the diversity of fruits and vegetables it would be impossible to give a comprehensive summary of all the research underway and of its potential to help the UK fruit and vegetable sector reduce its greenhouse gas emissions. The following paragraphs give just an idea of the sort of work that is going on.

Research into varieties that are able to withstand storage without spoiling is potentially of use, because the end result is less waste. One study undertaken by East Malling Research Centre (EMR) [311] is looking at naturally occurring clones of apples which, because of fundamental changes in their biochemistry, emit low levels of ethylene (ethylene hastens ripening and eventually decay). This enables them to store well for longer without spoiling. David Johnson of EMR points out that while these can lead to lower energy use in storage, it may be a challenge to introduce a new variety into the market place. The public does not, it appears, easily accept new varieties.[312]

Another completed study by the Horticultural Research Institute looked at developing broccoli varieties with an extended storage capacity. Broccoli, being a flower, has a very short life span; UK-grown broccoli tends to go from field to supermarket in about 24 hours; for Spanish imports the cycle is a little longer, at up to three days. Once in the supermarket the broccoli has a specified shelf life of two days. Broccoli that yellows within this two-day span is returned to the grower at the grower's expense.

This two-day specified cycle for broccoli is shorter than the average restocking cycle for most fresh produce –supermarkets tend to work on a three-day restocking cycle – and the HRI research has been successful in extending broccoli's lifespan to three days.

While this research might be useful and interesting it is unlikely to have a vast impact on waste in the broccoli supply chain. As highlighted, it is the home that is the most significant point in the supply chain for waste. It has also been observed that growers tend to overproduce so that they can provide supermarkets with continuity of supply. [313] The surplus is often left in the fields and this evidently represents a waste of the fossil fuel inputs used to grow the broccoli in the first place. Clearly the underlying cause of the waste is our and/or supermarkets' expectation that products should be consistently and ubiquitously available. This means that supply has to be able to meet demand whatever the fluctuations and vagaries of that demand and of other factors. In other words, the waste has less to do with technology than with today's marketing, retailing and consumption systems.

Research into breeds that make more efficient use of fertilisers is another approach that could potentially reduce greenhouse gas emissions; as already noted, fertilisers are very energy intensive to produce and excess nitrates in the soil can denitrify to form nitrous oxide. As an example, one ongoing Defra project (HH3506SFV) undertaken by the

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[310] Emma Hennessey, Defra, personal communication, January 2006
[311] David Johnson, East Malling Research Centre, personal communication, December 2005
[312] Steve Maxwell, WorldWide Fruit, personal communication, January 2006
[313] David Pink, Horticultural Research Institute, personal communication, 2006

Horticultural Research Institute is examining the scope for making more efficient use of nitrogen in crop rotations of horticultural crops. [314]

At the European level, the EU-Rotate_N[315] project is developing a new decision support system which should help growers estimate fertiliser requirements of field vegetables in the context of whole crop rotations. The aim here is to improve nitrogen use efficiency and reduce nitrogen residues in the soil.

These are all interesting and potentially useful projects. The breeding route, however, is not (as it stands) likely in itself to generate major or indeed even measurable savings in greenhouse gas emissions at the fruit and vegetable sectoral level. Improvements in fertiliser use efficiency are of course important because they help cut growers' costs (since fertiliser is expensive), and because they reduce environmental impacts in other areas, such as water pollution. However, since fertiliser use by the fruit and vegetable sector is very small in absolute terms compared with the far greater quantity that is applied on arable and grazing land, the impact on UK (or European) fertiliser greenhouse gas emissions will be minimal.

One more directly energy-saving approach is to extend the breeding season of indigenous produce. There are several Defra projects with this goal in mind. Project HH3716SSF[316] focuses on developing new varieties of raspberries that will crop over an extended season. Project HH3717STF has similar goals, these being to extend the season of stone fruit by breeding late-ripening cherries and early-ripening plums.[317]

These could indeed be helpful in reducing reliance on imports although of course the influx of imports is as much to do with cost as with seasonal availability; by itself a breeding programme cannot tackle this issue. That said, there is certainly a perception by consumers that for some foods at least (such as strawberries, asparagus and so forth) UK produce has a better texture and flavour than imports and so programmes such as these may well help improve the UK's competitiveness in this sub-sector.

5b. Agricultural production

As already highlighted in section 2a, the production of field grown horticultural crops is not especially energy intensive. Glasshouse production is, on the other hand, very energy intensive although even here the absolute contribution to the UK's CO_2 emissions is small.

The protected horticulture industry has a clear incentive to reduce energy since it accounts for such a large proportion of its costs. The recently negotiated Climate Change Agreement has given added impetus to the drive. However, as with other

[314] Making more efficient use of nitrogen in crop rotations of horticultural crops http://www2.defra.gov.uk/research/project_data/More.asp?I=HH3506SFV&SCOPE=0&M=CFO&V=WHRI

[315] http://www.hri.ac.uk/eurotate/index.htm

[316] http://www2.defra.gov.uk/research/project_data/More.asp?I=HH3716SSF&M=KWS&V=extend&SCOPE=0

[317] http://www2.defra.gov.uk/research/project_data/More.asp?I=HH3717STF&M=KWS&V=extend&SCOPE=0

industry sectors, many of the more obvious improvements have already been made. Figures by the Farm Energy Centre show that specific energy consumption has improved by 36% since 1985,[318] comparable with the UK's overall reduction in energy intensity during this period.[319] It is therefore proving harder to make additional changes. This said, it has been estimated that additional reductions of up to 10% are possible using existing technology and good management, without any compromise on quality or yield.[320]

One well recognised way of reducing energy use in this sector is through the use of Combined Heat and Power (CHP). Most greenhouses are heated by gas. However, with the installation of a CHP plant, gas and electricity can be co-generated. Put more accurately, heat is produced as a by-product of the electricity generation process; the gas (or other fuel source) is used to heat water which drives a turbine which produces electricity, and the steam is subsequently used to heat the greenhouse. As an added bonus the CO_2 emitted as a result can be pumped back into the greenhouse – tomatoes thrive in CO_2 enriched environments. Horticultural enterprises are heavy users of heat but have low electricity requirements and as a result surplus electricity can be sold back to the grid.

CHP can increase the overall efficiency of fuel use to more than 75%, compared with around 40% from conventional electricity generation – in other words, it nearly doubles the efficiency. Furthermore, because it often supplies electricity locally, CHP can also reduce losses from transmission and distribution.

However CHP is not as widespread as it could be since the regulatory environment does not favour the production of electricity by this means. Rather than investing in new CHP equipment it is cheaper and easier in the short term to continue with the old equipment and simply buy in the relatively small amounts of electricity required.

Despite this, there are examples of horticultural enterprises running on CHP or CHP-type systems – currently 25% of tomato growers make use of this technology. For historical reasons, the proportion is lower for other protected edibles.[321]

Two examples may be worth highlighting in more detail, one well established and one very new. These are not dedicated on-site stand-alone CHP plants as such. Rather they are both sites which have an arrangement with nearby manufacturers to use the waste steam and CO_2 that are by-products from the manufacturers' electricity generation requirements. In this sense they could be considered to be running on 'free' energy since the heat and CO_2 would have been generated whether they were there or not.

Cornerways Nursery, located near British Sugar's sugar factory in Wissington is the well established example. The glasshouse at Cornerways Nursery covers an area of five hectares and produces over 34 million tomatoes each year between April and November. Hot water and carbon dioxide are carried by pipe from the sugar factory to

[318] Chris Plackett, presentation given by the Farm Energy Centre at the FCRN fruit and vegetable seminar held in Manchester on 1 December 2005
[319] Digest of UK Energy Statistics, DTI, Table 1.1.4, http://www.dti.gov.uk/files/file17348.xls
[320] Chris Plackett, presentation given by the Farm Energy Centre at the FCRN fruit and vegetable seminar held in Manchester on 1 December
[321] Chris Plackett, Farm Energy Centre, personal communication, June 2006

the nursery. As an added benefit, water used primarily to wash the sugar beet (and therefore carrying some additional nutrients in the form of residual soil) is re-used to irrigate the tomato plants.[322]

A second, more recent example is located in Teeside. The scheme uses waste steam and carbon dioxide from a nearby manufacturer to heat 23 acres (9.3 hectares) of glass houses. The scheme claims to be able to grow tomatoes all year round for Sainsbury's, its sole customer. The scheme is different from a classic CHP scheme in that the site's requirement for heat, CO_2 and electricity can be individually controlled but it works on very similar energy efficient principles.[323]

For most CHP plants the primary fuel tends to be natural gas. But there is also potential for using other fuel sources, including biogas.

One life cycle assessment undertaken by the (then) Silsoe Research Institute modelled how energy demand would change were protected tomato enterprises to shift entirely to CHP. It found that energy use could reduce by 26% and greenhouse gas emissions by 17%.[324]

Interestingly, the study also found the glasshouse production of organic tomatoes to be more energy intensive than conventional production. Organic tomato yields tend to be lower and thus for any given area of heated greenhouse, energy requirements per kilogram of organic tomatoes will be higher than for their non-organic counterparts. Indeed, the Silsoe study found the energy requirement for organic tomatoes to be almost double that of conventional production, a figure which took into account the absence of nitrate fertiliser use on organic crops.

Yield per given area is critical for crops which are grown using heat. Indeed, one reason why energy use by the industry has not declined as much as it could have has been the shift in preference towards smaller cherry and speciality tomatoes. These produce lower yields and therefore the energy requirements are per both on an area and on a yield basis.[325] The question of people's shifting tastes is explored more fully in section 6 below.

So far technological options at the national level have been explored. There is also the European dimension to consider. The environmental and economic pressures to reduce energy use in greenhouses affect many countries within the EU; the European glasshouse industry is collectively (and unsurprisingly given the European climate) the largest in the world. In response, an EC funded project is currently underway[326] which seeks to improve the competitiveness of the industry and reduce its energy consumption. The project is investigating the energy requirements in greenhouses in four different geographical areas within Europe. Following this, a tool for auditing energy

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322 http://www.britishsugar.co.uk/RVEffbf81e84b1d4f3daea19a45f2c2b22b,,.aspx

323 http://www.j-sainsbury.co.uk/index.asp?PageID=424&subsection=&Year=2005&NewsID=593

324 Data prepared for forthcoming Defra report: *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*, Silsoe Research Institute, Defra project code IS0205 forthcoming

325 Gerry Hayman, British Tomato Growers' Association, personal communication November 2005

326 http://www.herts.ac.uk/aeru/projects/greenergy/index.htm

efficiency in greenhouses, a set of technical improvement measures and a guideline for optimising energy consumption in European greenhouses will be developed and tested in several case studies, taking into account current and upcoming European environmental legislation.

It may also be helpful to mention a new glasshouse technology being developed by the Dutch and now at the demonstration stage. The GeslotenKas® system, as it is called, is a closed integrated greenhouse system based on the use of an aquifer to store heat; details of how it works can be found on the company's website.[327] Innogrow, the manufacturers, claim that the system can increase average yields by at least 20% per square metre, reduce energy by 30%, reduce water use (since water is re-circulated) by 50% and, as a closed system, reduce the need for pesticides and other forms of crop protection by 80%. Both the technology and the demonstration project are being observed with close interest by the UK horticulture industry. It remains to be seen, however, whether this aquifer based system can be applied to the British context.

5c. Refrigeration

A great many organisations are working on refrigeration-related research. Some of the key players include the Market Transformation Programme, a Carbon Vision project (led by the University of Bath), Brunel University, the FrPERC research group at the University of Bristol, Cambridge Refrigeration Technology and the Carbon Trust. In addition trade bodies such as the Cold Storage and Distribution Federation and the Institute of Refrigeration will be involved one way or another in the work of these organisations. At the international level, the International Institute of Refrigeration is very influential.

Improving energy efficiency

Considerable scope exists for reducing emissions from cold storage. Much of the equipment currently in use is very old and hence highly inefficient.[328] Estimates for possible energy savings vary roughly between 20 and 50%.[329]

One industry expert[330] sets out the three fairly basic steps for improving energy efficiency. First, owners should specify and design for minimum temperature drops and refrigeration loads: this in essence means storing foods at a temperature no lower than necessary, using natural cooling where possible (for example, taking advantage of lower night time temperatures) using bigger heat exchanges and cooling towers where appropriate, keeping air circulation to the minimum needed and minimising pressure drops in pipes.

[327] http://www.innogrow.nl/en/1_00geslotenkas.html
[328] John Hutchings, Cold Storage and Distribution Federation, personal communication, December 2005
[329] see for example *How to improve energy efficiency in refrigerating equipment*, International Institute of Refrigeration, November 2003 http://www.iifiir.org/17NoteEN.pdf
[330] Robert Heap, Cambridge Refrigeration Technology, personal communication, January 2006

Second, they should buy the most efficient equipment available; this may be an obvious point but decision makers often favour short term cost savings over longer term running cost savings.

Finally, the equipment should be properly maintained to minimise leakages and inefficiencies. Research suggests that refrigerant leakages of between 10% and 20% can increase demand for energy by between 30% and a massive 270%.[331]

The industry commentator also points out that many UK companies have reduced their energy costs by 10-20% using zero or low-cost measures.

One briefing note by the International Institute of Refrigeration[332] estimates that 'good housekeeping' can improve energy efficiency by 20%. Examples include measures such as better insulation, more efficient motors and better 'door discipline' or automated closing doors. This view is shared by others. The draft Food Industry Sustainability Strategy indicates that, by drawing on the Market Transformation Programme knowledge base, the industry could achieve savings of about 20% on most product types, with some class leading products using 50% less energy than others in the same category.[333]

However it is by no means certain that this potential will be realised. What is achievable and achieved will of course depend on many factors; on whether short term cost or long term environmental gain (and economic efficiency) is sought, on whether efforts will focus on retrofitting and improving existing equipment or whether there will be major investment in new plant.

From conversations with the industry, the feeling appears to be that a compromise approach is most likely to be adopted - savings will be achieved through a mixture of retrofitting existing technology, improving the management of existing systems and developing novel technologies.[334] As with all new investments, there tends to be an economic and potentially an environmental trade off between ripping out all the existing structures and putting in new plant as opposed to retrofitting existing equipment. What level of savings will be achieved by this approach remains to be seen.

As highlighted in section 2c above, the greatest area of concern in the refrigeration sector is at the retail stage. Many of the supermarkets have already put in place measures to improve energy efficiency[335] but refrigeration still accounts for over 40% of

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331 *Refrigeration and air conditioning – the response to climate change*, Robert Heap, Bulletin of the IIR no 2001 – 5, International Institute of Refrigeration, 2001, http://www.iifiir.org/2enarticles_bull01_5.pdf

332 *Refrigerated storage: New developments*, Jan E Duiven and Phillippe Binard, Bulletin of the IIR, no 2002-2, International Institute of Refrigeration, http://www.iifiir.org/2enarticles_bull02_2.pdf

333 Food Industry Sustainability Strategy, Defra, 2006, http://www.defra.gov.uk/farm/sustain/fiss/fiss2006.pdf

334 Julius Brinkworth, Sainsbury's, personal communication, December 2005

335 see for example Marks & Spencer's 2005 Corporate Social Responsibility report http://www2.marksandspencer.com/thecompany/investorrelations/downloads/2005/corporate_social_responsibility_2005.pdf

energy use in store.[336] What is more, many of the energy saving 'quick wins' have already been won.

Additional improvements could be achieved by staff actually observing good practice but this can be difficult since many are low paid temporary, or part-time workers and not especially engaged in the issues.

Fairly substantial efficiency gains could also be achieved, for example in stores, by covering the refrigerator cabinets that are currently open.[337] Much depends too on new product developments in the food industry and how this will shape our buying habits.

What about mobile refrigeration? The International Institute of Refrigeration estimates[338] that for the transport of chilled goods, energy savings of about 50% are possible. For frozen goods, the savings may be less, but are nevertheless worth investigation.

Section 2c above showed that there has been a small decline in energy use from domestic cold appliances and that this trend looks likely to continue. However the extent of the decline will depend on the measures that are put in place and some commentators have noted that so far EU domestic appliance standards have not been sufficiently ambitious.[339] A higher minimum standard would have pushed the general efficiency standard of the bulk of UK fridges further upwards than has been achieved so far.[340]

Highly efficient fridges have however been developed and are on the market. One analysis by the Market Transformation Programme for example shows that the A+ models now available are 23% more energy efficient than A rated models and the figure rises to 46% for A++ appliances. [341] However sales of A+ and particularly A++ appliances have been very low in the UK as compared with other European countries. This partly reflects very limited supply – only 7.0 % of models available in the UK are rated A+ or better as compared with around 20% in France, where the consumer is nearly three times more likely to find a suitable appliance in the more efficient classes. Why this supply is so limited and what could be done to increase it could usefully be investigated further. Linked to this is the fact that since A rated appliances are subsidised by the EC, the unsubsidised A+ models appear relatively more expensive to the consumer.[342]

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[336] *Energy use in the United Kingdom: non-domestic building stock*, Resources Research Unit, Sheffield Hallam University, 2002

[337] Julius Brinkworth, Sainsbury's, personal communication, December 2005

[338] *Refrigerated transport: progress achieved and challenges to be met*, International Institute of Refrigeration, IIFIR, August 2003 http://www.iifiir.org/16NoteEN.pdf

[339] Boardman, B (2004) *Achieving energy efficiency through product policy: the UK experience*. Environmental Science and Policy 7(3), 165-176

[340] Boardman, B (2004) *Achieving energy efficiency through product policy: the UK experience*. Environmental Science and Policy 7(3), 165-176

[341] *BNC14: UK Market for A+ and A++ Refrigeration Products*, Market Transformation Programme http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=40

[342] *BNC14: UK Market for A+ and A++ Refrigeration Products*, Market Transformation Programme http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=40

Novel technologies

There are also the possibilities offered by novel refrigeration technologies to consider. Brunel University for example is developing a combined heat, power and refrigeration (CHRP) or trigeneration plant. This technology has the potential to reduce CO_2 emissions by 25-50% energy bills by over 30%.[343] In essence CHRP is an adaptation of the CHP principle; waste heat produced by the generator is fed into an absorption chiller which then provides the cold temperatures needed for frozen and chilled food. The technology could in theory be applied for use across the whole food industry - in cold stores, food-freezing factories and freeze-drying plants. One report suggests that a CHRP system could be launched commercially by 2007.

Another way of considering the refrigeration issue is to examine alternative approaches to food preservation. One available technology for example is food irradiation. This has been widely adopted in the US and in other parts of the world but has faced opposition in Europe both from the public and from consumer groups such as the Food Commission. While it may be that food irradiation could reduce reliance on the cold chain, two points need to be noted. The first is that the irradiation process may itself be energy intensive – more investigation is needed here. And secondly, perhaps more significantly, for bulk consignments it is very difficult to give a uniform irradiation dose to a bulk consignment without some parts being under-protected and others being damaged, making irradiation an impractical alternative to refrigeration.[344] In practice then, irradiation has tended to be used as an additional food safety measure rather than as a substitute for refrigeration.

Another more accepted technology is that known as 'SmartFresh.' This is already used fairly extensively on apples. Gases (1-MCP) are introduced into the storage environment which render the fruit insensitive to ethylene, the gas that triggers ripening and eventually decay. By slowing the ripening process SmartFresh can extend both the storage and the in-store shelf life of the product.[345] In theory the technology could help reduce cold storage requirements. In practice though this does not happen - the fruit is stored at the same temperature as it would have been, but the apple is crisper than under normal storage conditions. The energy used to produce and apply the SmartFresh gas is not known and would need to be taken into account when considering what energy saving potential it might have.

The policy and legal dimensions

Various EU and UK policies and measures influence (or will influence) energy efficiency in refrgeration. At the UK level, companies are given a financial incentive, through the Enhanced Capital Allowance scheme to invest in energy efficient equipment. In addition, information is available from organisations such as the Energy Saving Trust to enable purchasers (both domestic and commercial) to choose the most energy efficient equipment. Information on managing equipment in energy effiienct ways is also offered by organisations such as the Carbon Trust. Domestic white goods such as refrigerators and dishwashers are rated (from A++ to G) for their energy efficiency enabling people to make energy efficient choices.

[343] http://www.dti.gov.uk/technologyprogramme/casestudies/ENERGY_CONSUMPTION.pdf
[344] Robert Heap, Cambridge Refrigeration Technology, personal communication, March 2006
[345] David Johnson, East Malling Research Centre, personal communication, December 2005

It was felt by many working within the refrigeration sector that a great deal more could be achieved if refrigeration were able to secure a Climate Change Agreement.[346] [347] Discussions between the refrigeration industry and Defra have been ongoing and the various arguments for and against inclusion will not be discussed here. It is sufficient to say that the need for a CCA was felt by industry representatives with an interest in refrigeration along the whole of the supply chain.

At the EU level, the Framework Directive for the Eco-design of Energy Using Products (EuP) sets out a framework for the setting of eco-design requirements for energy using products before they can be placed on the market. The Framework Directive itself does not contain any immediate obligations for manufacturers; however the UK is in the process of transposing the framework directive into UK law, which means that by end of 2007 (if all goes to plan) UK manufacturers will be obliged, by law, to meet certain energy efficiency related obligations.

At the moment a key EU refrigeration issue is that of HCFCs, or F-gases as they are known. As from 2008, HCFCs will start to be phased out across the EU, leading to a total ban in 2015. The ban will require significant changes to existing equipment as well as investment in new plants, and as a result the refrigeration sector post-2015, simply by virtue of having to re-equip itself, is likely to be more efficient than it is at the moment.

Ammonia and CO_2 are likely to be the main refrigerant gases that will be adopted instead, with other options including propane-butane, water and even air. These refrigerants have low or no global warming potential but they are not problem free; some options such as ammonia are only suited to large plants and with others their use renders the refrigeration units less energy efficient than if run on HCFCs.[348] In short there are problems and benefits associated with all these alternatives.

Another EU regulation, this time already in existence, is the Quick-Frozen Food-Stuffs Regulation.[349] This specifies that foods which have undergone quick-freezing[350] need to be stored at -18°C or lower. Not all frozen foods are quick-frozen and these do not have be stored at any specific temperature. In practice, however, whether they are quick frozen or not, all stored foods tend to be stored at least -18°C simply because cold stores tend to be large, fairly un-compartmentalised warehouses where quick frozen and non quick frozen foods are kept together.

Obviously -18°C is far below the temperature needed to maintain most foods in their frozen state and to some extent this -18°C is a fairly arbitrary figure. It happens to be 0°F and the US – which still work in Fahrenheit – were integral to the development of the international code regulating foods, the *Codex Alimantarius*, which underpins the EU regulations.

[346] Julius Brinkworth, Sainsbury's, personal communication, December 2005
[347] John Hutchings, Cold Storage and Distribution Federation, November 2005
[348] John Hutchings, CSDF, personal communication, December 2005
[349] EU Council Directive 89/108/EEC and Commission Directives 92/1/EEC and 92/2/EEC
[350] a particular process whereby the zone of maximum crystallization is crossed as rapidly as possible, so ensuring that the proper texture of the food is preserved

More critically however, this low temperature was specified less for reasons of safety, and more to ensure that the taste, texture and appearance of the food in question could be preserved in optimum condition for as long as possible. The lower the temperature, the longer a frozen food can be stored. The Practical Storage Life (PSL)[351] of fruits and vegetables stored at -12°C is much shorter than those stored at -18°C. For example peas stored at -18°C will keep for two years while at -12°C their PSL is only six months. Spinach will keep for 4 months at -12°C, for 18 months at -18°C and for over two years at -24°C. [352]

Might there, however, be a case for arguing that it is not often necessary to store food for this long since in any case frozen food tends to move through the supply chain more quickly than the two years allowed by a storage temperature of -18°C? According to the International Institute of Refrigeration's handbook 'most products possess a substantially longer storage life at -18°C than the time elapsed between freezing and consumption.' [353] In other words the food is usually eaten long before it is at risk of losing its quality.

From an energy point of view, a rise in the legally permitted temperature would certainly be beneficial. According to the Institute of Refrigeration, 'A decrease in temperature lift of 1°C reduces the power consumption of a system by between 2% and 4%.'[354] Using the lower estimate of 2% per degree, a rise in average frozen food storage temperature from -18°C to -12°C could reduce energy use by 12%. If this saving was added to the potentially achievable efficiency savings that have already been highlighted then really substantial cuts in energy use could be achieved.

However, from discussions with industry[355] it appears that such a shift would require fairly substantial systemic changes. Take frozen peas, for example. Peas are harvested between June and August[356] and the majority are consumed by the following June. However, technically speaking, peas actually have a life span of three and a half years – two years at the manufacturer's storage site and 18 months at the retail and consumer stages. In order to achieve this life span the peas are stored at the manufacturer's cold store at -23°C. This temperature is evidently lower than the QFFR maximum of -18°C but from a manufacturer's point of view it is a 'safe' temperature which allows for any fluctuations in temperature that might occur due to the improper use or breakdown of equipment at the transport and storage stages, or from poor product handling.

Once the peas leave the manufacturer they travel to store. Mobile refrigeration is discussed in more detail in the section below. In-store freezers are set at -18°C but owing to a variety of factors (poor handling by staff, door opening by customers) the temperature can creep up to around -15 to -16°C. If the temperature rises too much, ice formation can occur and the appearance of the product will deteriorate. Situations can

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[351] defined by the industry as 'the period of frozen storage after freezing during which the product retains its characteristic properties and remains suitable for consumption or the intended process.'
[352] *Recommendations for the processing and handling of frozen foods*, 3rd Edition, 1986, International Institute of Refrigeration, Paris, France
[353] *Recommendations for the processing and handling of frozen foods*, 3rd Edition, International Institute of Refrigeration, Paris, France, 1986, p.130
[354] Institute of Refrigeration SES Technical Bulletin 5.1
[355] Caroline Hytch, Quality Assurance, personal communication, January 2006
[356] Caroline Hytch, Quality Assurance, personal communication, January 2006

and do arise when supermarkets send the produce back to the manufacturer (with the manufacturer incurring the costs) even though the problem was actually caused by a combination of factors at the supermarket.[357]

In essence, manufacturers keep their storage temperatures as low as possible to compensate for the less-than-ideal storage conditions at the retail outlet and thus minimise the risk of complaints and costs. The extra-cold storage at the manufacturing site buys a little extra time, as it were, for the pea. It was felt by industry[358] that raising the minimum temperature at the manufacturer's storage sites would reduce the life span and quality of the food further along the supply chain, leading to more returns, more spoiled products and so forth.

In short, the industry view on raising the temperature was somewhat negative. Does this mean that there really is no scope for change? A closer look at peas, and at the reason for their three and a half year required life span, suggests that there may well be some room for manoeuvre given cooperation and backing from all parts of the industry.

As mentioned, two years of the pea's three and a half year technical life span are allocated to the manufacturing stage. According to Unilever[359] frozen peas do need at least a year at the manufacturer's site simply because it takes so long to pack the 40,000 tonnes that are grown each year. But this also means that there is a whole extra year's worth of safety margin which may not (or not all) be needed.

As regards the retail stage it appears that supermarkets require at least a twelve month guaranteed life span on frozen foods. Foods with anything less than that are rejected. In practice, however, produce is sold far more rapidly than that. Once the food reaches people's homes it tends to be eaten quite quickly - Unilever estimates, based on the customer complaints information they receive, that on average people eat their frozen foods within about 2-3 months of buying them[360]

In theory then, it may be that the three and a half year life span of the frozen peas carries an excessively large safety margin and that the life span could be reduced to around two years. This could mean that higher minimum temperatures could be specified which in turn could yield energy savings. Further work would need to be carried out to ensure that the right quality was maintained.

It is also the case that were retail outlets to manage their refrigeration more effectively, there would be less need to set such low temperatures at the manufacturing stage. Better training by supermarket staff, less delay between the unloading and filling of freezer cabinets and more investment in better designed cabinets would all help.

So what might one conclude? In theory, it would be possible to raise the temperature if the reasons for so doing were made clear and there was close cooperation along the whole of the supply chain. Such a course of action could yield useful reductions in energy use, particularly at the cold storage stage. While energy use by commercial cold stores is not as great as that used by retailers it still represents useful savings.

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[357] Caroline Hytch, Quality Assurance, personal communication, January 2006
[358] Caroline Hytch, Quality Assurance, personal communication, January 2006
[359] Caroline Hytch, Quality Assurance, personal communication, January 2006
[360] Caroline Hytch, Quality Assurance, Unilever, personal communication, January 2006

In practice of course, since the Quick Frozen Foods Regulations are enshrined in EU law, and for various other reasons, it could be very difficult to change things. However it is perhaps an area which merits further exploration.

5d. Transport

The scope for achieving greater energy efficiency in the freight transport sector has already been highlighted elsewhere.[361] A range of measures can yield energy savings: these included better fleet management (including training drivers to drive more fuel efficiently), the design and specification of more aerodynamic vehicles, the use of information and communications technologies to plan routes and loads more effectively, better time management, and the use of cleaner fuels. All these are useful and savings of about 10-20% may be possible. However, it is uncertain whether technological change by itself will be able to compensate for two distinctly energy intensive trends which have already been highlighted above. The first is the overall and continuing growth in food related transport mileage.[362] The second is the increasing use of air for the transport of foods.

Reviewing the growing number of life cycle analyses that have been undertaken, it appears that the food miles issue has on occasion been overstated and that transport-related emissions account for a relatively small part of overall food life cycle greenhouse gas impacts.[363] This conclusion needs modifying when it comes to fruit and vegetables. Indeed when discussing transport and the fruit and vegetable sector, several points appear to be critical to the discussion.

The first is that for the fruit and vegetable sector, more produce is imported than for any other food commodity[364] with the exception of fish[365] and some alcoholic drinks.[366]

The second is that there is a correlation between transport and mobile refrigeration energy use and possibly with waste, as sections 2b, c and f have argued. In other words, the long distance transport of fruit and vegetables requires and is indeed predicated on the availability of mobile temperature control which, as already discussed, is highly energy intensive. It may be that waste levels for goods that are transported long distances may be higher than those carried shorter distances simply because they will need to be handled more; however it was not possible to find any research which focused on this issue.

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[361] Garnett T. *Wise Moves: exploring the relationship between food, transport and CO_2*, Transport 2000, November 2003.
[362] *The Validity of Food Miles as an Indicator of Sustainable Development*, Defra 2005 http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp
[363] Krutwagen B, Lindeijer E. LCI of food in the Netherlands, IVAM Environmental Research, paper in International Conference on LCA in Foods – Proceedings, Swedish Institute for Food and Biotechnology (SIK), Gothenbury, Sweden, 26-27 April 2001.
[364] Agriculture in the United Kingdom 2004, Defra 2005
[365] United Kingdom Sea Fisheries Statistics 2004, Defra http://statistics.defra.gov.uk/esg/publications/fishstat/uksfs04.pdf
[366] *Statistical Handbook 2004* British Beer and Pub Association, London, 2004

The third point to make is that the air freighting of foods has an overwhelming, and negative environmental impact and that fruit and vegetables are the largest air freighted food sector by volume. The signs are that the proportion of fruit and vegetables carried by this mode is likely to grow. This presents a serious problem and technological improvements alone, without fiscal measures, are unable to outstrip the rate of growth.[367]

Fourth, while technological efficiencies in, for example, refrigeration can yield substantial savings, the potential in the transport sector is not so great. Really significant reductions might indeed be achieved by the use of vehicles running on alternative fuels but the commercial viability of such vehicles is still a long way off. In addition, even when such vehicles do come onto the market, many of the older vehicles will still stay in use until they reach the end of their life span. The through-flow of more efficient vehicles is unlikely to be more rapid than the escalation of the problem itself.

Finally, the long distance transport of food – and fruit and vegetables in particular – is growing. As such the problem is likely to increase rather than lessen in importance.

5e. Waste

As section 2f above has already shown, waste rates along the fruit and vegetable supply chain vary. Waste levels are reasonably low where products are highly controlled, as in the food processing industry, and to an extent at the retail outlet,. These are contexts where waste equals visible costs and so measures are put in place to manage those costs, and that waste. This said, there are still considerable opportunities for improvement: between 2004/5 and 2005/6 Sainsbury's managed to reduce its volume of waste (of all types) by 8.5%;[368] hence further reductions may still be possible.

In the food processing sector advice on waste reduction in the food industry is provided by a range of bodies including the Faraday Food Processing Partnership. See for example their report on waste minimisation, reuse and recycling.[369]

As regards the harvest and post harvest stage one study suggests that measures such as better communication between growers and buyers, together with the use of more agricultural forecasting methods and more knowledge-sharing among growers would all help bring waste levels down.[370] However the focus of the report is on improving farmers' profit levels (certainly a useful goal in itself) rather than the environmental impacts of waste and there is a difference in the level of waste reduction needed to improve profits compared to that needed to make a measurable dent in food greenhouse gas emissions. Strikingly the report shows that if the amount of product ending up on the supermarket shelf – the 'pack-out' rate – were increased by five percentage points, the budgeted farm

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[367] Garnett T. *Wise Moves: exploring the relationship between food, transport and* CO_2, Transport 2000, November 2003

[368] James McKechnie, waste manager, Sainsbury's, personal communication, May 2006

[369] *Waste Minimisation, Reuse, and Recycling Strategies for the Food Processor*: A strategic report compiled for the Food Processing Faraday by the Scientific and Technical Information Section, Leatherhead Food International, in conjunction with Pera Knowledge http://www.fpfaraday.com/Files/Waste+Report+Printed.pdf

[370] *Cutting Costs: adding value in organics*, Food Chain Centre, Institute of Grocery Distribution, January 2006

profit would increase by 60 per cent. This then says more about the economics of supplying to the supermarkets as compared with the rest of the UK market than it does about practical measures to reduce waste.

Of course there will always be a proportion of the crop that is less than perfect. Technology alone is unlikely to reduce these imperfections very substantially. An alternative and perhaps more effective approach might be to reassess the notion of quality itself. This is explored further below but in the meantime Table 9, taken from the Organic Farm Management Handbook, is illuminating[371]:

Table 9 - Comparison of marketing outlets for vegetables

Indicator	Pre-pack	Wholesale	Direct Marketing
Marketable yield	Lowest (50-70%)	Medium/high (70-85%)	High (90-95%)
Grade out	30-50%	15-20%	5-10%
EC class	Class I (& II)	Class II	Class I & II
Crops range	limited range	medium range	high diversity

What this shows is that for direct marketing systems (such as box schemes, farmers' markets and so forth), waste levels are very low and the amount of produce grown that is actually sold is very high indeed. This mainly reflects a greater acceptance of imperfections by their customers. Losses from mechanical damage such as harvesting machinery can also be lower since hand labour is used more widely. There are, however, also a number of very large direct marketing schemes where there is greater deployment of machinery.[372] The pre-pack category (mainly destined for supermarkets) shows the highest proportion of grade-outs, or produce which is not destined for retail shelves.

Interestingly, in June 2006 Waitrose took a small step in challenging mainstream notions of quality by starting to sell class II fruit in its stores - produce which is perfectly edible but because it is misshapen, the wrong colour or the wrong size does not qualify as Class I. [373]

No work, to our knowledge, is being undertaken in the food service sector and this is clearly an area which demands more attention.

It is at the consumer level where the greatest waste occurs. WRAP is currently funding a range of projects which aim to reduce manufacturing and retail stage food and food packaging waste. Most of the funded projects focus on reducing packaging waste, mainly through, the reduction in weight of packaging materials, or light-weighting. There are however one or two which focus on reducing food waste mainly through the development of packaging technologies which extend the product shelf life. More recently however, WRAP has been commissioning exploratory research which seeks

[371] *Organic Farm Management handbook 2004*, edited by Nic Lampkin, Mark Measures and Susanne Padel, published by the Organic farming unit, Institute of Rural Sciences, university of Wales, Abersystwyth
[372] Chris Firth, Henry Doubleday Research Association, personal communication, February 2006
[373] Food and Drink Europe, foodanddrinkeurope.com
http://www.foodanddrinkeurope.com/news/ng.asp?n=68546-waitrose-fruit-vegetables-supermarket 20/06/06

better to understand in more detail what food we waste, why we waste it, what the impact of technological innovations on consumer food waste might be, and what strategies might change consumer behaviour in relation to waste.

However, it may be that even very major advances in shelf life extension and food preservation will not, by themselves, help reduce consumer waste. Waste at this scale is indicative of our attitudes towards vegetables and fruits (we don't like them enough to make the effort to eat them before they go off) and towards thinking ahead and planning our meals (we don't). It is entirely possible that better storage techniques in the home will not cause us to waste less – we will simply throw food away after two weeks instead of after one. It would be very interesting to know how levels of consumer waste have changed over time; we may have generated waste in the past because the storage technology was not there, whereas now this waste is avoided. On the other hand, possibly thriftier attitudes towards the food we bought in the past and a more rapid through-flow of food through our kitchens may have kept waste losses down where today they occur despite being technically avoidable. A little historical sifting might be in order here but in the meantime, the lower consumer-stage waste levels in the developing world may be an indication of what waste levels might have been. .[374]

It is also worth noting that while there is undoubtedly sense in the food industry's argument that since food packaging helps protect food from spoilage it earns its energy 'keep', if the food ends up being wasted anyway (regardless of the packaging) then the end result is not just more food waste but also more packaging waste. This is not an argument in itself for reducing packaging but it does suggest that packaging alone is not the solution.

A final word on composting. The issue has not been sufficiently discussed in this paper owing to lack of time and there is indeed considerable scope for increasing the amount of food waste that is composted in the UK. Schemes trialled by supermarkets have, as highlighted earlier, been technically successful although have not proved economically viable and as such are not longer operating.

As regards household composting, WRAP and local authorities have made considerable efforts to promote composting (with, for instance, brown collection bins and municipal composting plants). Their efforts have met with some success. On average (2003/4) in the UK we now recycle some 17% of all the waste we produce and of this 17%, 30% is recycled by composting. This figure represents an increase from 1996/7 where only 17% of the waste we recycled was recycled as compost.[375]

However it is important to emphasise that composting, while essential, is in itself only the best of the waste management options. It is not better than not wasting the food in the first place. Much depends, moreover, on the way in which the heap is managed – ignored and left to moulder by itself it can become methanogenic, so generating

[374] comment made by Julian Parfitt, WRAP, at the FCRN fruit and vegetable seminar held in Manchester December 2005

[375] Household waste recycling by material, 1996/7 -2003/4, Defra, http://www.defra.gov.uk/environment/statistics/waste/kf/wrkf15.htm

additional climate changing emissions. [376] This may be one of the arguments in favour of well managed municipal, rather than household composting.

5f. Conclusions for this section

Certainly the scope exists for reducing emissions through the use of better and cleaner technology. Many of the measures highlighted above are not specific to the fruit and vegetable sector alone and could be of benefit to all sectors of the food industry.

In some areas, such as refrigeration, it may be that absolute savings are achievable provided – and this is important – that reliance on the cold chain does not increase to such an extent that the growth outstrips the achievable efficiency gains. For other areas, in particular transport and waste, it may be that technology is less able to achieve change. Emissions in these categories are to a large extent driven by societal attitudes (availability of a wide and consistent supply of produce all year round) and cost structures (food is cheap; waste is therefore affordable). These cannot be tackled by technology alone. With agricultural production the picture is perhaps more mixed. Energy efficiencies can certainly be achieved in the protected crops sector and if this happens then for these crops the 'food miles' issue will become less important. However for field grown crops (where energy use is in any case less significant) the opportunities for reducing emissions may be fewer.

The problem is that action to reduce emissions will require lots of little actions at many different life stages - shaving a bit off refrigeration emissions, a bit off processing emissions, using a little less nitrogen, wasting a little less food. Taken together moreover, the savings might not add up to a huge amount. Might simply changing the way we consume make more of a radical difference to overall emissions? This question is considered next.

[376] *Life cycle assessment of food waste management options*, Sven Lundie and Gregory M. Peters, Journal of Cleaner Production, Volume 13, Issue 3 , February 2005

SECTION SIX: STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS: BEHAVIOURAL CHANGE

Policy makers worldwide increasingly believe that change in what and how we consume is essential if we are to achieve more sustainable patterns of development.[377] [378] [379] [380]

In the UK 'sustainable consumption' is a formal government policy goal and many other organisations, including those seen as having an influence on government policy, are focusing closely on the issue.[381]

This is not the place to consider what 'sustainable consumption' might mean in the generality, nor to examine how and if formal goals are actually being translated into government policy and practice. The purpose here instead is to consider three questions as they relate to the less greenhouse gas intensive consumption of foods. Such a goal is one, but not the only element, of sustainable food consumption. The questions are as follows:

- Would changing what and how people consume actually lead to significant GHG emission reductions from food?
- How far is it actually possible to change people's behaviour?
- What is the role of the individual as opposed to other stakeholders in the context of our food chain?

Much of what follows is exploratory in nature. Most of it deals with food in general rather than fruit and vegetables in particular largely because it is necessary to consider the make up of our diet in general and how shifts in one part of our diet might affect our consumption of, and impacts in other parts.

6a. Changing our pattern of consumption: would it make a difference?

This question is perhaps a question with a sub-question embedded within it. The primary question asks whether changes to our overall pattern of consumption are likely to make a difference to overall food related greenhouse gas emissions. The second embedded question is whether changes in the way we consume *fruit and vegetables* (what we eat and how we store and consume them) will have an effect. Since it is impossible to extricate the second from the first they are considered together.

As a starting point it might be useful first to see where the hotspots lie by food type.

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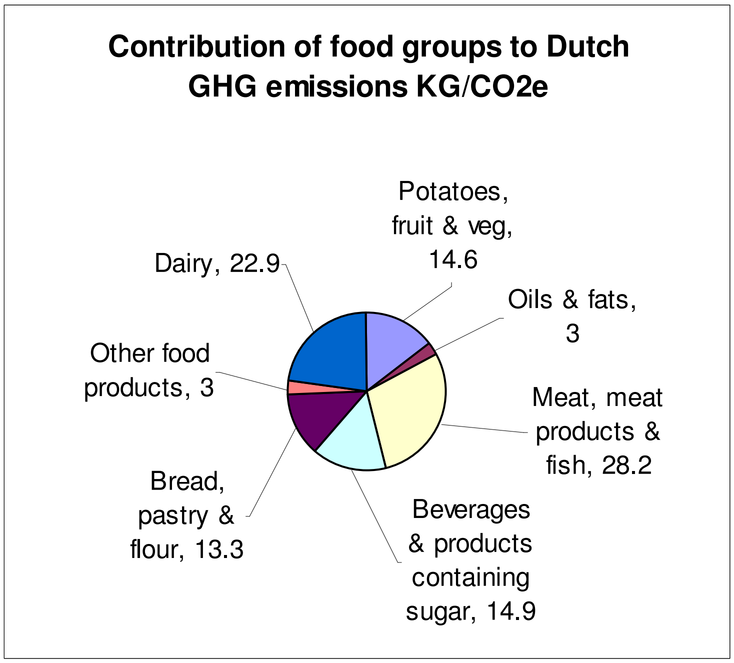
[377] United Nations Environment Programme http://www.unep.org/themes/consumption/
[378] *Changing Patterns UK Government Framework for Sustainable Consumption and Production*, DTI / Defra, September 2003 http://www.defra.gov.uk/environment/business/scp/pdf/changing-patterns.pdf
[379] *Securing the Future - UK Government sustainable development strategy*, Defra 2005
[380] Commission Communication: Draft Declaration on Guiding Principles for Sustainable Development" COM(2005) 218 final, 25.5.2005, European Commission, http://europa.eu.int/comm/environment/eussd/
[381] see fore example the work of the Sustainable Development Commission and its offspring, the Sustainable Consumption Roundtable

Several studies have attempted to separate out the relative contribution that different parts of the food chain make to food-greenhouse gas emissions. An example, taken from an input-output based study by Jan Kramer *et al*[382] is shown in Figure 8. This clearly highlights - as do other studies - [383] [384] the significant contribution made by meat and dairy products to total food chain GHG emissions. Note that the proportions allocated to each of the food groups are a function both of the average quantities that people eat and of the greenhouse gas intensity of the foods in question.

Figure 8



Source: Klaas Jan Kramer, Henri C Moll, Sanderine Nonhebel, Harry C Wilting, Greenhouse gas emissions related to Dutch food consumption, *Energy Policy* 27 (1999) 203-216, Elsevier Publications

Fruit, vegetables and potatoes by contrast contribute in this calculation only about 15%. This more or less agrees with the estimate given earlier in this paper: it was calculated that fruit and vegetable related emissions account for about 2.5 - 3% of total UK GHG emissions. Using the calculation that[385] that food-related greenhouse gas emissions account for about 20% of the UK total, this also works out at about 15% of the food chain total.

[382] Klaas Jan Kramer, Henri C Moll, Sanderine Nonhebel, Harry C Wilting, Greenhouse gas emissions related to Dutch food consumption, *Energy Policy* 27 (1999) 203-216, Elsevier Publications

[383] Wallén A, Brandt N, Wennersten R. Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy 7* (2004) 525–535

[384] *Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25*, European Science and Technology Observatory and Institute for Prospective Technological studies, full draft report, April 2005

[385] *Achieving the UK's Climate Change Commitments: the efficiency of the food cycle*, e3 Consulting, 2002; other approaches to calculating emissions come to a similar figure.

The implication of these findings might therefore be that eating fewer meat and dairy products is the single most helpful behavioural shift one might need to make. A reduction in the consumption of sugary and other arguably unnecessary foods could also make a smaller but nevertheless useful contribution. To substitute for the meat and dairy produce, more would need to be eaten of other foods, such as vegetables and carbohydrates.

If we made these changes then what sort of savings might we expect to see? The Swedish study by Wallén and others,[386] discussed many times already in this paper, considers this very question. It takes as a starting point for its analysis an argument put forward by Dahlin and Lindeskog,[387] that a diet lower in meat and dairy products, higher in a wide variety of fruits and vegetables (including root crops, potatoes, legumes and fruits) and lower in sugars and fats will be less greenhouse gas intensive than existing average Swedish patterns. Unfortunately the original Dahlin and Lindeskog paper is only available in Swedish and so it has not been possible (for this writer at least) to look at the detail of their arguments.

Wallén *et al* then go on to consider what effect a change in diet along these lines might have on overall food greenhouse gases. They do this by calculating what per capita annual food emissions are today (basing their analysis on a range of data sources which give GHG emission estimates for various commonly eaten foods) and then calculating what per capita annual food emissions would be if the proposed 'sustainable' diet were adopted.

Table 10 below, is taken from the Wallén paper and shows average food consumption patterns in Sweden today (1999 data) along side the dietary changes that Dahlin and Lindeskog propose.

In the 'average' diet, the GHG contribution made by meat and dairy products (excluding fish and eggs) is about 58% of total food emissions. A 36% reduction in meat consumption, 50% in cream and 30% in cheese (but a very slight increase in milk) brings the contribution of the meat and dairy sector to total food emissions down to 42% of a now lower total. Emissions from other food groups (legumes, root vegetables, other vegetables and so forth) increase as more of these foods are eaten to compensate for the reduction in meat and dairy products.

[386] Wallén A, Brandt N, Wennersten R. Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy 7* (2004) 525–535
[387] Dahlin, I., Lindeskog, P., 1999. Ett första steg mot hållbara matvanor (A first step towards sustainable dietary habits). Stockholms Läns Landsting, Centrum för Tillämpad Näringslära, Stockholm.

Table 10: Implications of a changed diet with less protein from animal sources

Product	Average food consumption today (kg per year per capita)	Proposed sustainable food consumption (kg per year per capita)	Difference%
Potatoes	51.7	83.2	+61
Root crops	4.74	32.8	+593
Pulses	0.73	7.28	+900
Other vegetables	36	59.1	+64
Bread	52.3	62.0	+19
Pasta	5.38	7.05	+31
Rice	3.59	2.34	-35
Other cereals	7.10	13.7	+93
Meat	52.9	34.0	-36
Fish	12.6	17.9	+42
Eggs	5.48	8.32	+52
Dietary fats	17.16	13.87	-19
Milk, including sour milk products	125	128	+2
Cream	10	5.00	-50
Cheese	16.8	11.7	-30
Fruits & berries	46.0	85.8	+86
Fruit & vegetable juices	31.9	16.0	-50
Sweets	12.0	6.00	-50
Soft drinks	76.0	38.0	-50

Source: Wallén A, Brandt N, Wennersten R. Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy 7* (2004) 525–535

However, and strikingly, Wallén *et al* find that, despite these dietary changes, overall food greenhouse gas emissions decline by only 5%.

This is perhaps a surprising conclusion and since this is the only paper (to our knowledge) available which has actually tried to put numbers on what the likely impact of changing our consumption patterns might be, some time is spent here examining it in more detail. How reliable are the data they use and the conclusions they draw?

As the following paragraphs argue, there are problems with the reliability of both. The most problematic areas in the paper concern the accuracy of the data used and assumptions made for meat and dairy products. The focus of the next few paragraphs is thus on meat even though the subject of this paper is fruit and vegetables; this digression into meat is relevant because how much of it we consume has a bearing on how much plant based food we might need to eat.

Problems with the data for meat and dairy produce

The main problem with the emissions data used for meat is that they are very likely to be fairly substantial underestimates. For example, the study estimates (figures not shown in the table above) that CO_2e emissions from beef are around 6.25 kg CO_2e/kg. But a recent study prepared for Defra by the (ex) Silsoe Research Institute puts emissions per kg of beef at 13 kg CO_2e. This is more than twice the Swedish figure,[388] reflecting either a difference in the livestock production system or a fairly significant difference in the method of calculation. A paper by Casey *et al* focusing on Irish suckler herds gives a range of between 9.57 – 11.25 kg CO_2e per kg of product[389] while a German study estimates emissions to be between 11 – 11.3 kg CO_2e/kg.[390] Again, these are all around double the figures given in the Swedish study. Note that the comparison figures cited here are agricultural LCAs only. They do not extend their analysis beyond the farm gate and as such they do not consider energy used in storing and transporting the meat. If these were added to the emissions generated at the agricultural stage, the overall figure would increase. On the other hand, the Swedish paper which gives far lower figures states that it includes in its calculations all emissions to the point of consumption. In other words the Swedish figure is likely to be an underestimate on several counts.

Moreover, and bizarrely, while emissions for fresh pork are given as about 6.1 kg CO_2e/kg, for frozen meat the figure is much, much lower at 0.20 kg CO_2e/kg. This is *1/30th* the figure for the unprocessed fresh meat when one would actually expect the figure to be higher. For cured meat and sausages the figure is also very small at 0.37%.

For milk, the paper gives a figure of 0.41 kg CO_2e/kg. This is again almost 1/3rd that of other life cycle estimates which suggest that (depending on the farming system), emissions for milk stand at between 1-1.3 kg CO_2e/kg of product.[391] [392] As with the meat, additional emissions will occur during the pasteurising, transport and distribution stages. The comparison LCAs cited do not consider these.

For cheese, the study assumes emissions of 8 kg CO_2e/kg cheese. This is lower than a Swedish study by Berlin[393] into semi-hard cheese which calculates emissions to be higher at 8.8 kg CO_2e per kg cheese. The vast majority of these dairy emissions come (as other studies have also shown) from the milk production process. These account for 8.3 kg CO_2e of the 8.8 kg CO_2e for cheese.

[388] *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Research project final report, Defra project code 1SO205, August 2005, draft

[389] Casey J.W, Holden N.M. Quantification of GHG emissions from sucker-beef production in Ireland, *Agricultural Systems*, 2006 (in press)

[390] Haas, G, Wetterich F and Köpke U. Comparing intensive, extensive and organic grassland farming in southern Germany by process life cycle assessment, *Agriculture, Ecosystems and Environment* 83 (2001) 43-53

[391] A Swedish study *Life cycle assessment of milk production — a comparison of conventional and organic farming*, Christel Cederberg, Berit Mattsson, Department of Applied Environmental Sciences, Göteborg University, Box 464, SE-413 90 Go¨teborg, Sweden, Journal of Cleaner Production 8 (2000) 49–60

[392] Casey J.W and Holden N.M. Analysis of greenhouse gas emissions from the average Irish milk production system *Agricultural Systems* 86 (2005) 97–114

[393] Berlin J. Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, *International Dairy Journal* 12 (2002) 939–953

But how accurate are the data Berlin uses for milk? Her study uses milk emissions taken from Cederberg.[394] Interestingly the CO_2e emissions the Cederberg study attributes to milk production are probably too low. According to Berlin's study, just over 10 kg of milk are needed to make 1 kg of cheese. This means she is basing her calculations on emission figures of 0.83 kg CO_2e per kg milk. This, as already noted above, is lower than most LCAs of milk would suggest.

Moreover the study implicitly assumes that all cheese is indigenously produced. This is unlikely to be the case in Sweden and certainly not the case in the UK where in 2002 only 65% of the cheese we consumed was of UK origin.[395]

A Finnish study of the global warming potential of various foods found the global warming potential for cheese to be about 13 kg / CO_2e per kg of cheese.

In short then, cheese related emissions are likely to have been underestimated by up to 50%. Of course there are many different types of cheese and the cheese examined, called Hushållsost, is not common here in the UK. Nevertheless it is a semi hard cheese and is therefore likely to be similar to the sorts of cheeses that are popular in this country. More to the point, it appears that it is not so much the type of cheese that determines the emissions but the milk production and how much milk is used. According to the British Cheese Board[396] it takes 10 kg of milk to produce 1 kg of cheddar, the same as for Hushållsost.

Reworking the figures presented in the paper for meat, milk and cheese suggests the difference between the average and the 'sustainable' diet is more substantial at 9%. In the 'average' consumption scenario, meat and dairy products account for 68% of CO_2e emissions; in the 'sustainable' scenario they come down to 60%.[397]

Note that this is still likely to be a considerable underestimate, given the exclusion of other life stages in the beef analysis and the fact that the re-calculation does not take into account the likely higher overall figure for processed meats (which make up a considerable proportion of our overall meat consumption).

Problems in its assumptions for meat and dairy consumption

However, the problems with the data are really only half the story. The second concerns the assumptions (or rather Dahlin's and Lindeskog's assumptions) as to what constitutes a 'sustainable' level of meat and dairy consumption.

The Swedes appear to eat a great deal of meat and dairy products and, as compared with UK consumption levels, the proposed 'sustainable' diet is still somewhat heavy on these products. Meat consumption in Sweden is double what it is in the UK and yet in this study only a 36% decline is proposed. For cheese the quantity consumed in Sweden is nearly 17 kg per person a year compared with 5 kg per person in the UK, in

[394] Cederberg, C. (1998). *Life cycle assessment of milk production: A comparison of conventional and organic farming*. Goteborg, Sweden: SIK, the Swedish Institute for Food and Biotechnology.
[395] *Dairy facts and figures 2003*, Milk Development Council, Cirencester, 2004, http://www.dairyuk.org/pdf/MDC_DFactsFig_1612.pdf
[396] http://www.britishcheese.com/aboutus.cfm?page_id=186&CFID=6755&CFTOKEN=76223461
[397] calculations available in appendix, on request.

the light of which one might reasonably argue that the suggested 30% reduction is modest to say the least.[398] The Swedes also consume 37% more milk than we do in the UK[399] and yet the 'sustainable' diet actually proposes a very slight (2%) increase in consumption. This is of course not at all to suggest that the UK diet is a model to emulate. It does show though that even in the developed world there are variations in how much meat and dairy produce we eat. As such, reductions to a 'sustainable' level are likely to be somewhat arbitrary and based in what is considered to be 'normal' in the country of the study in question.

It is also worth pointing out that average meat availability in the developing world is, according to FAO data, 28.5 kg per capita per year.[400] It is important to emphasise that this figure is based on *production* rather than actual *consumption* levels. By way of comparison the FAO calculates that in Sweden per capita availability is 72.4 kg (whereas consumption is 52.9 kg). In other words, the proposed Swedish sustainable *consumption* level for meat is still higher than the developing world average level of *supply*, which is in practice much higher than the actual amount that is consumed. Of course many developing world diets are poor in many nutrients but it is not clear that a lack of meat *per se* is a nutritional problem. On the contrary, a shift to more Western style consumption patterns, including an increase in foods containing high levels of saturated fats which can be found in meat and dairy products have led to a growth in obesity and associated health problems in the developing world.

One might then reasonably argue that a sustainable diet would in fact be substantially lower in meat and dairy products than proposed in this Swedish study. And as a result, greater reductions in emissions from the food sector could be achieved. In other words for meat it is possible to challenge the study's conclusions both on the basis of the accuracy of at least some of the data used and in terms of the definition they give of a 'sustainable' diet.

Other problematic factors to take into account.

Several other points are worth mentioning. For a start, and as the paper acknowledges, energy use for home storage and cooking is not considered. Changing patterns of storage and cooking energy use in the home is likely to yield small, but nevertheless useful reductions.

Second and more importantly, the study does not look at waste generated in the home or elsewhere. The figures given are for quantities of food purchased by the consumer. As such the waste generated during the production and distribution processes is excluded from their consideration, as is any resulting household waste. Waste and our attitudes and behaviour towards waste, are critical when considering GHG emissions from food, as the earlier sections of this paper have argued. Incidentally households

[398] *National Diet and Nutrition Survey*, summary report, ONS, 2004: note that this UK survey will be equivalent to the Swedish one because in both cases the data is based on actual consumption rather than on purchases or food available.
[399] *National Diet and Nutrition Survey,* summary report, ONS, 2004: note that this UK survey will be equivalent to the Swedish one because in both cases the data is based on actual consumption rather than on purchases or food available.
[400] FAO stat, 2002 figures

waste considerable quantities of the dairy products they buy as well as (already highlighted above) their fruit and vegetable purchases.

Finally the Swedish paper's premise is based on a very narrow view of behavioural change. It looks at what we eat and suggests that we ought to eat less of some things. This is only a partial picture of what sustainable consumption, from a greenhouse gas perspective, might mean. Greater sustainability in this respect is likely to require not just the consumption of less GHG-intensive foods but also the less greenhouse gas intensive consumption of foods. This may be a nice distinction, but it is nevertheless important. It is not, say, just about eating fewer meat products (although this is important) but also of redefining our notions of quality for fruits and vegetables in that cosmetic waste along the supply chain is reduced. It might require us to make do with less refrigeration by, for example accepting softer textured stored apples, or eating our food sooner after we have bought it.

What is more, and as has often been pointed out, changes in production and distribution patterns will affect changes in the way we consume. The paper assumes an increase in fruit and vegetable consumption but does not give detail as to which vegetables of fruits are to be preferred over others. For example how might the picture look if we moved away from eating greenhouse-grown or air freighted produce? Perhaps the difference might be small (in the light of the overall contribution made by fruit and vegetables to total GHG emission). However the question is relevant because changes such as these also have a bearing on certain trends in and future patterns of consumption. The problem is not just current emissions resulting from air freighted fruit and vegetables but what emissions might be if trends continue in the direction they are going. Put simply the paper does not acknowledge that a shift in diet *now* has the capacity to curb likely *future* increases in food greenhouse gas emissions.

In short, once all these factors are considered it is arguable there is potential for achieving far greater reductions through behavioural change than this paper suggests. It is difficult to put a sensible figure on what level of reductions might be possible partly because there is very little research on the subject and partly because the interaction of various factors make it very difficult for a single, magical number to be produced. It is possible to say, however, that the figure given in the Wallén paper is most likely a considerable underestimate.

Technology versus consumption?

As highlighted above, there is scope for technology to achieve useful reductions in emissions from the fruit and vegetable sector. This conclusion is likely to hold true for all food sectors. At present estimates suggest that across most life cycle areas (with the exception of transport where all the trends are going in the wrong directions) reductions of up to around 20% are achievable and fairly likely.

It is not possible to put a figure on the reductions which could result from changed patterns of consumption. Wallén *et all*'s conclusion that only around 5% could be achieved is, as has been shown, distinctly flawed. It is has also been suggested that it is very difficult to put a figure on what level of savings might be achieved through different patterns of consumption.

However it is likely not just that behavioural change can match the technological potential for reduction but also – and just as importantly – that really substantial technological change will demand of us behavioural adjustments.

Consumption and production exist in symbiosis with one another. Behavioural change will affect the technologies that are developed in response just as technological change will shape new habits, desires and norms. As such the real challenge is to seek to achieve change by viewing production and consumption as an integrated whole.

6b. Is it actually possible to change people's behaviour?

So far 'consumer behaviour' has been considered in purely abstract terms. Definitions of sustainable consumption are however irrelevant if there is no chance of actually getting people to change. The following paragraphs consider this issue in more detail.

Why do we do what we do?

There is a vast body of literature which looks at how we consume, why we consume and now – increasingly – what the impacts of what and how we consume are on the environment.[401]

As has been highlighted elsewhere, in order to even begin thinking about whether it might be possible to change the way people behave, we need to understand why they do what they do in the first place. Various researchers have highlighted the complexities of people's attitudes to and motivations surrounding consumption.[402] One recent study[403] which examines a huge range of the literature analysing motives for consumption suggests that in essence people's basic motivations can perhaps be distilled into the following:

- Consumption to meet our needs – a means of surviving, reproducing and staying safe
- Consumption to communicate with others the social, psychological and cultural dimensions of our lives;
- Consumption as routine: consuming is just something that we do because we always have and everyone else does too.

These three basic drivers are particularly true of food. Food sustains us; what and how we eat says a lot about us; but much of the time we eat without much thinking about it.

Figure 7 below indicates just a few of the meanings that may have resonance with many people.

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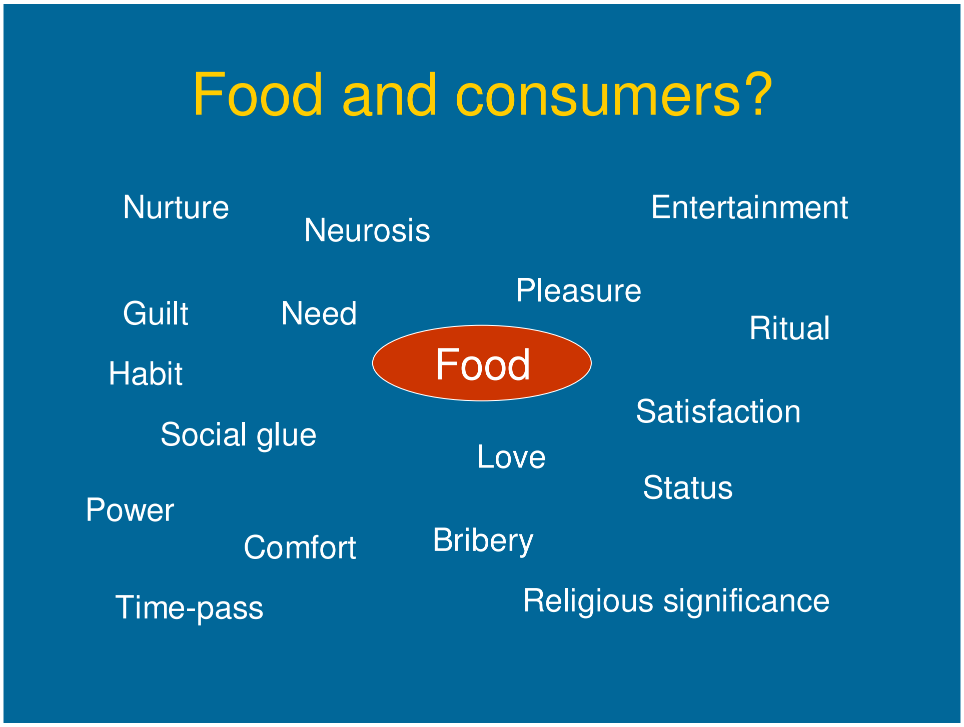
[401] see for example Reisch, L and I Røpke (eds), *Consumption – perspectives from Ecological Economics*, Edward Elgar, Cheltenham, 2005

[402] Michaelis, L., and Sylvia Lorek. 2004. Consumption and the Environment in Europe: Trends and Futures. Danish Environmental Protection Agency, Copenhagen.

[403] Jackson T. Motivating *Sustainable Consumption a review of evidence on consumer behaviour and behavioural change*: A report to the Sustainable Development Research Network, January 2005

Figure 7



Food and dietary change: a view from the health sector

What and how much food people eat is increasingly a matter of concern to public policy makers. Most of the concern has been focused on the effect our eating patterns have had on our health. With the rapid rise in the number of overweight and obese people, health bodies and others are trying to get us to adopt healthier eating habits.

How successful have they been? It might be useful to look at this issue in a little more detail since strategies that have been successful could conceivably be adapted and used to achieve environmental goals.

A very large and comprehensive review commissioned by the Food Standards Agency[404] reviewed a wide range of healthy eating interventions, based in different settings (schools, primary care units, workplaces, supermarkets) adopting a diversity of strategies (from intensive one-to-one advice to more general activities) and targeting people at different life stages – pregnancy, for instance. The study found that many were unsuccessful or achieved very minor (and possibly un-sustained) changes in diet. Some more successful interventions though were found and highlighted. These tended to be projects where there was a supportive environment, where the stakeholders (that is, those who needed to change their eating patterns) were involved in the design and

[404] *A critical review of the psychosocial basis of food choice and identification of tools to effect positive food choice: a summary*, Summary of the Main Findings of the Report Commissioned by the Food Standards Agency, NO9017, British Nutrition Foundation March 2004 http://www.nutrition.org.uk/upload/Food%20Choice(2).pdf

implementation of the project (children in school, employees at work), and where there was an interactive element (cookery clubs). Many of these successful interventions were small and focused on particular subsections of the community. As such it was difficult to see how a scaled up, one-size-fits-all approach would work.

In all then, what emerged most clearly was that it is very difficult to change people's behaviour directly and that successful interventions are few and far between. As regards 'lessons learnt' for the sustainable consumption agenda the only conclusion to emerge is that generic approaches are not helpful and that different strategies are likely to appeal to different people. This has been noted already by others with respect to sustainable consumption.[405]

Is the current system and way of consuming inevitable?

The difficulty of getting people to change is particularly great when it comes to the environment. If people cannot be persuaded to change their behaviour for reasons of self-interest (their health) then the chances of them doing so for the wellbeing of the planet are very slim indeed.

Indeed, according to food industry research, environmental concerns are way down the list of priorities for most people. Most shopping decisions are made on the basis of price, sell-by date and taste.[406] People will not actively choose to 'do without' nor will they buy foods with an environmental edge if they are not as cheap or not as tasty as the mainstream offerings. As such the food industry favours an approach to sustainability whereby the sustainability profile of mainstream foods is improved. In addition alternative choices where these exist may be provided.[407] 'Invisibly' lowering the fat content of a ready meal is an example of the former approach while providing fair trade coffee along side ordinary coffee is an example of the latter. Simply not stocking a product because it is environmentally damaging is rarely considered.[408]

The implication here – and indeed the assumption on which our economy is founded – is that choice is not just a good thing but something that people want. Many environmental organisations have argued that the choice available in supermarkets is illusory[409] [410] and that genuine systemic alternatives are not available. The truth or otherwise of this assertion is not examined in this paper. The purpose here is rather to ask whether people really *do* want choice *per se*, be it the normal or the environmental kind.

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[405] Darnton A. *Driving public behaviours for sustainable lifestyles:* report 2 of desk research commissioned by COI on behalf of DEFRA, 2004 http://www.sustainable-development.gov.uk/documents/publications/desk-research2.pdf
[406] Food Industry Sustainability Strategy, Defra, 2006, http://www.defra.gov.uk/farm/sustain/fiss/fiss2006.pdf
[407] Food Industry Sustainability Strategy, Defra, 2006, http://www.defra.gov.uk/farm/sustain/fiss/fiss2006.pdf
[408] although Marks & Spencer for instance now sources fish almost entirely from the Marine Conservation Society's list of sustainable species http://www.fishonline.org/press_releases/
[409] *Good Neighbours? Community impacts of supermarkets*, Friends of the Earth, 2005 http://www.foe.co.uk/resource/briefings/good_neighbours_community.pdf
[410] give Caroline Lucas ref

There is some research to suggest that in practice we do not appear to want choice as much as might be thought. One study[411] finds that when asked to make food choices for themselves and for others, people tend to assume that others want variety while when making personal choices the choices they make are far less varied. In other words the general assumption is made that choice is 'good' but in practice we may not actually exploit the wide range of choices available to us.

It is interesting to note that a recent report by the IGD finds (problematically for food manufacturers) that new products and innovations may fail because most shoppers take only a passive role when it comes to searching for these new products. Indeed only 7% of us claim to actively seek new products in-store – most of us just buy the same products week in, week out.[412] One might infer from these findings that far from meeting consumers' needs, the food industry is increasingly obliged to create needs. Once again one might conclude that we do not actively want more choice and perhaps we never have.

The problem, then, is less to do with the fact that people want a certain level of choice but that in general when it comes to food, we are creatures of habit. We want what we normally have.

On a larger scale however, while our individual shopping habits may be fairly repetitive, collectively a wide range of foods are bought. I might buy the same things week in and week out and so might you but our 'same things' will be different. As such people take advantage of the choice they have (however this is defined) because they have it. Since there are strawberries available in winter, they will buy them.

But if strawberries were not available in winter, would they miss them?

Some research has suggested that after a period of disruption, people adjust to changes in their circumstances and take their pleasure as they can get it, within the context of their new circumstances.[413] This would suggest that once the initial 'discomfort' of foregoing winter strawberries has passed, people will adjust to their new winter-strawberry-free existence. This view, known as the zero-sum game has its critics.[414] However most of the arguments against the theory focus on major life events such as divorce and bereavement, rather than on the somewhat trivial matter of strawberry availability.

On the other hand it is also the case that following periods of deprivation, people compensate by eating more of the foods that they had previously not been able to enjoy. Sugar consumption – and dental caries – rose dramatically following the end of rationing after the Second World War[415] Clearly people's memories are long and they will go back

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[411] Jinhee Choi, B. Kyu Kim, Incheol Choi, and Youjae Yi. *Variety-Seeking Tendency in Choice for Others: Interpersonal and Intrapersonal Causes*. Journal of Consumer Research, forthcoming, March 2006.

[412] *Innovations*, IGD, 2006 http://www.igd.com/CIR.asp?menuid=33&cirid=1789

[413] Unger, H. F. (1970) The feeling of happiness, *Psychology*, vol.7, p.27—33

[414] Veenhoven R. *Is Happiness Relative?* Social Indicators Research 24, 1991, pp. 1-34

[415] Moynihan P J. *The role of diet and nutrition in the etiology and prevention of dental caries*, Bulletin of the World Health Organisation 2005; 83 694-699, http://www.who.int/bulletin/volumes/83/9/694.pdf

to the consumption patterns they grew up with; consumption is also likely to increase as availability increases. This is not to say that there is a set, pre-defined level of consumption (of sugar or anything else) that people gravitate towards. For example, sugar consumption is to a large extent culturally defined; in affluent countries levels of consumption vary widely, without those who consume lower levels necessarily feeling themselves to be 'deprived.'[416]

There is also much to suggest that the main source of discontent is not lack *per se* but inequality:[417] What makes me unhappy is not that I cannot get hold of strawberries but that you can. Obviously there are basic fundamental needs for safe nutritious food (for example) that need to be met but much of what is considered necessary is relative. This is especially true of food where likes and dislikes are so culturally defined.

Moreover much of what is considered necessary is defined in terms of what one has. One Dutch survey for example[418] asked people which of 11 consumer goods that their households owned they considered to be a necessity. Whether or not consumer goods were perceived as necessities depended to a large extent on whether these goods were owned or not. It may of course be that a family of six is not only more likely to own a dishwasher but also more likely to have reasonable need of it than a dishwasher-less person who lives alone. It is also the case - and this is the point that the study was making - that people end up 'needing' what they have. This suggests and this is a position put forward by others too[419] that need itself may be arbitrary and context dependent.

As such might it be possible to suppose that, just as a luxury ends up becoming a necessity, so (following a period of adjustment) the loss of a 'necessity' becomes less of a loss as time passes? And might it not also be that it is not that a reduction in the availability of certain foods that is the problem *per se* but that the process of change, if not handled correctly, will be uncomfortable?

So is it possible to change consumer behaviour?

Clearly, and as highlighted above, an approach to changing consumption patterns which is based on trying to persuade people to change their behaviour is unlikely to work. The author of one study even goes so far as to suggest that changing attitudes is not particularly necessary, and recommends that '*Policies to drive behaviour change for*

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[416] FAO 2002 data http://faostat.fao.org/faostat/servlet/XteServlet3?Areas=%3E354&Items=2818&Elements=645&Years=2002&Format=Table&Xaxis=Years&Yaxis=Countries&Aggregate=&Calculate=&Domain=FS&ItemTypes=FS.CropsAndProducts&language=EN

[417] Easterlin, R.A. (1974) *Does economic growth improve the human lot? Some empirical evidence.* In: David, P.A. & Melvin, W.R. eds, Nations and Households in economic growth. Academic Press, New York, USA, page 89-125

[418] *Household Consumption, Quality of Life and Environmental Impacts*, Gatersleben and Vlek, in eds. Noorman & Schoot-Uiterkamp '*Green Households'*, 1998 – this was summarised in Darnton A. *The impact of sustainable development on public behaviour*: report 3 of desk research commissioned by COI on behalf of DEFRA, 2004 http://www.sustainable-development.gov.uk/documents/publications/desk-research3.pdf

[419] Hand M, Shove E and Southerton D. Explaining Daily Showering: A Discussion of Policy and Practice, Working Paper Series Number 2003/4, Sustainable Technologies Programme, ESRC http://www.sustainabletechnologies.ac.uk/PDF/Working%20papers/105a.pdf

sustainability should aim to change behaviours, and make changing attitudes a secondary objective.' In other words, his view, based on a review of over 100 studies, was that attitudinal change is not even a prerequisite for behavioural change.[420]

One might also add the very important point that people will change as and when the context (both economic and social) within which they make decisions changes. It is unreasonable to expect that consumers will themselves, on their own initiatives, change.

In short, perhaps the focus should not be on individual people. Perhaps the impetus for changing behaviour must come from somewhere else.

6c. What is the role of the individual in the context of all the fruit and vegetable supply chain?

Much of the debate on sustainable consumption is framed in terms of changing the behaviour of individuals. However, as has just been suggested, perhaps the problem lies with viewing the consumer as the lynch-pin of change.

According to many observers, it is certainly not all up to the consumers. Andrew Flynn *et al* for example[421] argue that retailers, along with producers, manufacturers and processors, and distributors, are involved in *creating* food choices for consumers. They highlight and emphasise the growing importance of private supply chain regulation in helping to modify and structure food choice. For instance, and as has already been highlighted in the earlier sections of this report, supermarkets shape both the varieties of food on sale (consider the rejected brown strawberries in section 5a) and decide what counts as 'quality,' rejecting that which is viewed as sub-standard. Sometimes this impact has been positive. At other times it may be that their overriding emphasis on consistency, uniformity and ubiquity, they have shaped the supply chain in ways that have negative environmental consequences. Of course the situation is not quite as simple as this since, by virtue of what they choose to buy and what they choose to leave behind, consumers give very clear signals to supermarkets as to how they define 'quality.'

Jackson (2005) also finds the notion of 'consumer sovereignty' to be both inaccurate and unhelpful.[422] He argues that policy makers '*are not innocent bystanders in the negotiation of consumer choice. Policy intervenes continually in consumer behaviour both directly (through regulation and taxes for example) and more importantly through its extensive influence over the social context within which people act*.'

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[420] Darnton A. *The impact of sustainable development on public behaviour*: report 1 of desk research commissioned by COI on behalf of DEFRA, 2004 http://www.sustainable-development.gov.uk/documents/publications/desk-research1.pdf

[421] Flynn A, Yakovleva N, Green K and Marsden T. *Consumption and Policy: the case of food, working paper*, undated, available on http://www.fcrn.org.uk/pdf/ken_green_chicken_potato_paper.pdf

[422] Jackson T. Motivating *Sustainable Consumption a review of evidence on consumer behaviour and behavioural change*: A report to the Sustainable Development Research Network, January 2005

It is suggested that government and the food industry need to take far more responsibility for driving forward sustainable consumption than has hitherto been the case. A range of measures are possible, from regulation and legislation, caps, quotas and bans to economic and fiscal instruments, voluntary agreements through to education, marketing, promotion and the nurturing of social pressure. They are not discussed here as they will be addressed further in future papers as part of the FCRN project.

One or two possible measures might be worth highlighting however simply because as concepts they are relatively new and may hold some potential.

The first is the concept of the Domestic Tradable Quota (DTQ). This was an idea initially proposed by the economist David Fleming and has been developed further in a recent Tyndall Centre report.[423] The DTQ is similar in principle to the EU Emissions Trading Scheme but is intended to operate at an individual level. People would be allocated a quota of emissions which they could buy or sell according to their requirements. Food is an area of consumption which could usefully be incorporated into the DTQ once more understanding of the life cycle impacts of food has been gained.

Another possibility to consider is a suggestion made at a recent FCRN seminar focusing on the fruit and vegetable sector.[424] It was proposed that retailers should routinely report on the tonnage of produce they import by air each year. This would appear to be a reasonably simple step for retailers to take. Reporting of this kind would be of interest both to government and to other industry observers such as environmental organisations, and would serve as one measure of sustainability. Publishing their track record in this area also gives supermarkets a collective incentive to reduce emissions either through efforts to develop non-air freighted alternative sources or to work with suppliers to shift existing supplies onto alternative modes. For some supermarkets there may be clashes with other priorities (supporting economic development in the developing world is often mentioned as one of them) but a way forward might be to examine ways in which these goals these might be met without such a grave environmental penalty being incurred.

[423] Starkey R and Anderson K *Domestic Tradeable Quotas: A policy instrument for reducing greenhouse gas emissions from energy use*, Tyndall Centre Technical Report 39, Tyndall Centre for Climate Change, 2005 http://www.tyndall.ac.uk/research/theme2/final_reports/t3_22.pdf
[424] Kath Dalmeny, suggestion made at FCRN fruit and vegetable seminar, Manchester, December 2005.

SECTION SEVEN: CONCLUSIONS

This section tries to draw together some of the observations and findings made in this report. It begins by summarising what we know about the contribution that the fruit and vegetable sector makes to the UK's greenhouse gas emissions. It then goes on to highlight areas where action to reduce emissions might be helpful. Finally it suggests areas where further research is needed.

7a. What do we know about the contribution that the fruit and vegetable sector makes to the UK's greenhouse gas emissions?

Several estimates have suggested that the food chain as a whole has been estimated to account for around a fifth of the UK's greenhouse gas emissions.[425] [426] A recent European study puts the figure for the EU as a whole even higher at 31%.[427] Clearly much depends on what is being considered and the methods adopted.

The evidence from studies also suggests that most of the food chain impacts occur during agricultural production[428] and that this is largely the result of the considerable contribution made by livestock rearing both to agriculture-stage emissions and to food chain emissions as a whole.

It was roughly calculated in this paper that the fruit and vegetable sector accounts for about 2-2.5% of the UK's greenhouse gas emissions or around 10-12.5% of total food-related emissions. These are very approximate figures and far more detailed analysis would be needed to reach a more accurate conclusion. The figures given may, however, serve as a 'good enough' indication of the general magnitude of the contribution.

This said, fruit and vegetable sector impacts may have been underestimated since the focus – owing to lack of fuller data – has largely been on UK horticultural production. For UK grown produce the impacts created during the course of growing, storing, distributing and selling produce in the UK have been considered but quantifying impacts for overseas production is very difficult. For overseas imported produce, the transport impacts are highlighted but overseas production stage, storage-related emissions and waste levels have not been properly quantified, since the data are not available. As our self sufficiency in vegetables and particularly fruit is so low, the picture that emerges of overall impacts is therefore very partial.

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[425] Achieving the UK's Climate Change Commitments: the efficiency of the food cycle, e3 Consulting, 2002
[426] Garnett T, *Food and Climate Change - from plough to plate to bin and beyond; food, climate change and life cycle analysis*, presentation given on University of Surrey Life Cycle Analysis Msc course, January 12 2006, University of Surrey, Guildford.
[427] *Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25*, European Science and Technology Observatory and Institute for Prospective Technological studies, full draft report, April 2005
[428] Krutwagen B, Lindeijer E. LCI of food in the Netherlands, IVAM Environmental Research, paper in International Conference on LCA in Foods – Proceedings, Swedish Institute for Food and Biotechnology (SIK), Gothenbury, Sweden, 26-27 April 2001.

The contribution that the fruit and vegetable sector makes to food chain emissions may well be growing. This is mainly because of changes in the types of fruit and vegetables that we are consuming, the most notable being our growing preference for Mediterranean style and air freighted produce.

Air freighted produce is particularly greenhouse gas intensive. Although at present the proportion of our food which travels by air is low, fruits and vegetables account for the majority of foods that travel in this way, and growth in air freighted fruits and vegetables is more rapid than general growth in the import of fruit and vegetables.

'Mediterranean style' vegetables also carry with them a high energy burden. These foods are mainly grown in Spain (where, as discussed, energy impacts may be greater than many studies have suggested) or grown in energy intensive heated greenhouses here as well as, it should not be forgotten, in the Netherlands. A very small proportion is also air freighted.

Another aspect of note for the fruit and vegetable sector is its reliance on cold storage. Cold storage makes a small but nevertheless note-worthy contribution to the UK's total greenhouse gas emissions and as a perishable food stuff, fruit and vegetables may account for a significant share of cold chain energy use.[429] Fruit and vegetables are, on the whole, kept in some form of cold storage from the point of production through to the point of consumption. Some varieties of fruit and vegetable will be more refrigeration-dependent than others.

Fruit and vegetables that have been processed or pre-prepared in some way, such as bagged salads, fresh fruit salads, topped and tailed beans and other trimmed vegetables aer particularly cold-chain dependent. Such foods are more vulnerable to damage and spoilage and as such require more refrigeration at all stages in the supply chain. Demand for these foods is growing and most of the growth in fresh produce (particularly for vegetables) over the next few years will come from this sub-sector of the market.

In all then, the likelihood is that dependence on commercial cold storage and temperature-controlled transport will grow slightly over the next few years. An increase in demand will be offset by significant improvements in energy efficiency but the extent to which savings will be sufficient to meet the need for stringent cuts in food chain emissions is unclear. As regards domestic refrigeration, while improvements in energy efficiency have already been made, these improvements have been almost entirely cancelled out by the increase in the average size of our fridges and in the number of fridges per head of population.

There is also a close relationship between transport and refrigeration, and increased dependence in one of these areas is likely to increase dependence in the other; sourcing from further afield will, for example, mean a longer time spent in mobile cold storage. Cold storage fosters and makes possible the development of longer supply chains.

There is also a relationship between waste and cold storage. While cold storage is energy intensive, it also helps reduce the amount of food that is spoiled and needs to be thrown away. It does not automatically follow, however, that more cold storage (or

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[429] Further research is needed to establish other intensive refrigeration units with meat, dairy and fish products likely to feature strongly

indeed further technological measures to reduce waste) will lead to reductions in waste. The amount of food that is thrown away may have more to do with our attitudes towards fruit and vegetables and towards waste than to the actual physical spoilage of the produce.

Waste was in fact the final major impact area highlighted in this paper. Wasted food is, in effect, a waste of all the energy that goes into producing, storing and transporting the product. Around a quarter of all produce grown ends up as waste. Most waste occurs at the household and food service stages but significant wastage also occurs elsewhere in the supply chain.

Much waste, particularly at the field and the retail stages, may occur as a result of societal definitions of 'quality.' Stringent supermarket standards governing size and appearance means that much edible produce is simply rejected. Consumers in turn reject produce in store which does not appear to be perfect, as they see it. It appears that supermarkets and consumers together ratchet up 'quality' standards beyond levels required to safeguard nutritional content or food safety.

Cooking was also examined and it appears that this is not a major impact area intensive stage because fruits and vegetables tend not to be cooked for very long, or indeed at all. This said, there can be huge variation in the energy intensity of different cooking techniques. A focus on energy efficient cooking across all food groups might help reduce demand for energy at this stage in the life cycle.

Perhaps what has emerged most clearly from this paper is the interconnectedness of the various life stages and particularly the complex relationships among waste, transport and cold storage. It has proved very hard, and beyond the scope of this paper, to explore what might happen to emissions elsewhere if action were taken to reduce impacts in one area (storage, for instance), but it is suggested that this could prove a very useful subject for research.

It might be worth pointing out (perhaps obviously) that any research findings that do emerge are only part of the story. The challenge for a policy maker is to know what to do with the knowledge. For example, if, as is probable, less stringent cold storage conditions in transport lead to more transport related waste, one policy approach might be to promote improved but more energy efficient cold storage technologies. Another approach might be to combine the emphasis on cold storage efficiency with measures to foster shorter supply chains. Of course if the latter approach were adopted the policy maker would need to take into account mode of travel – will road be substituting for sea, or vice versa? This will have implications both for transport emissions (the intensity of road travel is greater than that of sea travel) and for cold storage (on the other hand more time is spent in storage at sea than on the road).

Another finding which emerged implicitly if not explicitly is that once attempts are made to calculate the share a particular sector, or particular life stage makes to greenhouse gas emissions, the figures tend to separate out and dwindle down. The food chain is so very complex and there are so many different life cycle stages and food types to consider that once one begins to look at the impact of a certain category of foods the numbers being considered are actually very small. This unfortunately makes it difficult either to make a valid case for investing in measures that will reduce these emissions (the 'it's hardly worth the trouble' argument) or to put the measures in place once a decision has been made to do so. The sector is very large, employs a great many people and is global in its reach.

This paper has highlighted where the general hotspots in the fruit and vegetable sector are likely to be. It has also explored whether some fruits and vegetables can be considered to be particularly energy intensive. The tables in section three sought to classify produce according to whether they were high, medium or low in their greenhouse gas intensity. These tables should be seen as a starting point for discussion only and, with greater knowledge, may well need modifying.

Air freighted and Mediterranean style vegetables were put in the high-GHG category, with air freighted goods carrying the highest GHG burden.

Produce which is fairly robust and withstands storage conditions well without spoilage, was classed as low in GHG intensity. This category includes produce such as root crops and tubers, brassicas, and staple fruits such as apples, bananas and citrus fruits.

The 'medium and unknowns' category includes produce about which little is known as well as foods which for various reasons cannot be classified as low in GHG intensity. Possible greenhouse gas intensive characteristics include a propensity to spoil, a need to be stored at very low temperatures, or the fact that 'top ups' are frequently brought in by air. Further work on this category is particularly needed.

One useful indicator of the likely GHG intensity of a particular fruit and vegetable might be its perishability. Perishable produce is more likely to require low cold storage conditions. It will have a short life which means that if it comes from overseas it is more likely to need to travel by air. Perishable produce is more prone to spoilage and rotting and as such a relatively high proportion will be wasted. Foods that have been cut or prepared in some way (and are therefore relatively energy intensive at the processing stage) will also be more prone to spoilage and also refrigeration-dependent. As such they also are likely to rank as energy intensive.

7b. What do we know about ways of reducing greenhouse gas emissions from the fruit and vegetable sector?

There is considerable scope for improving the efficiency of glasshouse horticulture and of refrigeration (both stationary and mobile). Measures to extend the growing season of some popular crops (such as raspberries) in order to improve the position of UK growers relative to their overseas competitors will also be helpful.

Improvements in transport efficiency are particularly problematic. The medium-term technological potential for reducing transport related emissions is limited and growth in absolute distances travelled (and the growth in air freight) are likely to outstrip any savings made.

A shift towards greater self sufficiency may well lead to a reduction in transport related emissions and – perhaps more importantly still – help curb the growth in long distance transport. This is particularly important given the difficulties entailed in improving the energy efficiency of transport. However an increase in UK production and the extended storage of UK produce may lead to overall increases in cold storage energy use as well as greater levels of waste. Total self sufficiency (even if this were possible) is unlikely to be 'the' optimal answer and a balance will need to be struck between transport and mobile cold storage emissions on the one hand and waste and cold stationary storage emissions on the other. Of course, recommendations for greater self sufficiency not only fly in the face of current trends but also raise many, many questions about the economic competitiveness of UK growers as compared with growers overseas. This is evidently a crucially important subject which, unfortunately, it was not possible to examine in this paper. It was also noted that longer storage life is likely to lead to changes in product quality which – as it stands – consumers may find unacceptable. This raises questions about what we eat, what we want to eat, and who influences both of these.

As regards waste, particularly at the domestic stages, technological measures alone (such as improved packaging and extended storage life) are unlikely to reduce waste. A more fundamental approach which addresses our attitudes to and behaviours around waste is needed.

Indeed our behaviours around food in general demand further attention. We examined how far changes in what we consume (rather than simply how efficiently it reaches our plates) might help reduce greenhouse gas emissions.

Perhaps the most important change for our diet as a whole would be a shift to eating fewer meat and dairy products. These foods are responsible for the emission not just of fossil-fuel related CO_2 but also of nitrous oxides and methane which have a more intensive global warming potential than CO_2. However a vegetarian diet is not always better since some fresh produce carries with it a high energy burden.

The issue of dietary change is also relevant to healthy eating objectives. Government wants us to eat more fruit and vegetables and we considered whether an increase in fruit and vegetable consumption (as opposed to a deliberate effort to reduce meat and dairy consumption) would have an effect on overall food chain GHG emissions. Would there be a substitution effect? In other words, by eating more fruit and vegetables, would we eat fewer of other foods, leading to an overall reduction in emissions from those other foods?

Moderate increases in fruit and vegetable intake to around five a day would be unlikely to generate a substitution effect. However a *substantial* increase in fruit and vegetable consumption might produce this substitution effect and this in turn could decrease emissions from other food sectors. Whether overall emissions from the fruit and vegetable sector would increase a little, substantially, stay the same or decline depends not just on how much fruit and vegetable intakes increase but also on the *kinds* of fruits and vegetables which are eaten. Less meat but more air freighted produce may well not lead to reductions in food chain GHG emissions.

Government health policy is not specific in its recommendations; an increase in our consumption of a wide range of fruit and vegetables is advised but the environmental implications of various food choices are not mentioned. Health policy in this respect appears to be un-linked to any environmental goals that government might have for the fruit and vegetable sector.

We asked whether it was actually possible to get people to change; what people could do in theory, and the likelihood of them doing it in practice, are two very different matters indeed. Based on the evidence, awareness raising and campaigns that seek to appeal to people's sense of reason or altruism are likely to achieve very little. People are motivated to consume for a wide variety of complex and frequently irrational reasons. Consumption is not just about satisfying needs but also about economic, social and emotional self expression and – importantly – about habit. We consume the way we do because we always have.

This does not mean that behavioural change is either unnecessary or impossible. Change is certainly necessary and probably possible. The problems with efforts to tackle consumer behaviour arise precisely *because* they are aimed at tackling consumer behaviour. Consumers' behaviour is the outcome of a mesh of societal and institutional circumstances and rather than focusing on changing their behaviour – the effects - it is more helpful to address the societal and institutional circumstances that have shaped the behaviour in the first place – in other words the causes. The consumer, customer, individual, citizen, or whatever one might wish to call us, will change when the circumstances change. People are adaptable, tastes are to a very large extent arbitrary, and coordinated and concerted action together by supermarkets, other sections of the industry and government could achieve changes in what and how people consume. Moreover, as with the technological dimension, there is unlikely to be one single, simple action that could suddenly achieve drastic reductions.

To conclude, the fruit and vegetable sector contributes a small but important amount to the UK's overall greenhouse gas emissions. Many of the trends in the way the fruit and vegetable market is developing are unsustainable and the sector is of interest because it serves as a marker of our consumption of other foods and perhaps of our lifestyles in general. More work needs to be done to examine in greater detail the impacts of this sector and the scope for emissions reduction. Reductions are likely to be achieved through a mixture of technological improvements and behavioural change and should be approached in the context of overall efforts to reduce greenhouse gas emissions from the food sector.

7.c Recommendations

The Domestic Tradable Quota, a scheme similar in principle to the EU Emissions Trading Scheme holds great promise. Individuals are allocated a quota of emissions which they can buy or sell according to their requirements. Policy makers should focus serious attention on developing a workable scheme for use in the UK. Food is an area of consumption which could usefully be incorporated into the thinking on DTQs and further research into how this might be achieved should be undertaken.

Greater focus on air freight and measures to curb the growth in goods transported by air is required. For retailers, one practical and simple step they should take is to routinely report on the tonnage of produce they import by air each year.

Further efforts to improve refrigeration efficiency at all stages in the supply chain and particularly in mobile units

Further work is also needed to tackle the problem of domestic food waste. The work of WRAP is encouraging and needs to be further supported. Retailers have a role to play in highlighting to their customers the environmental consequences of food waste.

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