



Cooking up a storm

Food, greenhouse gas emissions
and our changing climate

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ABSTRACT

The subject of this report is food and its impact on the climate. We set out what we know about the food system's contribution to greenhouse gas (GHG) emissions and how they arise. We look at the technological, behavioural and policy options for reducing food emissions and highlight where the gaps in our knowledge lie. Finally we offer our conclusions and recommendations.

The food system as a whole contributes around 19% of the UK's GHG emissions, whether measured as a proportion of emissions generated within UK borders, or as a percentage of total UK consumption-related emissions. For the former, we calculate GHGs arising from food produced within UK borders as a percentage of total UK production-related emissions; for the latter, we include the embedded GHGs in the foods we import and measure them as a percentage of the emissions generated by the UK's consumption and use of all goods and services, whether indigenously produced or imported.

We adopt a life cycle perspective, considering the GHG impacts of the food chain in its entirety, from the process of, and inputs to, agricultural production through manufacturing, transport, retailing, consumption in the home and waste disposal. We find that agriculture accounts for around half of food's total GHGs with the impacts largely attributable to methane and nitrous oxide, both potent GHGs. Direct energy use and fertiliser production make smaller, but significant, contributions. Importantly, our calculations do not take into account emissions arising from deforestation or other changes in land use overseas that are caused by farming to produce food for our direct consumption and feed for our livestock. If these were included the figures would likely be much higher. The remaining 50% of food GHGs are fairly evenly distributed among the manufacturing, retailing, transport, catering and domestic stages.

When we consider the food chain's impacts by food type, we find that meat and dairy products account for around half of food's total GHG emissions. Most of these impacts arise at the rearing stage. Hence the major contribution made by agriculture itself reflects the GHG intensity of livestock rearing. With global demand for animal-source foods set to double by 2050 the implications for GHG emissions are profound. Other foods, such as fruit and vegetables, and alcoholic drinks, make smaller contributions to overall emissions but consumption trends within these categories indicate that we are moving in more GHG-intensive directions.

Reviewing the technological potential for reducing food GHGs we conclude that much can be achieved at every stage in the supply chain through better management and the deployment of efficient and renewable technologies. However, technological developments on their own are not enough since they do not address trends in our consumption that are inherently GHG-intensive. Changes in behaviour – in what and how we eat – are essential. As priorities, we need to reduce our consumption of meat and dairy foods, to eat no more than we need to keep ourselves healthy, to limit consumption of food that is of little nutritional value, and not waste food. Efforts to encourage us voluntarily to change will not achieve what is needed in the time available. Regulatory and fiscal measures that change the context within which we consume are vital. There are potential synergies between the goals of reducing food GHG emissions and improving our nutritional health, and policies should be developed to exploit these.

We conclude with recommendations aimed at government, the food industry, and the non-governmental community, as well as suggestions for further research. In particular we urge the UK Government to commit to achieving a 70% or more absolute reduction in food-related GHG emissions by 2050 and to set out how it intends to achieve these cuts. We also urge government to take a global lead in developing and defining food security strategies that explicitly marry the goals of nutritional well-being with GHG mitigation. It should advocate these strategies to international UN bodies, and through international fora such as the G8 Summit and the 2009 UN climate change conference in Copenhagen.

INTRODUCTION: STRUCTURE, PURPOSE AND METHOD

Everything should be made as simple as possible, but not simpler.
Albert Einstein

The subject of this report is food and climate change. The purpose is to set out the ‘state of play’ as regards our understanding of the food system and its contribution to greenhouse gas (GHG) emissions. We look at what we know about ways of reducing food related emissions, the measures that we as a society need to take, and where the gaps in our knowledge lie.

Its main focus is on food consumed by UK citizens. We look at impacts associated with our consumption of all food types, whether produced domestically or imported from other countries. Since we import (in net terms, by value) around 51% of the food we eat,¹ this consumption-oriented perspective gives a more accurate picture of our impacts than one which considers only the UK’s production-related emissions. We define consumption and production based emissions more fully in section two and, for reference, in the glossary.

The report begins with a brief overview of the scientific consensus on climate change, its causes and its possible impacts over the coming years (Section 1). We highlight the international and national agreements in place that are intended to tackle the problem.

In Section 2, the focus turns specifically to food; we give an overview of studies that have sought to quantify the food system’s contribution to climate changing emissions.

Section 3 considers impacts by life cycle stage (from plough to plate to bin) in more detail, showing how they are distributed along the supply chain. In Section 4, we consider impacts by food type, based on the partial analysis we have undertaken so far.

Section 5 considers the flip side of the coin – the potential impact of a changing climate on the food supply system. Given the global reach of our supply chains and the moral imperative to consider the impacts of climate change on those most likely to suffer them, we look at the global, rather than just the UK picture.

In Section 6 we discuss some of the challenges the life cycle approach raises for policy making. This prepares the ground for Section 7, which explores what we might do to reduce food GHG emissions through technological and managerial means. Can greater efficiency and innovation enable us to reach an 80% reduction in carbon dioxide (CO₂) emissions by 2050? We identify some of the technological options that have been proposed, or are being implemented, for reducing food chain impacts, giving examples of steps taken by the food industry. Although we look broadly at all stages in the supply chain, particular focus is placed on livestock related emissions, food refrigeration, and transport – since these are areas where we have focused most of our attention.

We then move on to consider the behavioural dimension, asking whether, in addition to technological measures, we may need to reconsider what and how we consume (Section 7). We explore what a low GHG way of consuming looks like, what challenges it poses to our

¹ Origins of food consumed in the UK: 2006, Table 7.5, Chapter 7, *Agriculture in the United Kingdom*, 2007, Defra.

current patterns of living, and the extent to which behaviour change actually has the potential to achieve measurable emission reductions (Section 8). We also ask how far a changed pattern of eating is compatible with the food industry's current core business values and practices. Finally we examine the sustainable consumption agenda from an international perspective, asking whether changes in how and what British citizens consume will actually affect global emissions.

Section 9 considers the relationship between GHG reduction and nutritional health, exploring where the synergies and conflicts might lie.

Section 10 reviews the food policy context, highlighting UK and EU policies that have a bearing on food related GHG emissions and examining how far these policies are sufficient or appropriate.

Finally, in Section 11 we offer some observations, conclusions and recommendations.

The report focuses only on food's contribution to GHG emissions. It does not discuss the relationship between the way we grow, distribute, sell and consume food and the many other extremely important environmental challenges we face, such as air and water pollution, or the impacts on biodiversity and water availability. Nor does it offer an analysis of the other social, cultural and economic dimensions of sustainability as they relate to food. These are indeed limitations but the relationship between food and climate change is already enormously complicated and its analysis represents sufficient enough challenge, at least for this particular researcher. We hope that by shedding some light upon the food – GHG relationship, those wanting to take a more multidimensional approach will find that some of the climate-related groundwork has already been done.

Method

This report draws upon and synthesises the findings of four earlier FCRN studies, each of which focused on particular aspects of food and its impacts: alcoholic drinks;² fruit and vegetables;³ meat, dairy and other livestock products,⁴ and food refrigeration.⁵ This report and the previous studies are all based on extensive reviews of the literature from fields as diverse as life cycle analysis (LCA), ecological economics, international development, and the sociology and psychology of behaviour. We also base our analysis upon the insights gained from five workshop seminars⁶ that brought together stakeholders from the food industry, government, universities, non-governmental organisations, and consultancies to share knowledge and expertise. Four of these events were undertaken to inform the content of the other studies, while

² Garnett, T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

³ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

⁴ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

⁵ Garnett, T. (2007) *Food refrigeration: What is the contribution to greenhouse gas emissions and how might emissions be reduced?* A working paper produced as part of the Food Climate Research Network

⁶ Focusing respectively on alcoholic drinks, fruit and vegetables, food refrigeration, meat and dairy products, and food climate policy.

the fifth explored the policy context within which food and its impacts are situated and yielded insights that inform this report.

Finally, and importantly, this paper draws upon the knowledge gained and shared during the course of establishing and running the Food Climate Research Network (FCRN). This initiative, which began four years ago in 2004 has, among other things, built up a network of around 1,000 individuals (and growing)⁷ drawn from a diversity of sectors – research institutions, the food industry, government and non governmental organisations – and who collectively embody expertise in a wealth of disciplines and interest. A final draft version of this report has been reviewed in some considerable depth by around 38 people representing this broad cross section and is thus heavily indebted to the insights and critiques that have been offered. However, while a huge number of individuals and organisations have helped during the course of writing this report, no one has formally endorsed (or indeed rejected!) its findings, nor has anyone been asked to do so. The network is just that – a network, not formally constituted group. The pronoun ‘we’ is used throughout these pages, but this is merely a literary convention.

Certain methodological approaches are taken both in this report and in the earlier studies. The main characteristic is synthesis – the integration of different disciplinary perspectives and insights to explore and address the multi-dimensional challenges posed by climate change and the contribution made by food. The goal of achieving ‘sustainable development’ requires nothing less than this. While primary research in all areas of the food chain will always be essential, there is also a strong need for analysis that brings different areas of knowledge together, considers their interrelationships and assesses what we can make of what we have so far. We hope that this, and the earlier FCRN papers, make some contribution towards this approach.

In particular we identify critical or nodal points where climate change impacts interact with other concerns, including international development and human nutrition. These nodal points represent a form of critical focus, where policy must integrate potentially conflicting moral concerns involving multiple stakeholders.

A further specific methodological characteristic of the FCRN approach is to integrate technological with more sociological perspectives on how people actually behave. In other words, we explore how technologies evolve over time, how these relate to and shape people’s behaviour and what the implications might be for future energy use and energy dependency at a system level. This approach falls outside the scope of LCA itself.

Who is this document for?

This report is aimed at various audiences.

Firstly, we hope that it will be of some use to decision makers in government or in industry who want to gain an overview of the food-climate issue as a whole, prior to developing policy in a specific area. Without an understanding of the bigger picture, specific measures may be ineffective, or indeed counterproductive. The report also sets out conclusions and recommendations that are specifically intended for their consideration.

Secondly, the intention is that researchers with expertise in a particular area can see how what they do fits into the wider picture and how, in the light of this broader context, they might wish to

⁷ As of September 2008.

direct the future course of their research. They may also find that material provided in this report triggers questions that may prompt them develop research projects.

Thirdly, the document is intended to inform campaigning organisations who wish to influence policymaking; we hope this report provides a useful (and impartial) source of information.

Finally, the document is for me; it serves as a dumping ground for the knowledge and insights I have gained during the first three years of running the FCRN. Having produced this report, my intention is to move into more specific areas of research, more particularly to continue further work on livestock within the context of climate change, international development, and food security.

TERMINOLOGY AND ABBREVIATIONS

Cauliflower is nothing but a cabbage with a college education.

Mark Twain

Carbon dioxide equivalent (CO₂e): This is the universal unit of measurement to indicate the global warming potential of GHGs, expressed in terms of the global warming potential of one unit of carbon dioxide. Over 100 years, CO₂ has a global warming potential (GWP) of one. The GWP of CH₄ has variously been given as 21, 23 or 25. The latest IPCC report gives the latter figure.⁸ For nitrous oxide (N₂O) the GWP has been given as 296 or 298, with the latter used in the latest IPCC report. Some gases used as refrigerants can have global warming potentials many thousands of times greater than CO₂. Note that in this and other FCRN reports, GWP values of 21 for CH₄ and 296 for N₂O are used, since these were the values given at the time of writing the working papers, upon which this synthesis report is based. The more updated figures do not affect the broad findings of this report.

C3 and C4 photosynthetic pathways: C3 and C4 plants differ in how and when they fix carbon. Most plants (over 95% of all species), including major crops such as wheat, barley, potatoes and sugar beet, use the C3 photosynthetic pathway. C4 photosynthesis is an adaptation to arid conditions which results in a more efficient use of water. The C4 pathway requires the expenditure of some additional energy but under hot and dry conditions, the ability of C4 plants to avoid photorespiration more than offsets the additional energetic costs of this pathway. Examples of C4 plants include maize, sugar cane and sorghum.

CH₄: Methane

CO₂: Carbon dioxide

Consumption-based emissions: A consumption-based calculation quantifies all emissions produced as a result of a nation's consumption. In other words it includes the embedded emissions in all goods imported (from steel, to bananas to flip-flops) and excludes the embedded emissions in products that the country exports.

Environmental input-output analysis: Economic input-output models describe the flows of goods and services within and between productive sectors (industries) and final demand sectors (households, government, exports, etc.) of an economy. Environmental input-output models additionally describe the inputs of various natural resources, including energy, and/or outputs of various emissions and wastes by each sector.

GHGs: Greenhouse gases. See also Kyoto Basket.

⁸ Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and Wratt, D. (2007) Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Global Warming Potential (GWP): This is used to compare the abilities of different GHGs to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide (CO₂), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) relative to that of CO₂. The GWP enables the emissions of various GHGs to be converted into a common measure, which is often referred to as the carbon dioxide equivalent (CO₂e).

IPCC: Intergovernmental Panel on Climate Change.

Kyoto basket: The Kyoto Protocol covers a basket of six GHGs produced by human activities: CO₂, CH₄, N₂O, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Life cycle analysis/assessment (LCA): This is a process for evaluating the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; assessing the impact of those energy and materials used and releases to the environment; and identifying and evaluating opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing the extracting and processing of raw materials; manufacturing, transportation and distribution; use, re-use and maintenance; recycling, and final disposal. The International Organisation for Standardisation (ISO), a world-wide federation of national standards bodies, has standardised this framework within the series ISO 14040 on LCA.

Opportunity cost: This essentially offers a 'what if?' perspective, and is a feature, albeit in limited form, of some consequential LCAs. For land, for example, it refers to the cost of forsaking the benefits of using land for one purpose by using them for another.

Organic agriculture: This is defined by the International Federation of Organic Agriculture Movements as follows: '*Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.*' In Europe, organic farming is regulated by EU regulation 2092/91 (to be replaced by 834/2007 in 2009). This sets out strict rules governing inputs and practices allowed and requires annual inspections of production units and processing plants by independent certification bodies.

N₂O: Nitrous Oxide

Nutrition transition: A phrase used to characterise both qualitative and quantitative changes in the diet. Societies undergoing the nutrition transition tend to move from diets that are predominantly unrefined and grain based towards those where foods of animal origin, and energy dense processed foods dominate. These diets are generally high in fat, sugar and other refined carbohydrates, and are often accompanied by broader changes in how people live, particularly a move towards more sedentary lifestyles. Societies that have undergone this nutrition transition experience increases in the incidence of obesity and in non-communicable diseases such as heart disease, diabetes and diet-related cancers. However mal- and under-nutrition can also be a problem since food may, in these societies, still be unequally distributed.

Parts per million (ppm): The ratio of the number of GHG molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a GHG per million molecules of dry air. Often the ratio is expressed in terms of volume and since the molar volumes of all gases are virtually the same, it comes to the same thing.

Production-based emissions: GHG emissions produced as a result of activities within a nation's boundary. These emissions are recorded in the nation's national Greenhouse Gas Inventory and reported to the United Framework Convention on Climate Change. A nation's progress in meeting its Kyoto targets is measured in terms of its production-based emissions.

Second order impacts: These become apparent once one moves away from a 'snapshot' atemporal analysis of GHG impacts towards a more dynamic exploration of systemic change. Second order impacts include, for example, the CO₂ emissions resulting from land use change. A 'straight' LCA will quantify emissions arising from the production of a crop but it will not necessarily capture the possibility that pasture or forest land may have been cleared for feed cultivation and that this change in land use has caused a one-off release of CO₂. Similarly, a life cycle comparison of imported versus domestically produced produce may not take into account investment in transport and associated infrastructure that may result from increasingly globalised supply chains.

UNFCCC: United Nations Framework Convention on Climate Change.

1. CLIMATE CHANGE: IMPACTS AND POLICIES

*listen: there's a hell
of a good universe next door; let's go
e.e.cummings, pity this busy monster, manunkind*

The aim of this section is simply to provide some context. We set out in brief why climate change is a problem, and what the UK government and the international community are doing to address it. This sets the scene for the main focus of the report, which is to examine the contribution that the food system makes to climate changing emissions, and the options for reducing them.

1.a. The science

The climate is changing and most of the change is caused by human activity. The latest (2007) report by the Intergovernmental Panel on Climate Change (IPCC) concludes that 'Warming of the climate system is unequivocal...' It states that 'Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely*⁹ due to the observed increase in anthropogenic greenhouse gas concentrations.'

In the last 100 years we have seen a global rise in temperature of 0.74°C. Eleven of the last twelve years (1995–2006) have been the warmest since records began in 1850.¹⁰ We are also experiencing a rise in ocean temperatures, rising sea levels, faster than average warming in the Arctic, ocean acidification, an increase in the intensity of extreme weather events and shifts in the life cycles of plant and animal species.

What is more, according to the IPCC's 2007 report, under business-as-usual scenarios (its AIB storylines),¹¹ we are likely to see a temperature rise of about 3°C by 2100 relative to the end of the twentieth century, within a possible range of 2 to 4.5°C.¹²

It is generally accepted that a rise of 2°C above pre-industrial levels, equivalent to a concentration of CO₂e in the atmosphere above 450 parts per million (ppm), delivers the probability of 'dangerous climate change'.¹³ If this were to occur we could experience major irreversible system disruption, with hypothetical examples including a sudden change in the

⁹ It defines this as 'over 90% certainty'.

¹⁰ IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7–22.

¹¹ N. Nakicenovic and R. Swart (Eds.) (2000) IPCC Special Report on Emissions Scenarios, IPCC, Cambridge University Press, UK.

¹² IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007) Edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Cambridge University Press, Cambridge, UK, 7–22.

¹³ *Avoiding Dangerous Climate Change* (2006) Edited by H.J. Schellnhuber, W. Cramer, N. Nakicenovic, T. Wigley and G. Yohe, Cambridge University Press.

Asian monsoon or disintegration of the West Antarctic ice sheet.¹⁴ Note that even at 450 ppm there is only a 50% chance of keeping the temperature rise to 2°C or lower.¹⁵

Even if the world stopped emitting any more GHGs as of now, we would still be ‘committed,’ due to time lags in the earth’s climate mechanisms, to a rise of 1°C by the end of the century (or 0.1°C per decade). This, then, leaves us with very little room for manoeuvre. Indeed, if we are to keep the global concentrations of greenhouse gases in the atmosphere to below 450 CO₂e ppm, and bearing in mind that the developing world economies need to grow so that their citizens can attain an adequate standard of living, then the developed world as a whole needs to reduce its emissions by 80%¹⁶ or more. The IPCC’s Fourth Assessment report says that a reduction of up to 95% may even be needed.¹⁷ Critically, we also need to be taking steps to reduce our emissions right now; the longer we put off taking action, the harder it will be to keep emissions beneath the 450ppm threshold.¹⁸

1.b. The policy context

The international community accepts that climate change is happening and that a sufficient policy response is needed – hence the United Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. This last is the most significant international agreement so far, and has been signed and ratified by the vast majority of countries, with the notable exception of the United States. In accordance with this Protocol, rich nation signatories (known as Annex 1 countries) who collectively account for approximately 60% of global emissions, are committed to reducing their emissions by 5% (on average) from 1990 levels by 2008–2012, although country-specific reductions vary. Developing countries are not obliged to reduce their emissions – a now major bone of contention in the context of rapid industrialisation in China, India and other emerging economies.

The EU (now with 27 members) counts as one signatory, and is committed as a whole to reducing its emissions by 8% on 1990 levels. Individual EU member states have individual targets within this overall objective, the UK’s being to reduce its GHG emissions by 12.5% by 2008–2012. Whether the EU actually achieves its targets (and it is now somewhat late in the

¹⁴ Schneider, S.H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C.H.D., Oppenheimer, M., Pittock, A.B., Rahman, A., Smith, J.B., Suarez, A. and Yamin, F. (2007) Assessing key vulnerabilities and the risk from climate change. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.)] Cambridge University Press, Cambridge, UK, 779–810.

¹⁵ *Avoiding Dangerous Climate Change*. International Symposium on the Stabilisation of greenhouse gas concentrations, Hadley Centre, Met Office, Exeter, UK, 1–3 February 2005.

¹⁶ Government proposals for strengthening the Climate Change Bill, Defra, February 2008

<http://www.defra.gov.uk/environment/climatechange/uk/legislation/pdf/govt-amendment-package.pdf>

¹⁷ Gupta, S., Tirpak, D.A., Burger, N., Gupta, J., Höhne, N., Boncheva, A.I., Kanoan, G.M., Kolstad, C., Kruger, J.A., Michaelowa, A., Murase, S., Pershing, J., Saijo, T. and Sari, A. (2007) Policies, Instruments and Co-operative Arrangements. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

¹⁸ Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK. (Although the Stern review takes as its threshold the higher CO₂e level of 550ppm – the adequacy of this figure has been increasingly called into question and is currently the subject of UK Government scrutiny).

day) very much depends on the extent to which measures that member states have planned are actually implemented.¹⁹

Although the UK is largely on track to meet its Kyoto obligation it has also set itself a domestic CO₂-only target of cutting emissions by 20% by 2010. This it is almost certain to miss, and indeed CO₂ emissions have been rising slightly in recent years, until falling by an almost insignificant amount (0.1%) between 2005–6.²⁰ It is important to note that the UK's reported emissions to the IPCC quantify impacts associated with *domestic* production and activity. They do not take into account emissions associated with the consumption of goods and services not produced in the UK, nor international shipping and aviation, since these do not belong to any particular land area. They do not take into account the fact that if we import more and produce less, this will be reflected in the GHG inventory as a decline in emissions.

Recent research in fact suggests that our embedded emissions – emissions associated with our consumption of goods and services – are actually growing. One study estimated total UK consumption-related emissions (including those from transport, tourism and the embedded impacts of imports) to be around 300 million tonnes of carbon equivalent, approximately 67% higher than the reported 2003 emissions.^{21,22} and 18% higher than 1990 figures. A report by the National Audit Office estimates consumption-based emissions in 2005 to be 12% higher than those reported.²³ Detailed calculations by Druckman *et al.* estimate carbon (only) emissions in 2004 to be 23% higher than the 1990 baseline, at 199MTC, and 30.5% higher than those for 2004.²⁴ These calculations are used as the basis for calculations given in this report. Note that Druckman's figures are currently being revised and are likely to be higher still.²⁵

At an EU level, in January 2008, the European Commission announced a package of legislation aimed at delivering a 20% cut in GHG emissions by 2020, a central plank of which will be the extension and strengthening of the EU Emissions Trading Scheme. The target itself has been criticised as insufficient and indeed at the United Nations Climate Change Conference (UNCCC) held in Bali at the end of 2007, the European Commission had itself proposed that developed countries should collectively reduce their emissions by 30% and that the EU would work to achieve this target, provided that other industrialised nations did too.^{26,27}

¹⁹ *Greenhouse gas emission trends and projections in Europe 2007: Tracking progress towards Kyoto targets*, EEA Report No 5 2007, European Environment Agency, 2007.

²⁰ *Statistical Release: UK climate change sustainable development indicator: 2006 greenhouse gas emissions, final figures*, Defra, 31 January 2008 <http://www.defra.gov.uk/news/2008/080131a.htm> accessed 5 February 2008.

²¹ Helm, D., Smale, R. and Phillips, J. (2007) *Too Good To Be True? The UK's Climate Change Record* 10th December 2007, paper published by Dieter Helm, Professor of Economics, Oxford University www.dieterhelm.co.uk.

²² *Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2005*, Report to Department for Environment, Food and Rural Affairs, The Scottish Executive, The Welsh, Assembly Government and The Northern Ireland Department of Environment, AEA Technology, 2007.

²³ *UK greenhouse gas emissions: measurement and reporting*, National Audit Office, London, 2008.

²⁴ Druckman, A., Bradley, P. and Papathanasopoulou, E. (2008). Measuring progress towards carbon reduction in the UK. *Ecological Economics* 66, pp 594-604.

²⁵ Angela Druckman and Tim Jackson, personal communication, September 2008.

²⁶ Europa press release: Climate change: *Bali conference must launch negotiations and fix 'roadmap' for new UN agreement*, Reference: IP/07/1773 Date: 27/11/2007, <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1773&format=HTML&aged=0%3Cuage=EN&guiLanguage=en> accessed 13 February 2008.

²⁷ Speech made by Stavros Dimas, Member of the Commissions responsible for the environment, Reference: SPEECH/07/812 Date: 12/12/2007.

As regards Bali, while this event failed to agree collective targets for reducing emissions, member states did at least reach some agreement on the need to address the problem of tropical deforestation. The details of how this might be achieved have not been worked out but the commitment is there. Since deforestation (mostly in tropical forests) accounts for 12% of global GHG emissions^{28,29} this is potentially a significant step forward.

The UK Government, in addition to its Kyoto targets, is currently in the process of passing a Climate Change Bill through Parliament. The subsequent Act will legally bind the UK to achieving a 60% reduction in CO₂ emissions by 2050 with five-yearly reduction targets and an interim goal of reducing CO₂ by 26–32% by 2020. The Act will also require Government to consider whether the 60% target should be increased to 80% in keeping with the most recent scientific evidence. It will additionally consider whether other GHGs (which currently contribute 15% to the UK's total GHG emissions) should be included in the target. To advise the Government on how it might meet these obligations, while balancing the environment with social and economic considerations, a Climate Change Committee has been set up, comprising a small group of individuals with strong economic and scientific backgrounds.

The Bill is pioneering and indeed unique at the nation level but it is not without its flaws. Importantly, the Bill does not take into account emissions embedded in imported goods and services, nor international aviation and shipping. As highlighted above, if these were included we would see a very different picture of the UK's progress. Moreover, it is not entirely clear what the penalty will be should the government of the day fail to keep the UK's emissions within the specified limits.

Strongly influencing the development of the Bill were the conclusions of the Stern Review on climate change. That report, commissioned by the Government and overseen by the economist Sir Nicholas Stern, concluded that while action to reduce GHG emissions would cost the global economy around 1% of its GDP a year, the costs of inaction would be equivalent 5% of annual GDP and could be as high as 20%.³⁰ Note that the Stern review assumed a CO₂e stabilisation target of 550ppm; stabilisation at 450ppm would, in its view be 'unobtainable at reasonable cost'.³¹

<http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/07/812&format=HTML&aged=0&language=EN&guiLanguage=en> accessed 13 February 2008.

²⁸ Nabuurs, G.J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., El Siddig, E., Ford-Robertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W.A., Matsumoto, M., Oyhantcabal, W., Ravindranath, N.H., Sanz Sanchez, M.J. and Zhang, X. (2007) Forestry. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

²⁹ Figures given in the Fourth Assessment Report vary: in Chapter 9, cited, the figure is 12% but in the synthesis document the estimate given is higher – 17%.

³⁰ Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK.

³¹ Chapters 9 and 10 in Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK.

2. FOOD AND ITS CONTRIBUTION TO GHG EMISSIONS – AN OVERVIEW

The great tragedy of Science – the slaying of a beautiful hypothesis by an ugly fact.

T. H. Huxley

This section provides a broad overview of the contribution that the food chain makes to GHG emissions. It briefly describes the life cycle perspective which we use (further discussion can be found in Section 6) and highlights the importance of considering the full range of GHG emissions and not just CO₂. It then discusses the distinction between production- and consumption-based approaches to quantifying emissions before using these to give estimates of foods' contribution to overall UK GHGs. This section prepares the ground for Section 3 (which considers each of the life cycle stages in more detail), and Section 4, that looks at emissions by food type.

2.a. The life cycle approach

In the 1990s concern for food and its environmental impacts focused mainly on 'food miles.' The original, much publicised, *Food Miles* report³² published by the then SAFE Alliance (now incorporated into Sustain) used the phrase to encapsulate a broad range of environmental and social problems resulting from the globalising of food supply systems, but the phrase over time became used to refer largely to the environmental impacts of transporting food long distances.

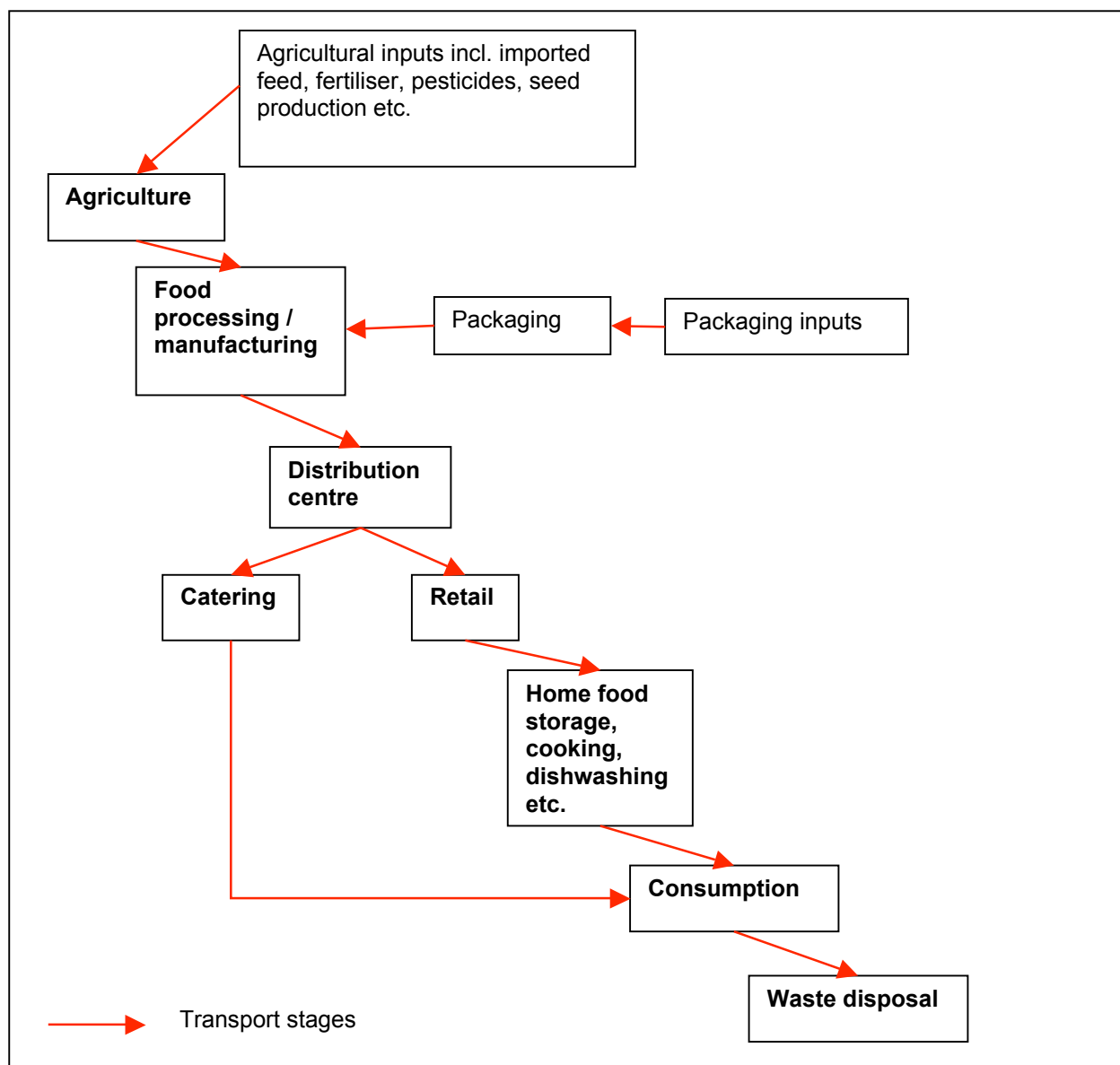
Since then, a more recent and fairly considerable body of research points to the need for a more comprehensive perspective that considers the impacts of food along its whole life cycle and not just at the transport stage.^{33,34} Life cycle analysis (LCA) takes account of impacts at all supply chain stages – from agricultural production (and its associated inputs) through to processing, packing, transport, retailing, home storage and preparation, and final disposal. Figure 1 gives a simplified illustration of a typical life cycle diagram, showing the various stages that demand consideration.

³² Paxton, A. (1994) *The Food Miles Report: the dangers of long distance transport*, SAFE Alliance, London.

³³ Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A., Mylan, J. (2006) *Environmental impacts of food production and consumption*. A report produced for the Department for Environment, Food and Rural Affairs (Defra).

³⁴ Edwards-Jones, G., Milà i Canals, L., Hounsome, N., Truninger, M., Koerber, G., Hounsome, B., Cross, P., York, E.H., Hospido, A., Plassmann, K., Harris, I.M., Edwards, R.T., Day, G.A.S., Tomos, A.D., Cowell, S.J. and Jones, D.L. (2008) Testing the assertion that 'local food is best': the challenges of an evidence-based approach, *Trends in Food Science & Technology* 19: 265–274.

Figure 1: A simplified diagram of life cycle stages in the food supply chain



It is also important to consider not just the impacts associated with each stage in the supply chain but the *interrelationship* between the different stages. Decisions taken to improve efficiency at one stage may lead to an increase in emissions at another stage. For example, a retailer's decision to reduce refrigeration emissions by using less cooling might cause greater levels of waste, representing the 'unnecessary' waste of all the emissions embedded in the product up to that stage. Alternatively, a shift to sourcing a product more locally may mean purchasing supplies that have been produced in a more GHG-intensive manner than those available from further afield; and growing numbers of research projects have investigated, or are currently looking at, this possibility.^{35,36} This said, there may also be 'win-win' situations –

³⁵ See for example the UK research council funded project: *Comparative Merits of Consuming Vegetables Produced Locally and Overseas* <http://relu.bangor.ac.uk/index.php.en?menu=0&catid=0>

measures to reduce packaging impacts by shifting to lighter packaging materials might increase the volume of food that can be packed into a lorry, and so reduce transport emissions.

The purpose of LCA needs to be considered. One reason for undertaking such an analysis is to obtain a snapshot of impacts in order to identify where the main areas for improvement lie. For example, the chocolate manufacturer Cadbury has quantified the GHGs emitted during the course of producing one 50g bar of milk chocolate. It appears that the production of the milk (which makes up 25% by weight of the bar's contents) contributes 60% to its overall GHG emissions, highlighting the need to focus on this particular input.³⁷ This approach, termed an 'attributional' LCA, may be useful for a company wishing to identify the environmental hotspots of its products in order to reduce the impacts of the goods it produces. Alternatively, the purpose might be to compare the environmental impacts of two products – tomatoes from two different suppliers, for instance. This can give an insight into the merits of different sourcing decisions.

A second approach, sometimes called consequential LCA, takes a 'what if?' approach, that is, it analyses the effects on the environment of particular changes in the system inputs or processes. Taking the bar of chocolate again as an example, a consequential analysis might consider what the impact would be if the milk content of the bar were lowered and the cocoa content increased. Or, more radically, what would happen if the prospective eater were to choose to eat something else instead: an apple, or a packet of crisps. Consequential LCAs provide policy-makers with guidance on different courses of action they might take but there are any number of 'what ifs?' to explore (what if we skipped the snack and drove to the gym instead?). We explore some of the potential limitations of LCA for policy-making, along with the need to combine the LCA perspective with other methods of analysis, in Section 6.

2.b. The importance of the different GHGs

When we refer to GHG emissions from the food chain, we mean not just CO₂ but other gases which also have a warming effect on the earth's atmosphere.

In the UK the gas responsible for 85% of our contribution to global warming is indeed CO₂, and this is mainly produced by burning fossil fuels. But while CO₂ accounts for the majority share of the warming effect, other gases play their part too, particularly N₂O and CH₄. Although present in the atmosphere in far smaller quantities than CO₂, these gases have a global warming impact that is significantly greater – around 23 times, in the case of CH₄, and 296 times for N₂O.³⁸ Certain refrigerant gases, while emitted in far smaller concentrations have a GWP that can be many thousand times greater than CO₂.

The different GHGs and the food chain

In the case of the food chain, the non-CO₂ gases make up a significant share of total emissions, particularly at the agricultural stage. In the UK, CH₄ contributes 7.5% to total consumption-related GHG emissions and of this, agriculture accounted for 38% in 2006, or 2.85% of the UK GHG total.³⁹ Nitrous oxide emissions contribute 6% to the UK's burden and here agriculture's

³⁶ Milà i Canals, L., Cowell, S.J., Sim, S. and Basson, L. (2007) Comparing Domestic versus Imported Apples: A Focus on Energy Use. *Env Sci Pollut Res* 14 (5) 338–344.

³⁷ Cadbury carbon footprint study, Cadbury, 2008.

³⁸ Sometimes different figures are used such as 23 for CH₄ and 298 or 310 for N₂O. These differences reflect scientific uncertainty and in any most cases do not have a major impact on the results of a given study.

³⁹ Defra statistical release: *UK Climate Change Sustainable Development Indicator: 2006 Greenhouse Gas Emissions*, final figures, 31 January 2008.

share is more important still; 67% is attributable to agriculture, or 4% of the UK's GHG total. In all then, the non-CO₂ gases arising from agricultural activities (and excluding other stages in the food life cycle) contribute to nearly 7% of all the GHG emissions emitted within the UK's borders.

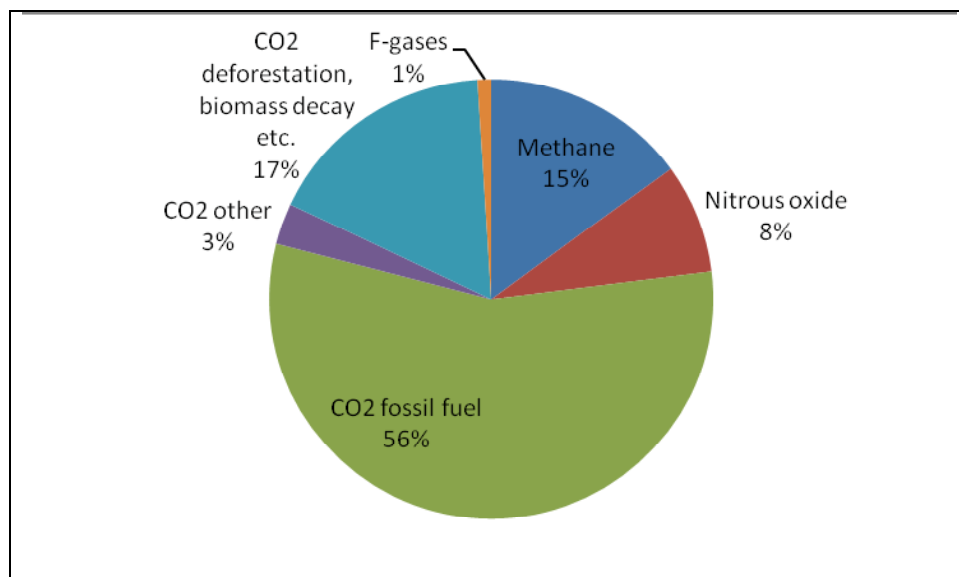
Table 1: Relative importance of the different GHGs in agriculture and contribution to UK GHG total

GHGs	UK GHG emissions – breakdown by gas type (production-oriented) %	Agriculture's direct contribution to UK production-oriented GHG total (excluding fertiliser production) %
Carbon dioxide	85	0.67
Methane	7.5	2.85
Nitrous oxide	6	4
Other Kyoto basket gases	2.5	
Total	100	7.52

Source: UK Climate Change Sustainable Development Indicators: 2006 Greenhouse Gas Emissions, final figures, 31 January 2008.

At the global level, the relative importance of CH₄ and N₂O is greater than for the UK as a whole, reflecting the fact that many countries are less industrialised than the UK, consume fewer fossil fuels, and rely more on agriculture – hence agriculture related emissions (in the form of CH₄ and N₂O) will be relatively more important.

Figure 2: Breakdown of global anthropogenic GHG emissions



Source: Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report, 2007.

CO₂ is important both at the agricultural stage and further along the supply chain from post-harvest/slaughter onwards, but for different reasons.

At the agricultural stage, while fossil fuels are used to power farm machinery and manufacture fertilisers, their contribution to CO₂ emissions, relative to other sectors of the economy is minor. This is shown in Table 1 above and discussed further in Section 3 below. Changes in land use contribute more significant quantities of CO₂. These result from soil carbon losses due to ploughing and, more importantly, through the conversion of pasture, savannah or forest land to tilled agriculture. Land use change can also remove carbon from the atmosphere and store it, an example being the conversion of tilled arable land to forest. Land use changes within UK borders does are fact having a net sequestering effect, although this varies by region. In Scotland, for instance, land use change has the effect of lowering emissions by 8% from what they would otherwise have been. In Wales the sequestering effect is far smaller whereas in England, changes in land use have actually contributed to emissions.⁴⁰ However, it is important to note that the UK is responsible for lost carbon sequestration overseas through its imports of certain goods (such as soy or palm oil). These are not taken into account in classic LCA, nor, indeed, in most GHG statistics. This is an issue we discuss further with regard to livestock (Section 4) and in Section 6, where we discuss some of the methodological challenges for LCA to address.

From the farm gate onwards, the importance of CO₂ emissions from the use of heat, transport fuels and electricity during processing, storage, and so forth, becomes relatively more important. By contrast the contribution of CH₄ and N₂O are negligible, and are not quantified here.

2.c. Estimates of food GHG emissions

To our knowledge, there are no global studies that attempt to quantify GHG emissions resulting from global food consumption; taking into account all stages from agriculture through to consumption. The 2007 IPCC report does however give an estimate for agriculture, putting its contribution to global emissions at 10–12% of the total.⁴¹ This figure does not include emissions associated with agriculturally induced land use change – that is, the release of carbon into the atmosphere resulting from deforestation or the conversion of savannah or pasture to arable land, or from overgrazing and subsequent soil erosion. If these are included then, according to one study⁴² agriculture's contribution is much higher at between 17–32% of all anthropogenic GHG emissions. Clearly the difference between these two figures (17% and 32%) reflects a huge element of uncertainty, much of which results from the difficulty of estimating emissions from land use change.

For the EU it has been estimated that agriculture contributes to 9% of the EU-15's GHG emissions in 2005.⁴³ For impacts associated with the whole of the supply chain – from

⁴⁰ *Greenhouse Gas Inventories for England, Scotland Wales and Northern Ireland: 1990-2005* Report to Department for Environment, Food and Rural Affairs, The Scottish Executive, The Welsh Assembly Government and The Northern Ireland Department of Environment by AEAT, August 2007.

⁴¹ IPCC, 2007: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Chapter 8.

⁴² Bellarby, J., Foereid, B., Hastings, A. and Smith, P. (2008) *Cool Farming: Climate impacts of agriculture and mitigation potential*, report produced by the University of Aberdeen for Greenpeace, Greenpeace.

⁴³ *Greenhouse gas emission trends and projections in Europe 2007: Tracking progress towards Kyoto targets* (2007) EEA Report No 5/2007, European Environment Agency.

agriculture through to consumption, one EU report⁴⁴ calculates (using environmental input-output analysis) that the food sector in its entirety accounts for around 31% of the EU-25's GHG emissions. It also reviews life cycle studies showing a range of estimates from 4% to 22%, the variation attributable to differences in what products were included in the analysis, the methods used and the delimiting boundaries.⁴⁵

2.d. Quantifying food emissions: the production versus the consumption approaches

As for the UK's food-related emissions, it is once again important to distinguish between a consumption- and a production-focused approach.

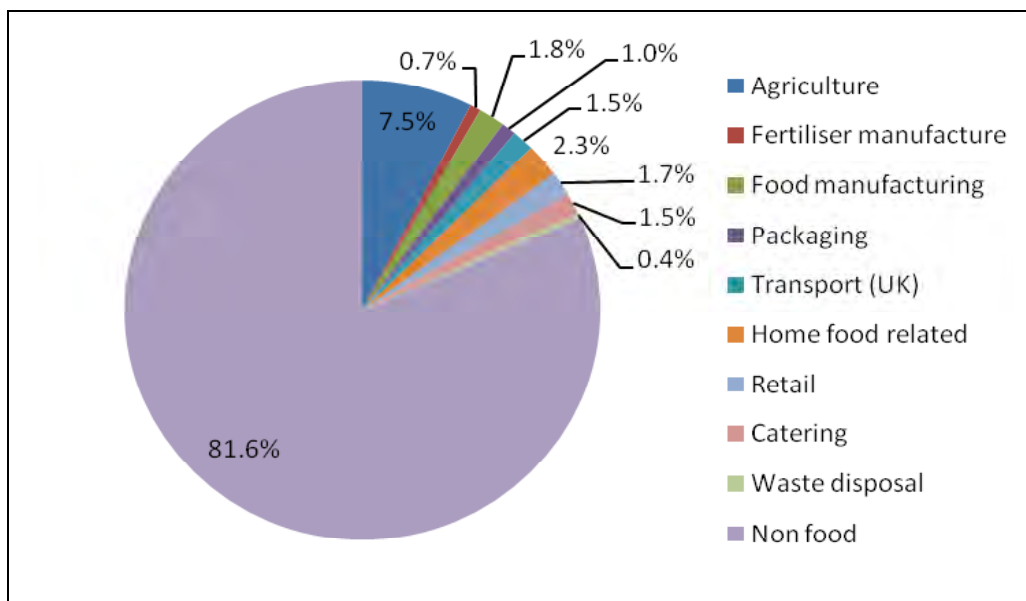
Figures 3 and 4 show the contribution that the food system makes to GHG emissions viewed from both the production and the consumption perspectives. Figure 3, the production-oriented pie-chart, shows emissions resulting from the production of food and its consumption in the UK. No deduction is made for emissions resulting from food production that is destined for export; equally no addition is made for the embedded emissions associated with food imported for consumption here. Food's contribution is calculated as a proportion of total UK-generated emissions as reported to the IPCC. This figure is currently 178MTCeq⁴⁶ and, as highlighted above, does not include the embedded emissions from imports, nor those associated with aviation and shipping. As can be seen, by this system of measurement, food-related emissions amount to 33MTCeq – or around 18.5% of total UK GHG emissions. These figures are merely an estimate – packaging-related data are scanty and the figure given is likely to be an underestimate. Data for catering-related emissions are also hard to come by.

⁴⁴ Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25, European Commission Technical Report EUR 22284 EN, May 2006.

⁴⁵ Includes a small share for narcotics.

⁴⁶ *UK Greenhouse Gas Inventory, 1990-2006. Annual report for submission under the Framework Convention on Climate Change*, AEA Energy & Environment, April 2008.

Figure 3: Food and its contribution to UK GHG emissions – a production-oriented perspective



Source: Garnett T, 2008, author's estimates – see Appendix for data sources.

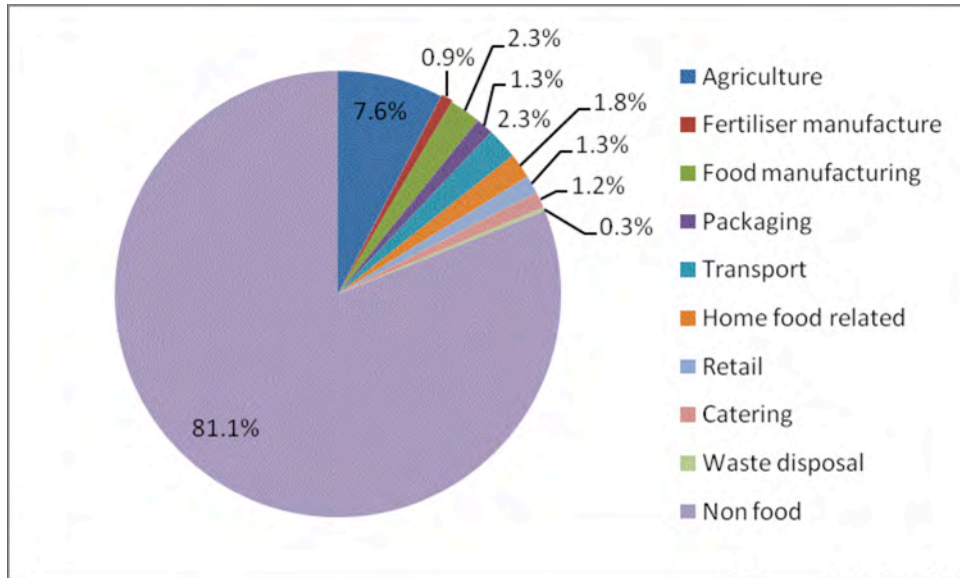
In our opinion a consumption-based view more accurately captures the *actual* impacts of UK activities and indeed of the contribution of individual consumption to GHG emissions. Of course, any estimate of the contribution of food consumption needs to be measured as a proportion of total UK consumption-based emissions which will be higher than the UK inventory's reported total (as discussed earlier). We use here as our basis the estimates of UK consumption-based CO₂ emissions given in Druckman *et al.*⁴⁷ as 199MTC and cited above (as noted earlier, the figures are in the process of being revised). Druckman's figures are for CO₂ only and carbon dioxide accounts for only 85% of the UK's total reported GHG (expressed in terms of GWP), with the remaining 15% made up of N₂O, CH₄ and other gases. It would be reasonable (although open to challenge) to assume that imported goods contain the same embedded make-up, making the total consumption-related figure 15% greater than that for CO₂ alone, or 229MTCeq.

Food consumption-related emissions constitute a proportion of this. According to our calculations, the impacts associated with our *consumption* of food in the UK amounts to some 43.3 MTCeq, or around 19% of total consumption-related emissions (that is, all the GHGs embedded in our consumption of goods and services)⁴⁸ although, as with the production estimates, this is very much an estimate. In addition, and very importantly, these figures do not take into account emissions arising from deforestation or other land use change overseas that are caused by farming to produce food for British stomachs.

⁴⁷ Druckman, A., Bradley, P., Papathanasopoulou, E. and Jackson, T. (2008) Measuring progress towards carbon reduction in the UK, *Ecological Economics* Volume 66, Issue 4, Pages 594–604.

⁴⁸ Garnett, T. (2007) *UK food consumption-related greenhouse gas emissions*, working draft, FCRN. <http://www.fcn.org.uk/fcnresearch/publications/Overall%20food%20GHGs.doc>

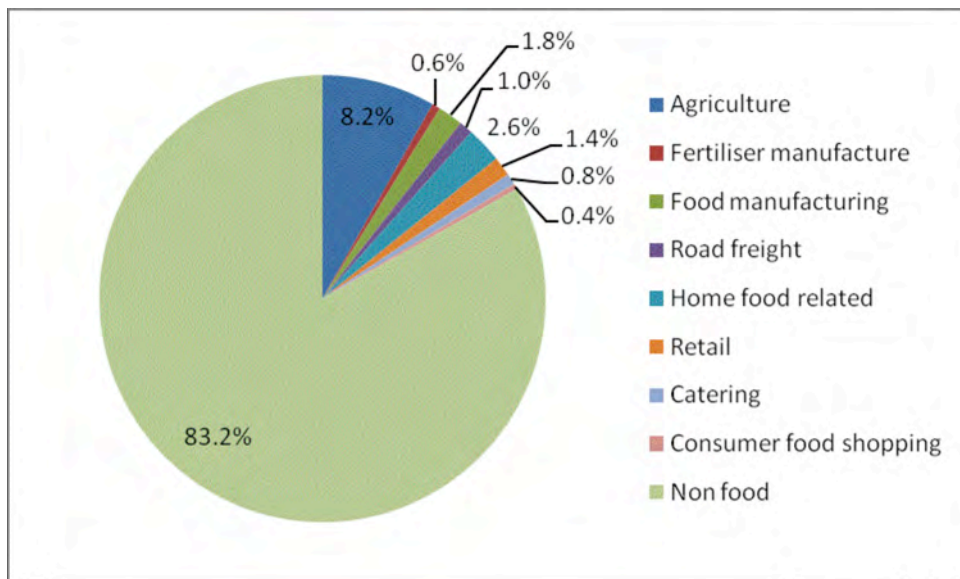
Figure 4: Food and its contribution to UK GHG emissions – a consumption-oriented perspective



Source: Garnett T, 2008, author's estimates –see Appendix for sources.

Preliminary analysis by Defra using slightly different data sources and assumptions yields a very similar figure.⁴⁹

Figure 5: Food consumption-related emissions – Defra calculations



Source: Preliminary analysis by Defra (2007).

⁴⁹ Preliminary analysis by Defra (2007) pers. comm. August 2007.

Both charts very clearly show that agriculture is, on average, the most important stage in the food life cycle and accounts for roughly half of all food GHGs (although as Section 4 shows, its importance, relative to other life cycle stages, will vary by food type). In the following paragraphs we look more closely at the contribution made by these various stages in the supply chain, before considering impacts by specific food type.

3. GHG IMPACTS ALONG THE SUPPLY CHAIN

Farming looks mighty easy when your plow is a pencil and you're a thousand miles from the corn field.

Dwight D. Eisenhower

This section looks at the contribution that different stages in the food supply chain make to GHG emissions. Taking the following life cycle stages in turn: agriculture, transport, refrigeration and waste, we quantify what contribution they make to the GHG total and discuss possible future trends. Examination of possible mitigation options is reserved for Sections 7 and 8. Note, too, that retail and manufacturing stage emissions are not discussed in this section. This is for two reasons. First, they are partly covered in the subsections on refrigeration and transport. And second, the sections on mitigation discuss these stages at some length and there would be considerable overlap and repetition if they were also discussed here. This is not the case for the other life cycle stages, which are perhaps a little more complex.

3.a. Agriculture

According to the UK's GHG inventory, agricultural activities as a whole represent 7% of the UK's GHG emissions.⁵⁰ Most of this is attributable to CH₄ and N₂O, which together account for about 87% of this 7%.⁵¹ Importantly, however, these emissions are calculated at source and, as such, the inventory calculations do not include fertiliser production, any transport associated with agricultural production, nor agricultural production overseas associated with direct or indirect consumption. An example of the latter would be the cultivation of oilcrops to produce oilseed cake to feed animals reared in the UK.

The production of fertilisers contributes significantly to the UK's GHG emissions. This is because the Haber-Bosch production process is energy intensive (generating CO₂) and also leads to the production of N₂O. According to FCRN calculations, the production of fertilisers in the UK contributes to 0.7% of the UK's total emissions.⁵² We do, however, import approximately a third of all the fertiliser used. Adding together the farming and UK fertiliser production figures, agriculture is found to contribute to nearly 8% of all UK production-related GHG emissions.

Recalculating agriculture's contribution to total UK GHG emissions using a consumption-based approach that takes into account emissions associated with fertiliser production as well as the embedded impacts of imported agricultural products (including fertiliser – see Section 2 above) obtains an end figure of 8.5%. Of this, 7.6% is attributable to the farming itself and 0.9% to fertiliser use. While this overall figure for agriculture is similar to the production-based inventory figure, *it represents a share of higher overall emissions*. Agriculture-related emissions in absolute terms are therefore higher than the UK inventory figures would suggest.

⁵⁰ *Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990–2005*, Report to Department for Environment, Food and Rural Affairs, The Scottish Executive, The Welsh Assembly Government and The Northern Ireland Department of Environment, AEA Technology, 2007.

⁵¹ *Ibid.*

⁵² Garnett, T., based on data provided by the Agricultural Industries Confederation and the British Survey of Fertiliser Practice.

Table 2: Agriculture’s contribution to UK GHG emissions

	Farming’s contribution to total GHG emissions %	Fertiliser production contribution to total UK GHG emissions %	Total agriculture stage emissions	Total GHG emissions (MTCeq)
Production-based	7.5	0.7	8.2	178
Consumption-based	8.5	0.9	7.6	229

Sources: See Section 2 for discussion of production- and consumption-related emissions.

It is, however, notoriously difficult to accurately assess emissions from agriculture. There are over 300,000 farm holdings in the UK,⁵³ each working with different soil, climate and day-to-day weather conditions, differing in what they grow, how they manage their livestock and crops, what inputs they use, and including an increasing proportion of organic or in-conversion systems.

Methane emissions from livestock can vary by time of year, according to the type of feed the animals eat, and the quality of the pasture they graze on. Moreover, the seemingly whimsical nature of nitrogen biochemical pathways means that N₂O emissions can fluctuate enormously by time of year, the wetness and porosity of soil, temperature and so forth.^{54,55} Even emissions from two separate patches of the same farm can vary wildly, making efforts both at quantifying and at mitigating emissions very hard indeed. Indeed, according to the UK GHG inventory report, soil N₂O emissions account for the widest range of uncertainty for all N₂O sources.⁵⁶

While we may not have a thorough understanding of N₂O, we do know that it is the most significant agricultural GHG and is therefore a major contributor to overall food chain emissions. According to Williams *et al.*,⁵⁷ in their study of ten of the UK’s major agricultural commodities, N₂O accounts for over 80% of the GWP of wheat, barley, maize, beans and soya cultivation; over 50% for potatoes, and around 30–50% for livestock rearing (where for some animals CH₄ competes for first place).

⁵³ *Agriculture in the United Kingdom 2006*, Chapter 3, Table 3.3, Defra, 2007.

⁵⁴ Conen, F., Dobbie, K.E. and Smith, K.A. (2000) Predicting N₂O emissions from agricultural land through related soil parameters. *Global Change Biology*, 6, 417-426.

⁵⁵ Oenema, O., Gebauer, G., Rodriguez, M., Sapek, A., Jarvis, S.C., Corré, W.J. and Yamulki, S. (1998) Controlling nitrous oxide emissions from grassland livestock production systems. *Nutrient Cycling in Agroecosystems* 52, 141–149..

⁵⁶ See Appendix 7, *UK Greenhouse Gas Inventory, 1990-2005. Annual report for submission under the Framework Convention on Climate Change*, AEA Energy & Environment, April 2007.

⁵⁷ Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk.

Defra is currently in the process of funding a much-needed project whose objective is to improve the accuracy of the emission factors used in GHG accounting in agriculture, through a mixture of modelling, field experimentation and analysis.⁵⁸ In addition, a research consortium, coordinated by the University of East Anglia – the Nitrous Oxide Focus Group – has been set up to understand the sources of N₂O, the chemistry and biology behind its production, its overall impact upon climate change and ultimately to develop techniques to mitigate its effect.

While estimates of agriculture's GHG contributions may need revising in the light of emerging findings, there is, in our view, an equally important area of research that does not receive adequate policy attention. It is this: the UK calculations do not take into account carbon emissions resulting from overseas changes in land use that are caused by UK consumption – the 'lost carbon sequestration' issue. The cultivation of agricultural products overseas for UK consumption can and does lead to land clearance and deforestation overseas; which in turn gives rise to releases of stored carbon. The FCRN livestock report discusses this in relation to soy, an important animal feed.⁵⁹ We highlight research^{60,61} showing that soy cultivation for, among other things, animal feed has been a major driver of deforestation in the Brazilian Amazonian region (note that demand has in part been driven by European demand for GM-free feed sources). Soybean cultivation is, moreover, forecast to grow rapidly over the coming decades and it is conservatively estimated that area used for cultivating soybean in the region could increase by more than 40 million ha.⁶²

Importantly, soybean cultivation not only makes use of land in its own right, but is also an important 'push' factor for deforestation by other industries. In other words, although soy production may not always take place directly on virgin rainforest, it takes land away from other uses, such as smallholder cultivation and cattle rearing, pushing these enterprises into the rainforest. As a highly profitable industry, it also provides income to purchase land for other purposes, including logging.⁶³ So, by acting as an important driver of deforestation in the region, soybean cultivation represents a serious threat to the Amazon environment.^{64,65} This concern is now starting to receive increasing attention because of the rapid expansion in biofuels production. As we discuss in the livestock section below, the relationship between biofuels

⁵⁸ *An improved inventory of greenhouse gases from agriculture* – Defra project AC0101 <http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=14409&FromSearch=Y&Publisher=1&SearchText=AC0101&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description> accessed 13 February 2008.

⁵⁹ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

⁶⁰ Woods Hole Research Centre http://www.whrc.org/southamerica/agric_expans.htm

⁶¹ ISTA Mielke, Oil World Annual 2004, Hamburg, May 2004 cited in Dros, J.M. (2004) *Managing the Soy Boom: Two scenarios of soy production expansion in South America*, WWF.

⁶² *Production Estimates and Crop Assessment Division Foreign Agricultural Service, USDA, January 2004* http://www.fas.usda.gov/pecad2/highlights/2004/01/Amazon/Amazon_soybeans.htm accessed 26 May 2005.

⁶³ ISTA Mielke, Oil World Annual 2004, Hamburg, May 2004 cited in Dros, J.M. (2004) *Managing the Soy Boom: Two scenarios of soy production expansion in South America*, WWF.

http://www.panda.org/downloads/forests/managingthesoyboomenglish_nbvt.pdf

⁶⁴ Woods Hole Research Centre http://www.whrc.org/southamerica/agric_expans.htm

⁶⁵ ISTA Mielke, Oil World Annual 2004, Hamburg, May 2004 cited in Dros, J.M. (2004) *Managing the Soy Boom: Two scenarios of soy production expansion in South America*, WWF.

http://www.panda.org/downloads/forests/managingthesoyboomenglish_nbvt.pdf

production and livestock farming is a complex one and there may be not only conflicts (in terms of competition for land use) but also potential synergies (using by-products from the biofuels production process for animal feed).

Another area that does not receive consideration in standard assessments of GHG impact⁶⁶ is the 'what if?' factor – that is, the opportunity cost of using land for one purpose rather than another. This 'opportunity cost' is described by Berlin and Uhlin as follows

'Different use of land is associated with different benefits but also with costs. In a decision-making situation the cost of employing a given asset can, according to the opportunity cost principles, be established by estimating the highest-valued opportunity that must be foregone or lost. The most appropriate measure when calculating the opportunity cost of different land use is accordingly the utility that could be derived from an alternative use. This is often expressed in monetary terms but... can also be expressed in, for example, reduced amount of greenhouse gases released'.⁶⁷

We discuss this issue in more detail in relation to livestock production, below, and in our final observations and conclusions (Section 11).

Finally, it is worth noting that emissions from land use, land use change and forestry (LULUCF) are reported separately in the UK GHG inventory. Emissions here are currently negative – that is, the sector currently sequesters 2 MTCO₂eq, thereby reducing the UK's GHG emissions by about 0.3%, although as noted, the situation varies considerably by region.^{68,69} This is not the case in many other countries, particularly South America, where land use change contributes large releases of CO₂ into the atmosphere.

3.b. Transport

A proper discussion of transport (whether freight or passenger) and its impacts must look at its contribution to a range of social and environmental concerns including accidents, noise, air pollution, congestion, the concreting over of natural landscapes and the fostering of obesogenic environments. These very important issues are the subject of campaigns by a number of non governmental organisations⁷⁰ and exploration by researchers. While they are not discussed here, the focus being on GHG emissions, this is by no means to suggest that they are not important. They are, and indeed they affect our lives more strongly (in the short term) than do emissions of invisible GHGs.

Transport and GHGs: is further worse?

With respect though to food transport and these 'invisible gases', many recent studies have sought to investigate the extent to which the distance food travels really does correlate with

⁶⁶ Berlin, D. and H.-E. Uhlin (2004). Opportunity cost principles for life cycle assessment: toward strategic decision-making in agriculture, *Progress in Industrial Ecology*, Vol. 1, Nos. 1/2/3, 187.

⁶⁷ Ibid.

⁶⁸ *Greenhouse Gas Inventories for England, Scotland Wales and Northern Ireland: 1990–2005 Report to Department for Environment, Food and Rural Affairs, The Scottish Executive, The Welsh Assembly Government and The Northern Ireland Department of Environment by AEAT, August 2007.*

⁶⁹ *UK Greenhouse Gas Inventory, 1990–2005. Annual report for submission under the Framework Convention on Climate Change, AEA Energy & Environment, April 2007.*

⁷⁰ For example the Campaign for Better Transport, the Council for the Protection of Rural England and Friends of the Earth.

greater environmental impacts. For example, the *Wise Moves* report⁷¹ published by the environmental organisation Campaign for Better Transport (at that time Transport 2000) found that food transport accounts for around 3.5% of the UK's consumption-related GHG emissions. It concluded that there was some correlation between shorter journey distance and lower emissions, but that there were many exceptions, owing to differences in the efficiency of production systems as well as in mode of travel and logistics. The report concluded that a life cycle approach to tackling food related impacts was needed, and this conclusion led directly to the setting up of the FCRN.

A Defra commissioned study⁷² sought to assess the validity of food miles as an indicator of sustainable development. It put GHG emissions associated with food distribution (including from overseas) at approximately 3% of the UK's production-related GHG emissions (this would obviously be lower from a consumption-related perspective, at about 2.25%) and concluded that distance *per se* was not an adequate gauge of environmental impact.

One New Zealand study⁷³ compared the GHG footprint of the British and New Zealand dairy industries and found that per kg of milk solids, the UK's emissions were 34% higher (and 30% more on a per hectare basis) than the New Zealand system, even allowing for shipping emissions. Note that there has also been strong criticism of the core assumptions made by the report's authors, which have been articulated in some detail by Murphy-Bokern.⁷⁴ For example, nitrogen inputs only are quantified, biological N₂O is not, which means that for New Zealand (where less synthetic fertiliser is used) N₂O emissions are underestimated. Direct energy use in UK dairy farming is overestimated, as is the level of concentrates fed. Finally, the functional unit used was 'milk solids'. New Zealand exports most of its milk and does so in processed, higher milk-solids form, such as cheese or butter. By contrast, 50% of the milk produced in the UK is consumed as fresh milk. In other words, like is not being compared with like.

However, the important point to note here is that the magnitude of emissions from other stages in the life cycle (and hence differences between the same key stages of two comparable products) can outweigh the environmental impacts of the transport element. Hence, a focus on transport alone can distract from other areas of environmental concern, such as the quantities of GHG-intensive livestock products we consume (discussed in Section 4).

The relative importance of transport will, moreover, vary by product type. For meat and dairy products, as we discuss in Section 4, the agricultural stage contributes overwhelmingly to GHG emissions associated with these foods and the impact of transport is less significant. For field grown fruit and vegetables however, the farming stages are relatively less important (although this is not the case for protected crops) and the significance of transport does start to show. Sim *et al.*⁷⁵ look at sourcing options for three kinds of fresh produce – Gala apples, runner beans and watercress – and assess the global warming and other environmental impacts. The study

⁷¹ Garnett, T. (2003) *Wise Moves: exploring the relationship between food, transport and CO₂*. Transport 2000.

⁷² *Validity of Food Miles as an Indicator of Sustainable Development*, Report produced by AEA Technology Environment for Defra, July 2005.

⁷³ Saunders, C. and A. Barber (2007) *Comparative Energy and Greenhouse Gas Emissions of New Zealand's and the UK's Dairy Industry*, Research Report No. 297, Lincoln University, New Zealand.

⁷⁴ Murphy-Bokern, D. (2007) Comments to the Food Climate Change Network on the Comparative Energy and Greenhouse Gas Emissions of New Zealand's and the UK's Dairy Industry (Caroline Saunders and Andrew Barber 2007).

⁷⁵ Sim, S., Barry, M., Clift, R. and Cowell, S.J. (2007) The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing. *Int J LCA* 12 (6) 422–431.

finds that the transport stage of the life cycle makes an important contribution to the environmental impact of these products.

Note the difference between relative and absolute impacts: while the *absolute* emissions associated with importing fresh vegetables from Spain and fresh pork from Denmark may be similar, the *relative* importance of the transport stage to the former will be far greater than to the latter. It may be more relevant to consider the GHG intensity of food types, as we do in Section 4, rather than life cycle stages.

Regarding fruit and vegetables, Sim *et al.* conclude that when in season it is generally environmentally preferable (from a GHG perspective) for UK consumers to buy British produce rather than produce imported from overseas – although of course we import many foods that cannot be grown here in the UK.

A combination of seasonality and transport distance by mode may perhaps be a more effective measure of GHG impact than either of these elements alone. It has been argued by many environmental groups a combination of eating locally and seasonally is a key element of (and indicator of) sustainable food consumption.^{76,77}

One paper, for example, finds that during the UK apple season, indigenously grown apples are clearly less GHG-intensive than imports. During the summer months however, before the UK growing season starts, apples imported from the southern hemisphere have the edge over UK apples maintained in cold storage.⁷⁸

Resource utilisation also affects the balance. The Youngs Seafood company took the decision to export its prawn de-shelling operations to Thailand. It commissioned the company Enviro to calculate the CO₂e emissions arising from transporting the product to Thailand, de-shelling it there and transporting it back again, taking into account all emission sources. The study concluded that no net increase in emissions had occurred.⁷⁹

Another study by Sim⁸⁰ found that GHG emissions resulting from the production of Spanish tomatoes, which are grown with little or no heating and lighting, are lower than those of British tomatoes that are grown in heated, lit glasshouses. In season UK tomatoes are, however, likely to be environmentally preferable (this is certainly so for lettuces).⁸¹ Complicating the issue

⁷⁶ *Organic vegetables bicycled in from Berkshire for star-studded charity banquet*, Soil Association press release, 11/03/08.

<http://www.soilassociation.org/web/sa/saweb.nsf/d39dda83e1f3c019802570ad005b4516/086031e0e22c8a2380257409002be23d!OpenDocument> accessed 9 July 2008.

⁷⁷ Sustainable Food, Sustain, <http://www.sustainweb.org/sustainablefood/> accessed 9 July 2008

⁷⁸ Milà i Canals, L., Cowell, S.J., Sim, S. and Basson, L. (2007) Comparing Domestic versus Imported Apples: A Focus on Energy Use. *Env Sci Pollut Res* 14 (5) 338–344.

⁷⁹ http://www.youngsseafood.co.uk/company/youngs/corporate_responsibility.asp – full report not available.

⁸⁰ Sim, S. (2006) *Sustainable Food Supply Chains*. Volume One. Portfolio submitted in partial fulfilment of the requirements for the degree of Engineering Doctorate in Environmental Technology (EngD), University of Surrey.

⁸¹ Edwards-Jones, G., Milà i Canals, L., Hounsome, N., Truninger, M., Koerber, G., Hounsome, B., Cross, P., York, E.H., Hospido, A., Plassmann, K., Harris, I.M., Edwards, R.T., Day, G.A.S., Tomos, A.D., Cowell, S.J. and Jones, D.L. (2008) Testing the assertion that 'local food is best': the challenges of an evidence-based approach. *Trends in Food Science & Technology* 19: 265-274.

slightly, it has been pointed out⁸² that a tomato grower might need heat and the beginning and end of the season and not in the middle – the ‘seasonal’ tomatoes in the late summer months will have a lower GHG footprint but this is only made possible because of the heating boost that was given at the beginning. One might also add that to justify the investment in the glasshouses, the plants and all the inputs, growers of horticultural products need to extend the season beyond the ‘natural’ growing season itself.

We have already pointed out that the transport question is about more than GHG emissions; analysis of the merits of production in country x versus country y need to take into account more than the notion of GHG efficiency. For example, the Almeria region of Spain, where much of its horticultural production is located, suffers from water shortages. According to current climate models (see Section 5 below), these areas are set to become more arid still as the effects of climate change intensify. One might question the wisdom of continuing to grow horticultural products in highly water-stressed areas. Sim⁸³ also shows that some Spanish production systems do worse in other environmental respects, such as pesticide use. What is more, there can be huge variability between production methods even within the same region, as Milà i Canals has shown for apples. In the case of tomatoes, some growers in Spain now use heating to boost production⁸⁴ – in which case the GHG benefits of importing them into the UK will be questionable.⁸⁵

It is important to note too, as the *Wise Moves* report pointed out, that while there may be trade-offs between measures to reduce transport emissions versus those to minimise production stage impacts, there can also be correlations between transport energy use and other forms of energy, including refrigeration. Food transported long distances also needs to be refrigerated for lengthy periods; many handling stages in the supply chain increase the possibility of waste occurring. What is more, apples from New Zealand may first be stored there before being shipped into the UK, or shipped here and then stored here⁸⁶ – a double whammy. There are after all only two main global harvests (northern and southern hemispheres) and so storage will always be needed at some point in the year if we are to maintain year round supplies.

So far the discussion has focused on transport in general but the air freight issue merits particular attention. Notwithstanding heavy media focus⁸⁷ on air freighted food, the vast majority is actually carried by ship and road. And in absolute terms emissions from air freight as compared with those from shipping and trucks are considerably lower. This said, per unit of food transported, air freight is by far and away the most GHG-intensive mode. According to the Defra food miles study, less than 1% all food is carried by air but it accounts for 11% of all food

⁸² Defra, pers.comm. July 2008.

⁸³ Sim, S. (2006) *Sustainable Food Supply Chains*. Volume One. Portfolio submitted in partial fulfilment of the requirements for the degree of Engineering Doctorate in Environmental Technology (EngD), University of Surrey.

⁸⁴ López, J.C., Baille, A., Bonachela, S., González-Real, M.M. and Pérez-Parra, J. (2006) Predicting the energy consumption of heated plastic greenhouses in south-eastern Spain *Spanish Journal of Agricultural Research* 4(4), 289-296.

⁸⁵ 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).

⁸⁶ In the latter case the situation is worse since the UK’s electricity mix is more carbon intensive than that of New Zealand which is based largely on hydroelectricity.

⁸⁷ *Food miles: The true cost of putting imported food on your plate*, Joanna Blythman, *The Independent*, 31 May 2007 <http://www.independent.co.uk/environment/green-living/food-miles-the-true-cost-of-putting-imported-food-on-your-plate-451139.html> accessed 26 February 2008.

transport CO₂ including customer car travel to and from the store. The FCRN fruit and vegetable study⁸⁸ finds that while 1.5% of fruit and vegetables are carried by air, these foods account for 40% of all CO₂ arising from fruit and vegetable transport (or 50% if passenger transport is excluded).⁸⁹

The Sim *et al.* study already referred to finds that during the UK growing season, air freighted Kenyan green beans are 20–26 times more GHG-intensive than seasonal UK beans.⁹⁰ Of course, people also eat green beans out of season and a non-seasonal analysis would give different results, depending on whether energy intensive inputs were being used to produce the crop in the UK – this is a hypothetical example since beans are not, in fact, grown out of season in this country. However, by way of comparison, a relative environmental assessment of rose production in Kenya and Holland found that during that during the UK winter months, roses imported to the UK from Holland have a GHG burden nearly six times greater than those air freighted in from Kenya.⁹¹ This reflects the very high energy requirements of Dutch greenhouses.

It is important, however, to emphasise that both have a high footprint. One of the psychological traps of the life cycle approach is that it can prompt dualistic conclusions. The product that has a lower GHG impact becomes ‘good’ while the other is ‘bad’ when in fact both have very high impacts – half a dozen Dutch roses contributes around 17.5 kg of CO₂ and even the less GHG-intensive Kenyan ones are responsible for the emission of 2.9 kg CO₂ per half dozen. There are, moreover, alternatives: British daffodils for example. This would, of course, involve cultural changes – among other things in what we define as being ‘romantic’.

Evidently, the GHG emissions arising from our food system are not sustainable, and while some of the alternatives suggested (eat local – without regard to season or type of food being consumed) may not necessarily improve on the current situation (or have unintended consequences in terms of water, diets/health, landscape or biodiversity), it emphatically does not mean that all is for the best in the best of all possible worlds. The findings of LCA need framing within wider perspectives on absolute impacts and on need and consumer behaviour. We explore these further in Section 9 below.

Of course, the environmental impacts of air freight cannot be considered in isolation from other social and economic concerns. Of the five top air freighters by volume to the European Union in 2004, four were developing nations. Kenya supplied 22% of the EU’s air freighted imports, Pakistan 8%, South Africa 6%, and Ghana 6% (the US supplied 14%).⁹² It has been estimated that between 1 and 1.5 million people in Sub-Saharan Africa are dependent one way or another

⁸⁸ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

⁸⁹ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

⁹⁰ Sim, S., Barry, M., Clift, R. and Cowell, S.J. (2007) The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing. *Int J LCA* 12 (6) 422–431.

⁹¹ Williams A. *Comparative Study of Cut Roses for the British Market Produced in Kenya and the Netherlands: Précis Report for World Flowers*, Cranfield University, 12 February 2007 <http://www.world-flowers.co.uk/12news/news4.html> accessed 14 February 2008.

⁹² *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.

upon export horticulture, with 120,000 people directly employed.⁹³ The contribution overall that flown-in fruit and vegetables make to the UK's GHG emissions is actually very small at around 0.2%; why, one might ask, should poor Africans have to suffer on account of our tender consciences, particularly since we could easily compensate for these emissions by, for example, walking, rather than driving to the supermarket, or passing on an evening at the pub?

In recognition of the development *versus* environment dilemma, the organic certification body, the Soil Association, has been undertaking a public consultation on what its policies should be with respect to air freighted organic produce. Some of its stakeholders have argued that the high environmental impact of this transport mode is incompatible with the movement's ideals. The Soil Association is continuing with a second round of consultation and appears to be moving towards a position whereby it will continue to certify air freighted food as organic if, by 2011, those businesses supplying them meet the Soil Association's Ethical Trade standards (currently in development) or are certified as Fair Trade. The former is an ambitious and potentially valuable initiative in that it combines for the first time in an international certification process both social and environmental standards. In addition, exporting businesses should develop initiatives to reduce their reliance on air freight as a step towards moving away from fossil fuel-dependent development.⁹⁴

In our view this seems to be a sensible position although many would disagree, including the Department for International Development (DfID) and the International Trade Centre.⁹⁵ While there are undoubtedly many excellent projects⁹⁶ providing secure employment and additional welfare benefits, in the long run, forms of economic development that are environmentally unsustainable are effectively sawing off the branch they are sitting on. There is currently interest by some air freight importers in using the Clean Development Mechanism or voluntary offsetting schemes. Whether these actually lead to genuine emission reductions depends very much on the details of the individual schemes and we note that there have been many criticisms both of the CDM and of voluntary offsetting initiatives.^{97,98} So far the positions adopted by DfID and other aid agencies have been somewhat defensive.^{99,100} While it would be damaging simply to pull the plug on African farming, seeking to support and extend the current situation will not be helpful in the long run. DfID and other international development agencies need to be urgently investigating the options for supporting development that is fundamentally low in GHG intensity. A greater public communication of where DfID are going on this issue would be helpful.

⁹³ MacGregor, J. and Vorley, B. (2006) *Fair Miles? The concept of "food miles" through a sustainable development lens*, International Institute for Environment and Development, London.

⁹⁴ Press release: *Soil Association to ensure air freighted organic food benefits poor farmers – and challenges UK Government to do same for all air freighted produce*, Soil Association 25/10/2007 <http://www.soilassociation.org/web/sa/saweb.nsf/89d058cc4dbeb16d80256a73005a2866/3a1c3d1cc0d10bff8025737f002d919b!OpenDocument>, accessed 14 February 2008.

⁹⁵ A joint agency of the United Nations and the World Trade Organization.

⁹⁶ For example the Ghana-based Blue Skies company – see www.bsholdings.com

⁹⁷ Schneider, L. (2007) *Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement*. Report prepared for WWF by Öko-Institut E.V. Berlin, 5 November 2007.

⁹⁸ *Bad deal for the planet: Why carbon offsets aren't working... and how to create a fair global climate accord*. International Rivers, Berkeley, California, 2008.

⁹⁹ *The economic impact of a ban on imports of airfreighted organic products to the UK*, International Trade Centre, UNCTAD/WHO, 2007.

¹⁰⁰ *Buy a Kenyan rose this Valentine's Day*, Department for International Development press release, 13 February 2008, <http://www.dfid.gov.uk/news/files/pressreleases/ethical-valentine.asp>

So far this discussion seems to be pointing towards the view that while the transport stage is environmentally significant for some products, particularly for fresh produce and more particularly still for those that are air freighted, a focus on food miles alone can distract from heftier impacts at other stages in the supply chain. As we discuss further in Section 4, the more appropriate focus of concern might not be how far our food has travelled but the proportions of different foods on our plate. Some foods, whether locally grown or not, are inherently more GHG-intensive than others.

Transport, the second order impacts and the implications for GHGs

Nevertheless, transport also generates some troubling second order, or indirect impacts.

We have already pointed out that as supply chains globalise, there will be more transport. This is a 'first order' or direct consequence – emissions (in the absence of a clean fuels revolution) will grow in absolute terms. However, these direct impacts have gone hand in hand with infrastructural, systemic changes that bring with them their own impacts. As supermarkets and manufactures commit to securing supplies or locating their manufacturing plants far from home, their decisions have given impetus to further investment in new or expanded infrastructure – roads, ports, runways, air freight handling facilities, as is clearly being seen in the emerging economies.¹⁰¹ These construction activities will produce their own environmental (including GHG) impacts but more importantly, they foster a situation where supply chains become committed to, and predicated on, long distance sourcing and distribution. The presence of new infrastructure makes it easier and cheaper to source from further afield and of course the cost of investment needs to be recouped. This fosters the continuation of, and increase in, long distance sourcing. By contrast, sources closer to home may be less economically attractive because labour costs are higher. As a result, local enterprises go out of business, leaving no closer-to-home choice available. These are what we mean by the second order impacts of food transport, and they tend not to be considered in formal LCA.

It is possible however, that the situation may be changing. There are signs that the huge increase in oil prices may be starting to make local or regional sourcing more economically attractive.¹⁰² The avowed public demand for local or British food (to be taken with a pinch of salt, given the difference between what people say and what people buy) makes decisions to source more locally that much easier.

Air cargo growth also appears to be slowing,^{103,104,105,106} and the inclusion of aviation in the EU emissions trading scheme may have a part to play too. There is also some evidence of modal shift to rail and road as buyers seek cheaper, less oil intensive, alternatives.

¹⁰¹ Rajiv Gandhi Airport to set up centre for perishable cargo, India Aviation, 19 August 2008, <http://www.indiaaviation.aero/news/airline/13460/59/Rajiv-Gandhi-Airport-to-set-up-centre-for-perishable-cargo> .

¹⁰² Anecdotal evidence based on discussions with individuals from within the food industry, July 2008.

¹⁰³ IATA show airfreight drop in May, Air Cargo News 7 July 2008
http://www.aircargonews.net/article.asp?art_id=3488.

¹⁰⁴ JFK Freight Falls 6.4 Per cent, Air Cargo News
http://www.aircargoworld.com/break_news/07172008a.htm, accessed 18 July 2008.

¹⁰⁵ Continental loses \$3 million http://www.aircargoworld.com/break_news/07172008_chtm, accessed July 2008.

¹⁰⁶ Europe's air cargo falls, Air Cargo News, 11 September 2008
http://www.aircargoworld.com/break_news/09112008_chtm.

It is hard to know, however, whether these are temporary, or structural changes. Some air freight industry commentators, for example, predict that aviation growth levels will bounce back to high growth levels¹⁰⁷ or are already doing so.¹⁰⁸ Growth in passenger flights seems to be less affected by fuel costs and it must be remembered that high food volumes are carried in the belly of passenger craft.¹⁰⁹ Many countries are continuing with their expansion plans.¹¹⁰ It should also be noted that many countries heavily subsidise their air freight operations and are still continuing their infrastructure development programmes,¹¹¹ sometimes with the support of international aid agencies.¹¹² It remains to be seen how things will play out.

It is important to bear in mind too that oil price rises are affecting not just the cost of transport leg but the food supply chain in its entirety. Commodity prices as a whole are rising and the costs are played out along the whole of the chain. The cost of transport needs to be balanced against cost elsewhere in the supply chain and it is still entirely possible that for many commodities the more distant source will remain the most economical one.

Another reason why the 'food miles' concern should not be dismissed as unimportant is this: while other industry sectors are beginning, slowly, to clean up their act and even achieve absolute reductions in emissions, green transport fuels are either a long way down the line (hydrogen for example), or environmentally and socially questionable (biofuels). The growth in transport has so far been the great intractable, unbudgeable problem, with its importance, relative to those from other life cycle stages, growing. This is perhaps an overly pessimistic view – as oil prices rise, alternative modes of transport such as rail and short sea shipping become, as noted, more attractive. What is more, there is still massive scope for improving the efficiency of these alternative modes and these could reduce the GHG intensity of transport considerably. This said, as ever, a combination of political will and economic feasibility is needed. Section 7 discusses modal shift, and its scope for reducing transport related GHG emissions in more detail.

Finally for transport, there is the 'what if?' question to consider. We have already highlighted the fact that UK grown products such as tomatoes may be more GHG-intensive to produce in a greenhouse than their sunnier-climed counterparts. But while this may be the 'correct' life cycle answer today, what if, over the next few years, the UK protected horticulture sector were to invest heavily in cleaner or renewable heating and lighting technologies? There is more scope for applying clean fuel sources (biomass, trigeneration, wind and solar) to stationary infrastructure such as commercial greenhouses than there is to moving infrastructure –

¹⁰⁷ *Global air freight forecast to return to strong growth, says OAG*. Official Airline Guide 21 May 2008 <http://www.oag.com/oagcorporate/pressreleases/08+OAG+Air+Freight+Forecast+May08.html> accessed 9 July 2008.

¹⁰⁸ *US air cargo growth grows*, Air Cargo News 9 September 2008 http://www.aircargoworld.com/break_news/09082008b.htm.

¹⁰⁹ *IATA turns attention to freight, as passenger demand increases ahead of expectations*. Air Transport News, 03/07/08 <http://www.airtransportnews.aero/cgi-bin/analysis.pl?id=439>

¹¹⁰ *Turkish operator buys three freighters* Air Cargo News 9 September 2008 http://www.aircargoworld.com/break_news/09052008a.htm.

¹¹¹ *Rajiv Gandhi Airport to set up centre for perishable cargo*, India Aviation, 19 August 2008, <http://www.indiaaviation.aero/news/airline/13460/59/Rajiv-Gandhi-Airport-to-set-up-centre-for-perishable-cargo>.

¹¹² *New Airport Construction to Strengthen Helmand Province*, USAID Afghanistan, 3 August 2008, downloaded from http://www.adp-af.com/index.php?page=en_News.

transport vehicles. Indeed one study found that technically there is potential for UK horticulture to be carbon neutral.¹¹³

What if, coupled with this, increased desertification in Spain forced its horticulture industry to increase its use of energy-using irrigation (a likely scenario)? In these circumstances the UK tomato may become the less GHG-intensive choice. In other words, the answers given to particular life cycle questions can change, depending on what policy-makers actually decide to do and, relative to other life cycle impacts, the prominence of transport increases. Of course what is true of the UK could equally be true of Spain. The Spanish horticulture sector could make concerted efforts to apply renewable technologies to its enterprises, and indeed the use of renewable energy is higher in Spain than it is here.¹¹⁴ As highlighted before, there are also other environmental and social questions that need to be considered, and water scarcity in the case of Spain is a particularly obvious one.

A final point to note for transport is that in future years, as the impacts of climate change start to hit home in the developing world, and agricultural production becomes increasingly vulnerable to climate induced shocks, we may see a growth in imports from rich northern latitude countries to the developing world. How this affects transport-related emissions remains to be seen but perhaps merits further investigation.

Local versus global and the self-sufficiency question

This brings us round to the question of self-sufficiency. Currently we import (in net terms, by value) around 51% of the food we consume.¹¹⁵ Viewed in terms of calorie-sufficiency the figure is probably higher (since we are self-sufficient in grains) but calorie sufficiency is of course only one measure of food security. It is worth bearing in mind that the UK has not been self-sufficient in food for hundreds of years. In the 1840s, around 40% of domestic demand was being supplied by imports.¹¹⁶ In the 1890s a third of the meat consumed in Britain was imported¹¹⁷ and indeed in London most of the meat consumed came from overseas.¹¹⁸

For many environmentalists and development groups there is a link between a more sustainable, equitable and secure food system and one that is more self sufficient.^{119,120} This view is based partly on a conviction that importing foods from thousands of miles away is environmentally damaging and socially inequitable, and partly from a sense that one can have more control over the way indigenous goods are produced than those grown on unknown

¹¹³ *Direct energy use in agriculture: opportunities for reducing fossil fuel inputs*. Final report to Defra by Warwick HRI, Defra project AC0401, May 2007.

¹¹⁴ *PROGRESS: Promotion and growth of renewable energy sources and systems* Final report for the European Commission, Contract no.: TREN/D1/42-2005/S07.56988, Utrecht, 5 March 2008 downloaded from http://ec.europa.eu/energy/res/publications/index_en.htm 20 August 2008.

¹¹⁵ *Origins of food consumed in the UK: 2006*, Table 7.5, Chapter 7, *Agriculture in the United Kingdom* 2007, Defra.

¹¹⁶ Davis R (1979), *The Industrial Revolution and British overseas trade*, Leicester, cited in *Food Security and the UK: An Evidence and Analysis Paper*, Food Chain Analysis Group, Defra, December 2006.

¹¹⁷ *Victorian Agriculture*, University of Guelph,

<http://www.uoguelph.ca/ruralhistory/research/crowley/victorianAgriculture.html>.

¹¹⁸ Oddy, D. J. (2006). *Food quality in London, 1870-1938*, XIV International Economic History Congress, Helsinki, 2006, see <http://www.helsinki.fi/iehc2006/papers1/Oddy.pdf>

¹¹⁹ Mulvany P. (2008) *Food Sovereignty Principles*, UK Food Group, London, <http://www.ukfg.org.uk/ukfg-resources.php> downloaded on 20 August 2008.

¹²⁰ *Sustainable Food*, Sustain, <http://www.sustainweb.org/page.php?id=395> downloaded 20 August 2008.

terrain. Growing your own, it is argued, can protect a nation from the vagaries of economic and climatic conditions overseas.

There are several underlying assumptions here and the security and environmental issues perhaps need to be treated separately. Taking the security question first, is there a specific risk-avoidance argument for shortening the supply chain? This is a difficult question to answer. All supply chains are exposed to risk of one kind or another and although a shorter supply chain will not be vulnerable to some of the risks threatening a global one, the reverse is also true. The risks may be different but not necessarily of less magnitude. Various recent food safety crises such as BSE, Avian Influenza and Sudan Red are all examples of security risks associated with long distance sourcing and potentially affecting a large number of people. On the other hand, if we base our food security on the availability of food grown within, say, a 100 mile radius, then we may be at risk of hunger during poor growing seasons, or during a localised outbreak of *Listeria*, for instance. Others elsewhere might not be affected, but the health and food security of local people could suffer greatly. Arguably, therefore, a well-prepared business is a flexible one – one that develops as broad a supply and market base as possible in order to spread its risks and respond to events with agility.¹²¹ In short, it can be dangerous to put all one's eggs in one basket.

On the other hand this 'flexible' approach can make life very difficult indeed for suppliers. Without secure long-term contracts and a sense of the volumes they need to produce they cannot plan ahead or indeed invest in some of the cleaner technologies and systems that need to be put in place. Insecure, short-term contracts can undermine food production and thereby reduce food security.

Importantly, we cannot talk about food security without considering our energy security.¹²² As we increase our reliance on energy imports,¹²³ so food grown or manufactured in this country will, relying as it does on energy inputs, be inherently import dependent. It has been argued that we should perhaps be aspiring to achieve food security at the European level, since at this scale energy security is a more achievable goal.¹²⁴ It is also important to point out that measures to reduce the dependence of the food sector on energy inputs will, by this measure, also increase food security.

The environmental arguments are perhaps harder to answer. As highlighted above, the relationship between transport and environmental impact is not always clear although we have argued that there are additional important, and damaging, second order consequences of basing economic structures upon globalised provisioning systems. It may also be the case that sourcing more from the UK enables greater control over the quality (and environmental sustainability) of production, although many overseas production systems are in fact highly regulated and controlled by UK retailers. We also need to consider the impacts of export horticulture on food security and long term environmental sustainability in the developing world.

¹²¹ Garnett, T. (2003) *Wise Moves: exploring the relationship between food, transport and CO₂*. Transport 2000.

¹²² *Food Security and the UK: An Evidence and Analysis Paper*, Food Chain Analysis Group, Defra, December 2006 <http://statistics.defra.gov.uk/esg/reports/foodsecurity/default.asp>

¹²³ *Meeting the Energy Challenge: A White Paper on Energy*, Department of Trade and Industry, May 2007.

¹²⁴ *Food Security and the UK: An Evidence and Analysis Paper*, Food Chain Analysis Group, Defra, December 2006.

It is, perhaps, more helpful to explore self-sufficiency from the perspective of long-term changes in the global climate. As we discuss in Section 5, while all regions of the world will ultimately suffer from the consequences of a warming climate, agricultural production in northern latitudes (including the UK), may initially benefit. Countries in the southern hemisphere, on the other hand, and particularly those that are already agriculturally vulnerable, are already beginning to suffer the negative consequences of a warmer, more volatile climate. They will not be able to grow as much or so predictably and so the number of people at even greater risk of hunger will grow.¹²⁵ There is therefore a strong moral case for the UK and other wealthy northern countries to ensure that their farming sector is robust enough to grow enough food not just for their own populations, but for people overseas. There is of course a danger that this point is used as an argument for maintaining high levels of EU subsidy for EU agriculture – a situation that would be damaging to developing world growers. Perhaps the key point is that strong local, regional and national supply networks are important as are global ones – we do not have the luxury of choice.

3.c. Refrigeration

Today's food system is built upon refrigeration. For many foods, refrigeration is a feature of almost every stage in the supply chain, from the point of harvest or slaughter onwards.

Refrigeration creates GHGs both because of the energy used to operate the equipment and because of the inherent GWP of the refrigerant gases most commonly used. The analysis in this section draws upon a detailed FCRN study of food refrigeration, its impacts, its place in our society, and the options for emissions reduction.¹²⁶

3.c.i. Food refrigeration: its contribution to UK GHG emissions

It is hard to quantify precisely what contribution refrigeration makes to the UK's GHG emissions since the number of enterprises that use refrigerated equipment and the size and efficiency of this equipment varies very widely. Roughly speaking, we have estimated, based on partial data, that food refrigeration contributes about 3–3.5% of the UK's GHG emissions.¹²⁷ Data for energy use in refrigeration are available for the food manufacturing, retailing and domestic stages of the supply chain. These total about 2.4% of UK GHG emissions. We have added a further half to one per cent to account for the hidden 'embedded' energy of foods (such as meat, fruit and vegetables) that are grown or manufactured abroad and imported, together with the additional unquantified energy used by mobile refrigeration units while food is being transported within the UK. Overall, therefore, the UK cold chain is responsible for something in the order of 15% of total food chain emissions.¹²⁸

¹²⁵ Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, J. and Tubiello, F.N. (2007) Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.)], Cambridge University Press, Cambridge, UK, 273-313.

¹²⁶ Garnett, T. (2007) *Food refrigeration: What is the contribution to greenhouse gas emissions and how might emissions be reduced?* A working paper produced as part of the Food Climate Research Network

¹²⁷ Ibid.

¹²⁸ See Garnett, T. (2007). *UK food consumption-related greenhouse gas emissions*, working draft, FCRN, <http://www.fcrn.org.uk/frcnresearch/publications/Overall%20food%20GHGs.doc> for the food GHG total.

There is much technological scope for improving the efficiency of refrigeration and the refrigerated supply chain and indeed the Market Transformation Programme (MTP) projections indicate an absolute decline in domestic and commercial refrigeration-related emissions.¹²⁹

However we argue that these MTP figures are open to challenge. Efficiency improvements need to be set in the context of behavioural trends that are hurrying us in ever more refrigeration dependent directions. Back in 1970, over 40% of the UK population did not have a fridge, and only 3% owned a freezer.¹³⁰ Today, ownership of some sort of fridge-freezer combination is virtually universal in this country. Cold chain technology is now embedded in each life cycle stage of today's food system; its ubiquity means that new food products and technologies emerge that are predicated on refrigeration and as such exacerbate and increase our refrigeration dependence. It may be worth bearing in mind too that what is true for refrigeration may also be the case for other energy-using technologies upon which we have come to rely. Indeed, for all the technologies we use, we need to consider not just the carbon emissions associated with their use, but the extent to which they foster a shift towards or away from further reliance on energy-using technologies.

To explore what the implications might be for future energy use it may be useful to take a closer look at how our refrigeration dependence came about. We discuss some of the key drivers in the paragraphs that follow, and then explore the relationship between refrigeration and two key areas of concern – food waste, and food safety.

3.c.ii. Food security, economic growth, working women and time

The Britain of the 1940s and 1950s was still facing high food prices, rationing, and was grappling with the need to build up its food resources and security. Innovations by the food industry were seen as welcome contributions. Companies, for their part, were keen to exploit the potential offered by emerging technology to meet the nation's demand for more varied, affordable food.

With the economic growth that followed the end of the Second World War, average British incomes rose and more women entered the workforce. By 1971 nearly 60% of working-age women were economically active and of course the figure is higher still today at 74%.¹³¹ The result at the household level was more money to spend but less time to shop for food. Prior to this, perishables could be bought daily but now shopping trips had to be made less frequently, which in turn created a need for more effective long-term food storage.

This was increasingly becoming available. The post-war period was characterised by a rapidly intensifying love affair with all things technological. With the growing ownership of televisions, and the introduction of commercial advertising, people were exposed to vigorous advertising not just of cold (and other) appliances, but also of frozen food, an added convenience for the working woman.¹³²

¹²⁹ *Sustainable Products 2006: Policy analysis and projections*, Market Transformation Programme, 2006

¹³⁰ Table presented in *DECADE: Domestic Equipment and Carbon Dioxide Emissions – Transforming the UK Cold Market*, Environmental Change Unit, University of Oxford, 1997.

¹³¹ This is when the Labour Force Survey begins: see *Employment by age and sex – First Release dataset*, Office of National Statistics (data for earlier years are unfortunately not available): http://www.statistics.gov.uk/downloads/theme_labour/LMS_FR_HS/WebTable01.xls

¹³² Cox, H., Mowatt, S. and Prevezer, M. (1999) *From frozen fishfingers to chilled chicken tikka: Organisational responses to technical change in the late twentieth century*, Centre for International Business Studies, South Bank University, Paper 18-99, ISSN No. 1366-6290.

Another change in our shopping patterns has been the almost total demise of daily food deliveries. As more women went out to work, there was no-one at home to receive deliveries. So deliveries could not be made. When daily deliveries were the norm, there was less need for households to own a refrigerator. The onus of (cold) storage was pushed higher up the supply chain and placed on manufacturers and distributors. Indeed in her study of Dutch domestic architecture, the anthropologist Irene Cieraad highlights this relationship between deliveries and daily refrigeration needs.¹³³ She notes that post-war sales of refrigerators were very low in the Netherlands, where daily deliveries were the norm. This is in contrast with Finland where the home delivery system did not exist, and where sales of refrigerators were much higher.

3.c.iii. Marketing, supermarkets and the supply chain

How did all of the necessary infrastructure develop?

In the early days of the domestic freezer, the appliance was very expensive, owned by a tiny minority of the population and viewed largely as a handy means of storing seasonal gluts rather than for storing processed frozen food. Cox *et al.*¹³⁴ argue that it was the frozen food manufacturers themselves who were key to the development and widespread uptake not just of the frozen foods themselves but also of the technological infrastructure. Unilever, a frozen-food pioneer, had, towards the end of the Second World War, acquired the company Birds Eye.

This company already owned subsidiaries producing fish, meat and vegetable products and it already operated its own retail chain of fishmongers. But to make a success of the frozen food concept they needed to sell more products than could be managed through their stores alone. In the 1950s, very few shops had freezers, so in 1957 Birds Eye persuaded two refrigerator manufacturers to design and market 'open-top' display cabinets for retail use.¹³⁵

In return, the company agreed to sell its food only to those retailers who installed them. Later, Birds Eye developed a policy of leasing refrigerated cabinets to some of its more important retail customers on condition that the equipment was used only for stocking Birds Eye products or for other non-competing foods. Meanwhile, consumers were bombarded with an array of Birds Eye marketing and in-store inducements. Thus, in pioneering the mass consumer market for frozen foodstuffs, Birds Eye actually needed to create the infrastructure before households could be offered the product in sufficient quantities to make manufacturing worthwhile.

As the use of frozen food by caterers increased, smaller firms producing unbranded goods entered and broadened the market. This increase encouraged other companies to come in too, specialising in the provision of processing, storage and distribution services for these manufacturers. The role of independent suppliers expanded and their freezing capacity began to rival those of the proprietary branded manufacturers. The consequence was an increase both in frozen food sales and in sales of the domestic freezers needed to store the food.

Hence the frozen food concept spawned the freezer infrastructure, which in turn catalysed further frozen food developments, which in turn extended the infrastructure. Put simply, the

¹³³ Cieraad, I. (2008) The milkman always rang twice: the effects of changed provisioning on Dutch domestic architecture Pp. 163-181. In Hussey, D. and Ponsonby, M. (Eds.) *Buying for the Home: Shopping for the Domestic from the Seventeenth Century to the Present*. Aldershot: Ashgate.

¹³⁴ Cox, H., Mowatt, S., and Prevezer, M. *From frozen fishfingers to chilled chicken tikka: Organisational responses to technical change in the late twentieth century*, Centre for International Business Studies, South Bank University, Paper 18-99, ISSN No. 1366-6290.

¹³⁵ Ibid.

infrastructure generated further infrastructure. This observation may be worth bearing in mind when one considers how the food industry might further develop and what, as a result, the energy implications might be.

Cox *et al.*¹³⁶ also note that the more recent growth in chilled ready-meals has been enabled by another technology – the retailers' information technology (IT) capacities. The short shelf life of chilled meals requires responsive logistics systems, which are themselves underpinned by and dependent on sophisticated IT. In short, the cold chain – and the environmental impacts arising from it – is about more than the refrigeration technology itself. It is about a nexus of transport, packaging, retail and IT infrastructure within which refrigeration technology is situated. How these and perhaps new technologies and infrastructures interact and develop in future years, and what the environmental impacts might be, is impossible to say. It is likely, however, that new developments will arise.

3.c.iv. Supermarkets and transport infrastructure

In addition to the frozen food and its accompanying infrastructure, from about the 1970s onwards the UK saw the development, and rapid expansion, of the supermarket format aided by a massive programme of motorway building and increasing car ownership. This proved the turning point for the freezer and ownership levels rose rapidly.^{137,138} As such the domestic freezer's ubiquity reflects not just the growth in national supermarkets and in national distribution systems, but it has also helped foster their further development. The domestic freezer is now the final point in a long and temperature-controlled supply chain.

Data on shopping patterns going back to the immediate post-war period are unfortunately not available, but more recent data from 1989¹³⁹ show that while the overall number of shopping trips has declined, the number undertaken by car has increased, as has the average distance travelled. Hence car-based travel and food refrigeration have developed symbiotically. More recent signs that the average number of number of shopping trips (for all purposes) and the average distance travelled per person may be slightly slowing – average number of trips per person per year fell by 13% between 1995/97 and 2005 while the average distance travelled to the shops fell by 4%.

Food-specific data are harder to come by; there is, however, one study of long-term changes in shopping patterns in Portsmouth,¹⁴⁰ a city which reflects national demographics. This study finds that the proportion of people shopping twice a week or more frequently rose from 17.5% in 1980 to 40.7% in 2002. The authors point out that this has clearly been aided by the growth in the number of supermarket stores near to where people live and work.

¹³⁶ Cox, H., Mowatt, S. and Prevezer, M. *From frozen fishfingers to chilled chicken tikka: Organisational responses to technical change in the late twentieth century*, Centre for International Business Studies, South Bank University, Paper 18-99, ISSN No. 1366-6290.

¹³⁷ Shove, E. and Southerton, D. (2000) Defrosting the Freezer: From Novelty to Convenience. A Narrative of Normalization, *Journal of Material Culture*, Vol. 5, No. 3, 301-319.

¹³⁸ Although one observer notes the fact that buying half a sheep, say, was cheaper than buying smaller cuts and therefore acted as a major incentive for purchasing a freezer. (Robert Heap, Cambridge Refrigeration Technology, personal communication, December 2006).

¹³⁹ Department for Transport, personal communication October–November 2006.

¹⁴⁰ Clarke, I., Hallsworth, A., Jackson, P., Kervenoael, R., Aguila, R. P. and Kirkup, M. (2006) Retail restructuring and consumer choice 1. Long-term local changes in consumer behaviour: Portsmouth, 1980–2002 *Environment and Planning A* 2006, volume 38, pp. 25-46.

The study also finds that the proportion of trips taken by car fell from 95% in 1980 to 89.5% in 2002, in contrast with the National Travel Study data where the proportion remained constant. Note that the Portsmouth study looks at changes over a long period of time (20 or so years) whereas the National Travel Survey follows food-related travel for a period of only six years, so the two may not be comparable.

Interestingly, the Portsmouth study also reveals a growth in the number of very short food-shopping trips (less than five minutes travel time to store) and a small rise in the number of very long ones (more than 30 minutes – and still constituting only 3% of all food trips). The number of food trips made on the way to or from home has stayed the same; the number made coming back from work has actually declined. Most of the new trips are made when coming back from ‘other destinations’ – a definition that excludes other shops. Perhaps this means that on the way back from work people go on to do other leisure activities and only then make their way home via the shops.

One other revealing finding from the Portsmouth study is that people buy a smaller proportion of the overall food they need at each shopping trip. This is unsurprising – if they are shopping more frequently they are likely to be buying smaller quantities.

The authors of the Portsmouth study suggest that these changes may be due to a number of factors, including:

‘... more hectic lifestyles and a greater proportion of food being sold that is ‘fresh’, chilled, or frozen rather than dry packaged, thus necessitating more frequent shopping. We might speculate too, that this shift masks other important changes in shopping habits, such as the reduction in the number of small, local stores over the last thirty years. This may have forced customers into using the larger stores more frequently for ‘top-up’ shopping as well as their main primary shop.’¹⁴¹

Note that the study looks only at the major store developments and did not look specifically at the growth in the multiples’ smaller store formats. With the growth in single-person living and perhaps a less planned food shopping culture, future years may see this tendency to shop more frequently continue.

One survey shows supermarkets, per square metre, to be more energy intensive than other food shops¹⁴² (although it has been argued that if one were to measure energy use per volume of *food turnover*, the conclusion would be different).¹⁴³ Either way, it is clear that food refrigeration accounts for a large share of their energy use.^{144,145,146} This heavy use of refrigeration reflects both the type of foods that supermarkets sell and the decisions made as to whether or not they need to be displayed in a refrigerated unit. Meat is arguably one product that really does need to be stored cool and when refrigeration use by butchers’ shops and

¹⁴¹ Elsewhere the paper notes that the concentration of multiples has increased, from three in the early 1980s to seven in 2002.

¹⁴² Elsayed, M. A., Grant, J.F., Mortimer N. D. (2002). *Energy use in the United Kingdom: non-domestic building stock: 2002 catalogue of results*. Final report for the Global Atmosphere Division of Defra. Contract reference number EPG 1/1/53 Report reference number SCP 4/12.

¹⁴³ At the time of writing (July 2008) Defra is funding research into this issue.

¹⁴⁴ See <http://www.johnlewispartnership.co.uk/Display.aspx?MasterId=81f00253-1639-4749-a590-d2cd32540b62&NavigationId=613>

¹⁴⁵ See <http://www.jsainsburys.co.uk/files/reports/cr2005/index.asp?pageid=59>

¹⁴⁶ The figure includes ‘catering’ but this is likely to be relatively unimportant.

supermarkets is compared, one finds that both use fairly similar amounts of refrigeration per square metre. However, when it comes to fruit and vegetables, it is interesting to note that, according to the survey cited, greengrocers use almost no refrigeration whereas in supermarkets, many fruits and vegetables are displayed in refrigerated cabinets. In other words, supermarket decisions as to what requires refrigerating have increased the use of refrigeration. What is more, most supermarkets are now open seven days a week and a few twenty-four hours a day. This means that there is relatively little opportunity for the lights to be dimmed and the covers to be put on refrigerated display cabinets, both energy-saving measures. The consequences are inevitably more energy use. The availability of more brands and more variations on particular product types may mean that more (refrigerated) shelf space is required on which to display them. In other words, more choice leads to larger stores and a larger chilled food area, which in turn leads to greater refrigeration requirements.

3.c.v. Housing design and indoor temperatures

Changes in housing design have also played a role in our growing refrigeration dependence. Food has always needed to be stored in cool conditions. A feature of most middle class homes (and an aspiration of working class homes) until about the 1960s was a larder – a cool separate room for keeping food. Plans for Joseph Rowntree’s model ‘garden village’ built at the turn of the 20th century for instance, show that houses were designed with larders,¹⁴⁷ while a few years later, the Government-commissioned Tudor Walters Report of 1918¹⁴⁸ recommended that every house should contain, among other things, a scullery and a larder.¹⁴⁹

The post World War Two era saw a boom in house-building, and between 1948 and 1958 one household in six moved to a new-build house or flat.¹⁵⁰ Even as late as this period, larders were still a feature of these new-build homes and were used.¹⁵¹ However, in 1961 Parker Morris published his Government-commissioned report, *Homes for Today and Tomorrow*.¹⁵² This set new standards for social housing that sought to meet the changing needs of the modern family. In addition to generous minimum space standards,¹⁵³ Parker Morris concluded that there should be more living and circulation space, mainly split into an area for quiet and leisure activity, and an area for eating; the latter could be an enlargement of the kitchen. The formal Sunday-best parlour no longer featured. Tellingly, nor did the larder.¹⁵⁴ The report also placed great emphasis upon better, whole-home heating (in 1970 only 31% of homes had central heating).¹⁵⁵ This was the standard that helped de-specialise the hitherto separate functions of the various rooms. If all rooms are to be used at all times, then they all need to be warm. Homes with central heating and hence higher general ambient temperatures, with little demarcation between cooking and

¹⁴⁷ See <http://www.jrf.org.uk/centenary/homes.html>

¹⁴⁸ Often called the ‘homes fit for heroes’ report, this was commissioned by the Government in 1917 to set standards and to produce model plans and specifications for the building industry in preparation for the house-building programme which was to start at the end of the First World War.

¹⁴⁹ See <http://www.homeownersales.co.uk/1900.html>.

¹⁵⁰ Lyon, P., Colquhoun, A. and Kinney, D. (2004) UK food shopping in the 1950s: the social context of customer loyalty, *International Journal of Consumer Studies*, 28, 1, pp. 28–39.

¹⁵¹ Personal communications with people living and growing up in 1950s-built houses.

¹⁵² Parker Morris (1961) *Homes for Today and Tomorrow* (The Parker Morris Report). London: Ministry of Housing & Local Government, HMSO.

¹⁵³ Ironically, homes built for private buyers were far less spacious.

¹⁵⁴ Brierley, E. S. (2004) [The Social and Environmental influence of the Parker Morris Report](#), *Journal of Applied Psychology* (ISSN 1454-8062).

¹⁵⁵ Brierley, E. S. (2004) [The Social and Environmental influence of the Parker Morris Report](#), *Journal of Applied Psychology* (ISSN 1454-8062).

living areas and with no provision for a separate food storage area, are likely to pose problems when it comes to keeping food cool.

Whether the Parker Morris standards took for granted the widespread ownership of the refrigerator or whether they indirectly helped spur on the rise in uptake is unclear. Low-income groups who were eligible for social housing were perhaps those least likely to be able to afford one but, in the absence of alternative arrangements, the new housing design might have rendered its purchase necessary.

On the other hand this correlation may be too simplistic – the role of marketing and the changing cultural and economic factors also, as discussed, played a very important part. It is of course also the case that most of the population did *not* live in new-build accommodation but in older homes that were less likely to have central heating and more likely to have separate food storage space. One might suggest however that societal changes in our living arrangements helped contribute to a situation that was favourable to the uptake of the domestic refrigerator.¹⁵⁶

The introduction of central heating also raised indoor temperatures. Average internal temperatures have risen considerably from a mean of 12°C in 1970 to 18°C in 2004.¹⁵⁷ These figures are the mean temperature for all rooms; the living area (which, as noted, may also be the kitchen) is normally a couple of degrees warmer. In all then, the average temperature of today's kitchen is likely to be much warmer than it was in the past, making it much harder to keep food fresh without refrigeration. Some evidence suggests that the average internal temperatures are continuing to increase.¹⁵⁸

3.c.vi. Changing food tastes

Although the basic raw ingredients of our diet – meat, dairy products, fruit, vegetables, cereals, fats and sugars – have not changed much since the 1950s (although we are eating more fruit), within those food categories we seem to have developed a taste for the more perishable foodstuffs, such as salads.¹⁵⁹ We are also choosing to eat many foods in processed form; potatoes, say, which have been processed and then frozen or chilled. Other changes such as the massive increase in consumption of chilled soft and alcoholic drinks in the home have also increased refrigeration dependence. In addition, we may have extended our definition of which foods need refrigerating, with pickles and jams (foods that are by definition already preserved) now routinely stored in the fridge.

It is very important to emphasise that the domestic refrigerator is only the final stage in the cold chain. Today, all fruits and vegetables – including those that we might not store refrigerated at home (potatoes, onions, bananas) are temperature-controlled at most other stages in the supply chain. A focus only on the domestic stage obscures the fact that temperature control earlier on in the supply chain is now universal for all fresh and some other products. This would not have been the case for all foods in the 1950s. In future years, our changing, warming climate is also likely to increase demand for refrigeration. Foods such as eggs, which today are usually retailed on open shelves, may need to be refrigerated in coming years. Moreover, in hot weather our preference for chilled and frozen foods is also likely to grow.

¹⁵⁶ Bowden, S. and Offer, A. (1994) Household appliances and the use of time: the United States and Britain since the 1920s, *Economic History Review*, XLVII, volume 4. pp. 725-748.

¹⁵⁷ Utley, J. I. and Shorrocks, L. D. (2006) *Domestic Energy Factfile: Owner-occupied, local authority, private rented & registered social landlord homes*, Defra, Building Research Establishment, Energy Saving Trust.

¹⁵⁸ 17 million UK homes exposed to winter 'gremlins'/ Energy Saving Trust/ICM Poll, 18 January 2006

¹⁵⁹ *Family Food*, Defra 1974–2004/5.

3.c.vii. *The technology-behaviour relationship*

In conclusion, the interactions among refrigeration, packaging, food transport, food product innovations and various socio-economic developments have helped create cultural norms and practices that are highly energy-dependent. Technology and behaviour thus feed on and are intimately related to one another.

As such, refrigeration serves as a symbol, or marker of unsustainable energy use and behaviours in the food system. While technological improvements are important and indeed essential, they do not tackle the reasons *why* we need to use refrigeration: that is, what it is about the foods we eat and the way we manage our lives that renders refrigeration necessary. Nor do efficiency measures address how refrigeration has catalysed developments in other parts of the food supply chain that can lead to rising energy use and GHG emissions. Policies need to address, therefore, not just refrigeration energy *use*, but also refrigeration *dependence*.

3.c.viii. *Food safety and waste*

Food safety is clearly a major concern and storing food at adequately cool temperatures can play a vital role in keeping food safe to eat. However, while no one wants to become ill or die of food poisoning, is a food system which uses less refrigeration inherently more risky?

While the short answer is yes, the long answer may be more nuanced. Temperature control is certainly very important in ensuring our food is safe to eat. However, the presence of refrigeration has, as highlighted, shaped the development of the sorts of foods we choose to eat, the way we shop, and the way we cook. Refrigeration is now essential because of the types of food we choose and the frequency with which we shop. In short, refrigeration has made itself indispensable. It is worth noting too that refrigeration has enabled other food safety problems to arise. It has facilitated the development of longer supply chains which themselves have given rise to international incidence of certain forms of food poisoning. *Salmonella* (in eggs and poultry) and the widespread Sudan Red colouring safety alert are fairly recent examples.

Refrigeration is not always used to preserve the safety of our food; often it is used to preserve its quality. For some foods refrigeration is used, and considered necessary, so as to ensure our food conforms to certain quality standards as much as to preserve its safety. The question then arises as to how far refrigeration is 'necessary' in order to maintain food safety standards and how far it is simply used to preserve food in the condition we have now come to consider as 'normal'. The distinction between 'necessary' and 'cosmetic' refrigeration is of course a difficult and subjective one, and different lines will be drawn by different people.

The advantage of food refrigeration is not just that it stops food from going bad (or delays the process) but that it also has a role to play in waste reduction. This has relevance to the food-GHG issue since wasted food represents a waste of embedded GHG emissions. While, however, there is a relationship between appropriate refrigeration and less waste given two *identical* sets of purchases and an *identical* period of time before it is eaten, the reasons why we waste food are highly complex. It does not automatically follow, however, that more cold storage (or indeed further technological measures to reduce waste) will lead to reductions in waste or, conversely, that in a less refrigeration dependent past (or in less refrigeration dependent households elsewhere in the world) we wasted more food. The amount of food we waste may have much to do with the relative cheapness of food (current food price rises notwithstanding) and our nonchalant attitudes towards wasting food.¹⁶⁰ These prices and attitudes have, one might argue, gone hand in hand with the development of energy using technologies, such as refrigeration, that have provided us with a year-round supply of cheap, abundantly varied food. How we shop for food (and how often), and our attitudes to food and to wasting it, strongly

¹⁶⁰ *Understanding food waste*, Waste Resources Action Programme, March 2007.

influence how much we throw away. We have discussed this in some detail in the full FCRN refrigeration paper referred to earlier.¹⁶¹

3.d. Waste

Around 18–20 million tonnes of food is wasted in the UK each year, with household food waste making the single largest contribution at 6.7 million tonnes.¹⁶²

Food waste contributes to GHG emissions in two ways, one with minor and the other potentially very significant impacts. Regarding the former, if food waste is landfilled it degrades and can generate CH₄. Based on published data¹⁶³ we find that that degrading waste in landfill sites accounts for about 0.3% of the UK's GHG emissions. In theory, however, using anaerobic digestion systems, this waste could actually become a source of energy, offsetting the need to use fossil fuels.

But food waste has another, potentially far more significant, relationship with climate change. Wasted food is also a waste of all the embedded emissions associated with its production, processing, transport and retailing. Most food waste is produced by households, by which stage the food now embodies all previous life cycle stage impacts. The Government funded Waste Resources Action Programme (WRAP) has estimated that UK householders waste 30% of the food they buy and of this approximately 60% is edible, or would have been were it eaten within its sell-by date.¹⁶⁴ Note that the discussion that follows deals mainly with household waste, since this is where most research attention has been focused to date. WRAP is now also undertaking work on waste at earlier stages in the supply chain.

WRAP estimates that food waste at the household stage alone embodies a waste of 18 million tonnes' worth of CO₂, which is equivalent to 2% of the UK's production-related emissions. Note that the 0.3% figure mentioned earlier refers to actual emissions generated at landfill sites. The 2% given here are avoidable emissions – that is, emissions that could theoretically be avoided simply by not growing, transporting, retailing and purchasing food that ends up uneaten. These emissions are already accounted for in figures given for agricultural production, manufacturing and so forth – they cannot be counted again as that would be 'double counting.' The figure does, however, illustrate the point that a significant proportion of the food we produce 'emits in vain', since it is not eaten.

Fruit and vegetables are the biggest single category of food wasted in the home, representing 42% of all food waste by weight. Bakery products make up 23% while home-cooked and ready meals (whose embodied emissions will include those arising from food processing and cooking) account for a fifth of all food waste. Meat, fish and dairy products, perhaps the most GHG-intensive of all food categories, together account for 14% by weight of wasted food. Milk that ends up being poured down the sink is not included in the figure.¹⁶⁵

WRAP, through its *Love Food Hate Waste* campaign, is urging us to waste less food and indeed 'wasting less' constitutes one of the government's five 'pro-environmental behaviour'

¹⁶¹ Garnett, T. (2007) *Food refrigeration: What is the contribution to greenhouse gas emissions and how might emissions be reduced?* A working paper produced as part of the Food Climate Research Network.

¹⁶² WRAP estimates 2008, http://www.wrap.org.uk/retail/food_waste/nonhousehold_food.html, based on mixed data sources.

¹⁶³ Karen Fisher, ERM, personal communication, August 2007 based on data from Fisher K, Collins M, Aumônier S and Gregory B. *Carbon Balances and Energy: Impacts of the Management of UK Wastes*, Defra R&D Project WRT 237 Final Report, ERM, December 2006.

¹⁶⁴ *The Food we Waste*, Project code RBC405-0010 Waste Resources Action Programme, Banbury, 2008.

¹⁶⁵ *The Food We Waste*, Project code RBC405-0010 Waste Resources Action Programme, Banbury, 2008.

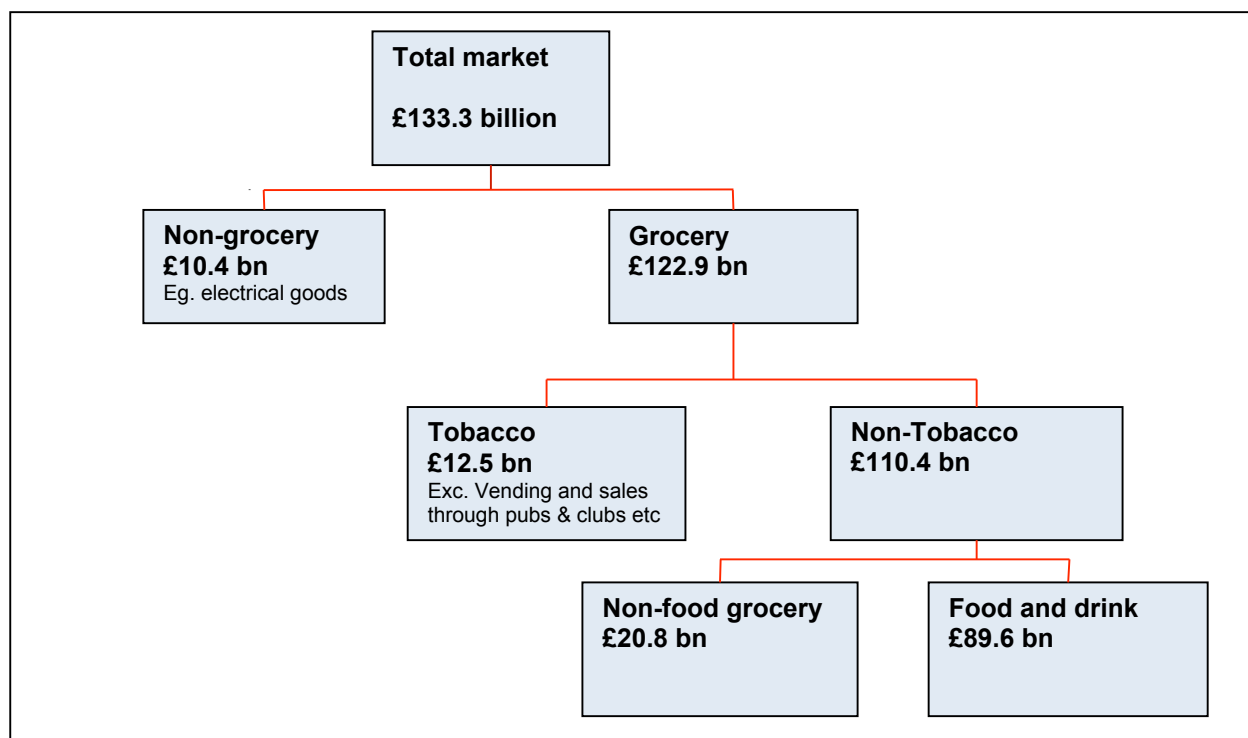
recommendations for food which are discussed further in Section 8. However, while no one could possibly argue with the sentiments behind this campaign, the logic behind it may be a little simplistic. In essence it runs as follows: if we didn't waste so much food, we wouldn't need to grow, process, transport and retail so much and so food-related emissions would decline.

But is that what would really happen? What actually is the link with consumption and production?

If people wasted less food, they might use the money saved to 'upgrade' to more expensive foods; if so, what would the environmental impacts be? They could switch to buying more 'sustainable' products such as MSC approved fish – or to more luxury products, such as blueberries flown in by air. Alternatively they might use their money to buy more non-food goods or services – and how do the impacts of increased DVD purchases, or holidays, compare with the embedded emissions of the food they are no longer buying? Crucially, if people wasted less food, and so bought of it, how would retailers respond? Would they expand overseas with renewed vigour? Tesco, for example, already has over 1200 stores across Europe and Asia.¹⁶⁶ Would this expansion replace other stores? And are these other stores more or less efficient? Or are they just fuelling demand?

Would food retailers step up their non-food range which, as Figure 6 shows, already accounts for a significant and growing chunk of their turnover?

Figure 6: Grocery market breakdown of sales by product group in 2007



Source: IGD, UK Grocery Outlook, 2007.

What would the impact be on the agricultural suppliers? Would they grow less food? Would they diversify into new food areas or into non-food enterprises – golf courses for instance? Or tourism? Or biofuels? Would they seek to increase their sales to customers in other countries? Or would they simply go out of business? This is a multi-balled game of snooker and all of us playing are beginners. None of the consequences can be readily foreseen.

¹⁶⁶ Annual review and summary financial statement, Tesco, 2007.

What is clear, however, is that initiatives encouraging us to waste less food, while important in raising awareness of the issue, are not by themselves enough. A policy approach that considers the food system as a whole and asks how the economics and *structures* of provisioning might need to be changed, is essential.

This is easier said than done. Tackling ‘the system’ implies the presence of a highly centralised, ‘command and control’ type of political system – which we don’t have. And even if we did, history shows that these heavy-handed political approaches have themselves been highly inefficient.

Another way forward might be to introduce a price for carbon and then leave it to the market to resolve the issue. Recent higher food prices are themselves an embryonic form of carbon pricing since they reflect in part higher CO₂ emitting fuel costs. To be effective, carbon pricing must operate at an international level and this is a possibility being explored in the run up to the Copenhagen Summit in 2009, where a post-Kyoto way forward is being negotiated. In addition, the carbon price must include emissions by all the GHGs, including CH₄ and N₂O. Omitting them would give a very distorted picture of food’s true contribution to global warming.

So far our discussion has focused largely on household waste as this is where most of it occurs in the food supply chain. Other stages are important too, however, and a recent Defra report found that, for the sample they examined, food waste as a per centage of production ranged from 2% to 33%, with a median value of 6%.¹⁶⁷

What is perhaps most interesting about the waste that occurs at the retail and manufacturing stage is that it provides insights into the relationship between retailers, suppliers and shoppers. For retailers, the over-riding concern is to ensure total consistency and availability of the product in question. This can mean over-ordering, which in turn leads to waste. Retailers demand that their suppliers should be able to provide what they need, when they need it, often at short notice. Manufacturers in turn, respond by over-producing products and also by ordering in extra raw ingredients so that products can be made up at short notice.¹⁶⁸ Where the ingredients are perishable, this can be an additional source of food waste. All this, in turn, reflects retailers’ perceptions as to what customers want: wants that, arguably, they have helped create.

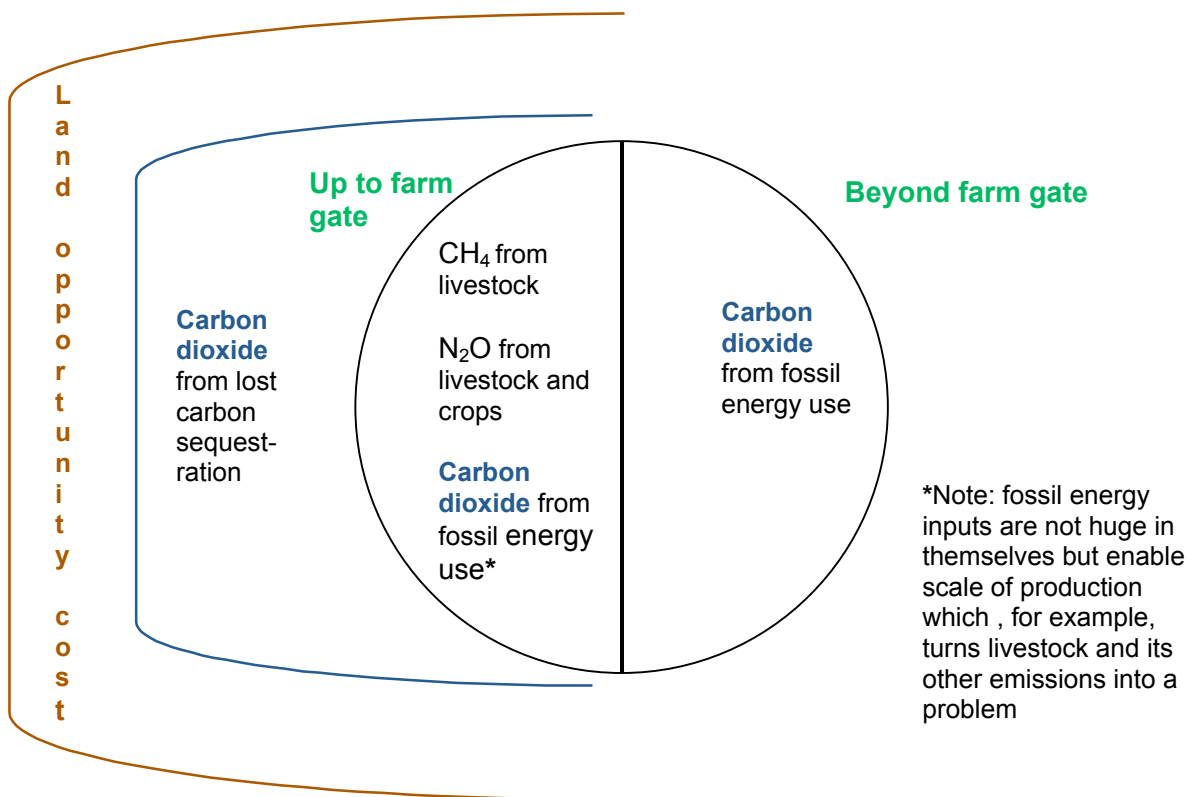
3.e. The relative importance of the different gases by life cycle stage

This section has taken a life cycle perspective, discussing the impacts of different stages and their individual contribution to overall food GHGs. We conclude this section by discussing the relative importance of the different GHGs by life cycle stage. Figure 7 shows in diagrammatic form how the different gases contribute to overall food chain emissions.

¹⁶⁷ *Sustainable Waste Management in the Chilled Food Sector*. Report produced by Imperial College for Defra, Defra 2007.

¹⁶⁸ Note that, at the time of writing (June 2008), Defra is commissioning research looking at food waste in the manufacturing part of the chain.

Figure 7: Pre- and farm gate emissions: the differing roles of the GHGs



For agriculture, the main gases of concern are CH₄ from ruminant livestock,¹⁶⁹ N₂O from both arable and livestock systems and the CO₂ releases that result from changes in land use. Ultimately there are also the GHG implications of the opportunity cost to consider. While fossil energy use does not appear to be so critical to overall agriculture related emissions it is important to remember that it performs a vital catalytic function: oil based inputs make possible, for example, the intensive cultivation of large numbers of animals that, in turn, generate CH₄ and N₂O emissions. Without fossil energy inputs, we would not have managed to farm at such a scale or such a level of intensity. In short, fossil energy sources seed-fund production systems that contribute significantly to global warming.

From the farm gate onwards however, the importance of CO₂ from fossil fuel combustion becomes more straightforwardly apparent. Note that we have applied the opportunity cost concept to the agricultural stage only but it might easily apply to the post farm gate stages too. For example: what should we optimally choose to use our energy on – manufacturing ice-cream or improving transport systems in rural areas?

¹⁶⁹ And paddy rice cultivation in countries where rice is grown.

4. GHG EMISSIONS BY FOOD TYPE

Give me a string bean, I'm a hungry man...
Bob Dylan, *Talkin' World War III Blues*

The previous section looked at the contribution that different life cycle stages make to food GHG emissions. This section takes a product-specific approach: it looks at three main food types and considers what contribution they make to GHG emissions and why. These three foods are livestock based foods, fruit and vegetables, and alcoholic drinks.

The analysis we present is based on detailed studies of these foods undertaken during the course of the FCRN project.^{170,171,172} Resource constraints have not, unfortunately, allowed us to examine all the main food groups. Cereals are, to an extent, discussed in our examination of livestock products, although only at the agricultural stage. There is no analysis here of sugar and sugar-containing foods, of oils and fats, or of soft drinks. It will also be apparent that we devote far more space to livestock products than we do to fruit and vegetables and alcoholic drinks. This reflects the fact that meat and dairy products are by far and away the most GHG-intensive foods. Note that what follows here is only a brief summary of our findings; more extensive analysis can be found in the studies themselves.

The advantage of a food specific approach is that 'emission hotspots' – stages in the life cycle where environment impacts are greatest – can be identified. Figures 3, 4 and 5 above, show that, as a whole, agricultural production contributes to around half of all food related GHG emissions and that this stage is the most environmentally significant in the food life cycle. Yet while this is true in general, the relative importance of different life cycle stages varies considerably by food type. For some foods, the cultivation of the raw ingredients is less environmentally impactful than, for instance, the processing, or the transport stage, or the activities associated with cooking and storing the food in the home. Table 3 below highlights the emissions hotspots for just a few different types of food. For some foods of course, the impacts are quite evenly distributed along the whole of the supply chain – there is no individual culprit.

¹⁷⁰ Garnett, T. (2007). *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

¹⁷¹ Garnett, T. (2006). *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

¹⁷² Garnett, T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

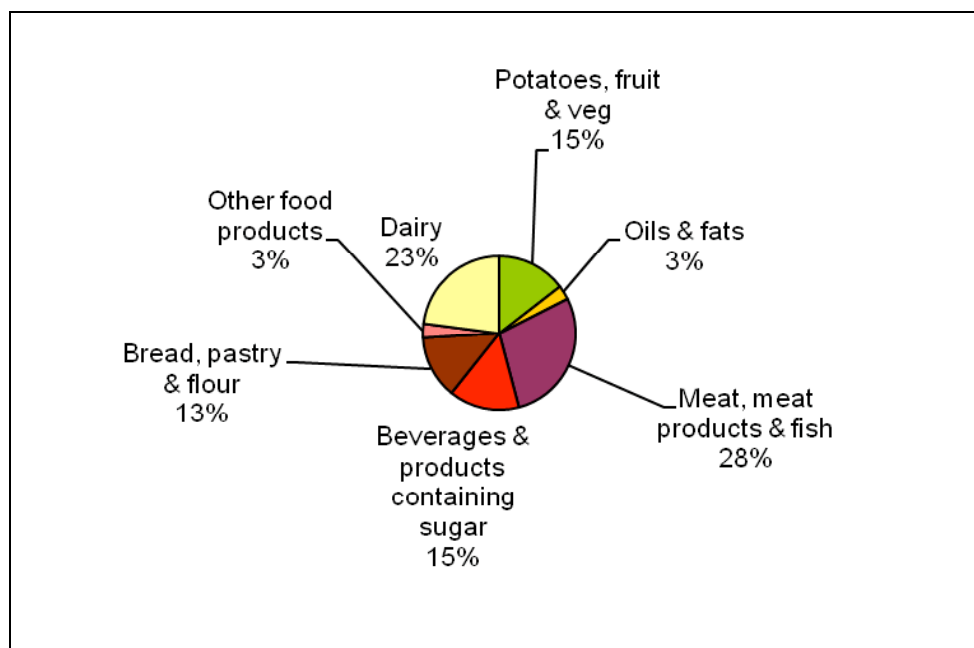
Table 3: Foods and their emission hotspots

Food	Life cycle stage hotspot	Source
Meat and dairy	Agriculture	Berlin, J. (2002) Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, <i>International Dairy Journal</i> 12 939–953 Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B, Flynn, A and Mylan, J (2006) <i>Environmental impacts of food production and consumption, A report produced for the</i> Department for Environment, Food and Rural Affairs
Fresh fruit and vegetables	Variable – transport can be significant depending on distance and transport mode; production most significant for produce grown in greenhouses. Cooking may dominate if produce is cooked	Sim, S., Barry, M., Clift, R., Cowell, S.J. (2007) The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing. <i>Int J LCA</i> 12 (6) 422–43 <i>Environmental Impacts of Food Production and Consumption: A research report completed for the Department for the Environment, Food and Rural Affairs by Manchester Business School, December 2006</i>
Bread	It depends – combination of agriculture, transport and baking	Anderson, K. and Ohlsson, T. (1999) Life Cycle Assessment of Bread Produced on Different Scales <i>Int. J. LCA</i> 4 (1) 25–40
Crisps	Agriculture 40%; processing 30%; Packaging 15%; transport 9%; disposal 2%	Walkers Carbon Footprint – http://www.walkerscarbonfootprint.co.uk/walkers_carbon_footprint.html
Chocolate	Agriculture (dairy milk production) 60%	Cadbury pers.comm. September 2008

Clearly in order to achieve reductions, all stages of the food life cycle require attention. However to tackle the problem of food-generated GHG emissions, it can also be useful to cut up the cake differently, and consider impacts not just by life cycle stage, but by food type.

When looked at this way, it becomes apparent that certain types of foods are inherently more GHG-intensive than others. Figure 8, taken from Kramer *et al.*, shows that meat and dairy products account for over half of all food’s GHG emissions.

Figure 8: Contribution of food groups to Dutch GHG emissions kg/CO₂eq



Source: Kramer, K.J., Moll, H.C., Nonhebel, S. and Wilting, H.C. (1999) Greenhouse gas emissions related to Dutch food consumption, *Energy Policy* 27 203–216.

Fruit and vegetables, starches and sugary foods each contribute around 13-15%.

The remainder of this section discusses the three food groups that, as highlighted, we have looked at in most detail, beginning with foods of animal origin.

4.a. Livestock: foods of animal origin

There is a large and growing literature on the GHG emissions associated with livestock rearing.^{173,174,175,176,177,178} The findings broadly conclude that livestock products are GHG-intensive compared with other food groups, and that the vast majority of impacts occur at the farm stage, with subsequent processing, retailing and transport playing more minor roles.^{179,180}

¹⁷³ Casey, J.W. and Holden, N.M. (2006) Quantification of greenhouse gas emissions from suckler-beef production in Ireland, *Agricultural Systems* 90, 79–98.

¹⁷⁴ Casey, J.W. and Holden, N.M. (2005) The Relationship between Greenhouse Gas Emissions and the Intensity of Milk Production in Ireland, *Journal of Environmental Quality*, 34:429–436.

¹⁷⁵ Cederberg, C. and Mattson, B. (2000) Life cycle assessment of milk production — a comparison of conventional and organic farming, *Journal of Cleaner Production* 8 (2000) 49–60.

¹⁷⁶ Cederberg, C. and Stadig, M. (2003) System Expansion and Allocation in Life Cycle Assessment of Milk and Beef Production *Int J LCA* 8 (6) 350–356.

¹⁷⁷ Lovett, D.K., Shalloo, L., Dillon, P. and O'Mara, F.P. (2006) A systems approach to quantify greenhouse gas fluxes from pastoral dairy production as affected by management regime, *Agricultural Systems* 88.

¹⁷⁸ Basset-Mens, C. and van der Werf, H.M.G. (2005) Scenario-based environmental assessment of farming systems: the case of pig production in France, *Agriculture, Ecosystems and Environment* 105 127–144.

¹⁷⁹ Berlin, J. (2002) Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, *International Dairy Journal* 12 939–953.

¹⁸⁰ Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A. and Mylan, J. (2006) *Environmental impacts of food production and consumption, A report produced for the Department for Environment, Food and Rural Affairs.*

These too are the findings of the FCRN livestock study; what follows is largely based on this work.¹⁸¹

It has been estimated in a report by the Food and Agriculture Organisation (FAO) that, globally, the livestock system accounts for 18% of GHG emissions.¹⁸² At the European level, the EU-commissioned report referred to earlier¹⁸³ puts the contribution of meat and dairy products at about 13% of all EU GHGs.

For emissions arising from livestock consumption in the UK, we have attempted a very approximate estimate, using as a basis for our calculations a study by Cranfield University¹⁸⁴ that calculates GHG emissions per kg of different livestock products (eggs, milk, beef, pork, sheep meat, poultry). When we multiply these per kg emissions by total consumption of these products in the UK, we find that the rearing of livestock for our consumption generates 15.7 MtCe_q. As a proportion of the UK's total national consumption-related GHG emissions this constitutes around 8% (see Section 2 above for a discussion). The figure is very approximate but serves as an adequate starting point for exploring the livestock–GHG relationship further. Note that this figure takes into account imported products and excludes livestock products produced in this country and then exported. It does not include emissions resulting from slaughtering, processing, cooking or other stages.

This contribution, according to the Cranfield analysis is largely attributable to emissions of CH₄ and N₂O. CO₂ emissions, arising largely from the use of field machinery, milking parlours and so forth, are generally less significant for ruminants – although for intensive pig and poultry production their importance is greater. Other studies find that CO₂ plays an even less important role for ruminant systems. Olesen *et al.* find that N₂O contributes on average about 49% of the total GWP, and CH₄ about 42% – leaving a CO₂ contribution of only 9%.¹⁸⁵ A comparison of two beef farms places higher emphasis on N₂O emissions (60%), and less on CH₄ (25%), but again finds CO₂ emissions to be low at 15%.¹⁸⁶ According to Schils *et al.*,¹⁸⁷ for a dairy system, CH₄ accounts for 49% of emissions, N₂O 27%, and CO₂ 24%. Gibbons *et al.*¹⁸⁸ give the following breakdown for a mixed dairy and beef farm: CH₄ – 54.4%; N₂O – 36.5% and CO₂ – 9.2%. However, these findings ignore the catalytic role that energy inputs play.

¹⁸¹ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

¹⁸² *Livestock's Long Shadow*, Food and Agriculture Organisation, December 2006.

¹⁸³ Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25, European Commission Technical Report EUR 22284 EN, May 2006.

¹⁸⁴ Williams, A.G., Audsley, E. and Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

¹⁸⁵ Olesen, J.E., Schelde, K., Weiske, A., Weisbjerg, M.R., Asman, W.A.H. and Djurhuus, J. (2006) Modelling greenhouse gas emissions from European conventional and organic dairy farms, *Agriculture, Ecosystems and Environment* 112 207–220.

¹⁸⁶ Flessa, H., Ruser, R., Dörsch, P., Kamp, T., Jimenez, M.A., Munch, J.C. and Beese, F. (2002) Integrated evaluation of greenhouse gas emissions (CO₂, CH₄, N₂O) from two farming systems in southern Germany, *Agriculture, Ecosystems and Environment* 91 175–189.

¹⁸⁷ Schils, R.L.M., Verhagen, A., Aarts, H.F.M. and _ebek, L.B.J. (2005) A farm level approach to define successful mitigation strategies for GHG emissions from ruminant livestock systems, *Nutrient Cycling in Agroecosystems* 71. 163–175.

¹⁸⁸ Gibbons, J.M., Ramsden, S.J., Blake, A. (2006) Modelling uncertainty in greenhouse gas emissions from UK agriculture at the farm level, *Agriculture, Ecosystems and Environment* 112, 347–355.

Clearly the differences between the 18% of the FAO calculation, the 13% of the EU report and the 8% we estimate for the UK are significant. The differences reflect in part different methods of calculation and – inevitably – the inherent difficulties of making any estimates for large-scale activities involving living creatures and high variability in practice and land type. There are, however, other explanations for the differences. As with the estimates given for agriculture above, the importance of livestock rearing relative to other GHG-emitting national activities will depend on how developed a country is, and the balance between agriculture and other industrial and domestic activities. This too will account for some of the variation in estimates. Perhaps most importantly, the FAO figure includes livestock-induced land degradation and deforestation, and the ensuing release of CO₂, an issue we touched upon earlier (and also discuss in Section 6). The EIPRO calculation does *not* include land use change. Nor do we, owing to lack of data; we cannot, however, overemphasise the importance of its inclusion in any fuller analysis.

Whatever the differences between the figures and the assumptions, the impacts are clearly significant. With consumption of meat and dairy products anticipated to double by 2050 (see Section 8 for a discussion)¹⁸⁹ emissions are set to grow.

Ultimately, we have to eat, and feeding ourselves will always generate an impact. If we did not consume meat, milk and other livestock foods we would still have to expend energy and emit GHGs to produce substitute foods – although of course many of us in the developed world could also eat less. The same applies to alternatives for leather, wool, manure and rendered products. In other words, there will always be an ‘opportunity cost’ of securing foods and other products from non-animal sources. Moreover, livestock use waste food and by-products, and graze on land that cannot be used productively for other forms of agriculture. As such, they provide waste disposal services and improve resource efficiency. When livestock are part of a rotation, as in mixed livestock-arable systems, they help build organic matter and fertility in the soil; this aids the cultivation of the crops that follow.

Put very simplistically one could argue that if we did not eat the livestock that make use of this unproductive land then we would have to feed ourselves by growing crops on alternative land – and land suitable for cropping is increasingly scarce. We would have either to encroach upon other land areas (with possibly damaging effects), or to intensify production (where possible) on existing arable land, with possibly harmful environmental consequences. It is against the opportunity costs of non-animal alternatives, and the resource efficiency function of livestock rearing that we should properly weigh the GHG burden of livestock production.

Hence in order to gain a true picture of the impacts of livestock production and consumption, we need to consider more carefully both the inputs to, and the multiple outputs from, the livestock production system.

4.a.i. Inputs

The main inputs to livestock production are, broadly speaking, energy, feed (including forage), land and water (the latter is not discussed here, although it is evidently very important). For feed and grazing land, we need to consider several questions. Firstly, we must examine not only the direct, first order, impacts of livestock production but also the indirect consequences of land use change. We call these the ‘second order impacts.’ Secondly, we need to explore the ‘what if’ consequences of using these inputs for alternative purposes – could they be used for something else and what might the implications be for GHG emissions? This approach is clearly needs- rather than demand-oriented. It assumes finite resource limits, particularly on the availability of land and the capacity of the atmosphere to absorb GHGs without catastrophic disruption. In the light of these assumptions, it asks what the most appropriate way of feeding ourselves might be.

¹⁸⁹ *Livestock’s Long Shadow – Environmental Issues and Options*, FAO, December 2006.

Most food projections such as those published by the FAO¹⁹⁰ and the International Food Policy Research Institute (IFPRI)¹⁹¹ take current demand trajectories as an unquestionable given. We argue in Section 8 that this position is ultimately unrealistic.

Energy

Energy-derived emissions arising from livestock production are relatively speaking low. Through the use of renewable inputs such as wind and solar power, and biogas from digestion, they may also be relatively straightforward to tackle, as Section 7 discusses.

However, while on the face of it fossil energy use does not make an enormous contribution to overall GHG emissions, we have already noted that it performs a vital catalytic function: oil based inputs make possible the intensive cultivation of large numbers of animals that, in turn, generate CH₄ and N₂O.

Feed

Livestock in the UK consume four main types of feed: forage (usually grass), oilseeds, cereals and by-products arising from agriculture and the food industry. We discuss forage in the section on land.

Oilmeals

Oilmeals are a key element of the livestock diet. Some, namely soy, are not so much by-products of oil production as co-products; the relative economic balance between soymeal and soy oil fluctuates, but as a general rule the cake and oil account for two-thirds and one-third of the crop's economic value respectively,¹⁹² and in some years demand for the cake actually drives oilseed cultivation. Measured by weight, every 100 kg of soybean yields 20 kg of oil and 80 kg of cake or meal¹⁹³ and so in absolute terms, the value of the cake is higher. While soy oil ranks in value as one of the less valuable vegetable oils (peanut, cottonseed, corn and rapeseed oils attract higher market prices), soymeal cake carries the highest value of the oilseed cakes.¹⁹⁴ Economically, therefore, soy cake should by no means be classed as a by-product since it has very considerable economic value.

A key concern for soy is the potential 'second order' impacts of oilseed cultivation that we have already highlighted in the section on agriculture, above. This concern is starting to receive major attention because of the rapid expansion in biofuels production and is relevant not just to soy but to palm oil, sugar, and other feedstocks.¹⁹⁵ Livestock rearing is implicated not just for the reasons highlighted but also because of the complex relationship between biofuels production and livestock farming, a relationship that is both conflictual and synergistic.

At present the rush to grow crops for biofuels is one of the factors that have led to raised feed prices since the available supply of livestock feeds has thereby been reduced. If we continue to demand both biofuels and animal protein produced from feed grains then one or all of three

¹⁹⁰ *World agriculture: towards 2030/2050. Interim report. Prospects for food, nutrition, agriculture and major commodity groups* Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations Rome, June 2006.

¹⁹¹ Rosegrant, M.W., Paisner, M.S., Meijer, S. and Witcover, J. (2001) *Global Food Projections to 2020: Emerging Trends and Alternative Futures*, International Food Policy Research Institute, Washington D.C.

¹⁹² *Food Outlook: Global Market Analysis*, Statistical Appendix Table A24 – Selected international prices for oilcrop products and price indices, Food and Agriculture Organisation, 2008.

<http://www.fao.org/docrep/010/ai466e/ai466e14.htm>

¹⁹³ Nonhebel, S. (2004) On resource use in food production systems: the value of livestock as 'rest-stream upgrading system', *Ecological Economics* 48 221–230.

¹⁹⁴ Table 10. U.S. oilseed meal prices, *Oil Crops Outlook*, August 13, 2008, Economic Research Service, United States Department of Agriculture.

¹⁹⁵ *Are biofuels sustainable?* First Report of Session 2007–08, House of Commons Environmental Audit Committee, January 2008.

consequences will occur.¹⁹⁶ One possibility is that more land will be cleared to accommodate the additional demand. Alternatively, increased inputs will be applied to increase productivity. Both approaches may lead to increases in GHG emissions; lost carbon sequestration from the former; more energy and fertiliser emissions from the latter. A third alternative is that land used for less commercially profitable crops will be taken over. These types of crops will then either be grown on marginal land (lost carbon sequestration) or production will simply cease, with damaging consequences for poorer people who tend to rely on them.

But biofuel and livestock production may also complement each other.¹⁹⁷ During bioethanol production, alcohol is produced, leaving a residual product rich in protein, fibre, various micronutrients and yeast. Such a product could reduce the need to grow dedicated feed crops but while this in itself may be environmentally beneficial, a scenario in which first generation biofuel production and livestock rearing were actually to complement one another, increasing the profitability of each, would give further impetus to both activities – and the negative environmental consequences of these activities, including GHG emissions, would grow.

In short, the cultivation of agricultural products overseas for UK consumption including, but not limited to, oilseeds can lead to land clearance and deforestation overseas; this in turn, gives rise to releases of stored carbon. LCAs of livestock impacts do not, as a rule, take into account carbon emissions arising from overseas changes in land use that are caused by UK consumption. This has a particular bearing on some of the mitigation issues proposed as we discuss in Section 7.

Cereals

Cereals are a major source of nutrition for pigs, poultry, dairy cows and for beef cattle in intensive systems. Livestock consume more than half¹⁹⁸ of the 20 million tonnes of cereals consumed in the UK: over 50% of wheat and over 60% of barley. The FAO calculates that globally, one-third of the cereals grown are used to feed livestock¹⁹⁹ while the World Resources Institute puts the figure higher at 37%.²⁰⁰ While livestock in the developing world generally consume far fewer cereals and rely more on foraging and by-products, this situation is anticipated to change²⁰¹ as production systems intensify and as we see a growth in chicken and pig production systems that tend to be highly grain-dependent. The recent increases in cereal prices may dampen but not block this effect.

30-37% represents a very considerable share of world cereal production and it prompts several questions. What is the GHG 'opportunity cost' of using land to feed animals rather than feeding people? Is it not less GHG-intensive for hungry people to eat cereals directly since much of the energy value is lost during conversion from plant to animal matter? It has indeed often been argued that feeding cereals directly to animals is wasteful since plant foods could be more

¹⁹⁶ Kløverpris, J., Wenzel, H. and Nielsen, P.H. (2008) Life Cycle Inventory Modelling of Land Use Induced by Crop Consumption Part 1: Conceptual Analysis and Methodological Proposal, *Int J LCA* 13 (1) 13–21 (2008).

¹⁹⁷ Cottrill, B., Smith, C., Berry, P., Weightman, R., Wiseman, J., White, G. and Temple, M. (2007) *Opportunities and implications of using the co-products from biofuel production as feeds for livestock*. Report prepared by ADAS and Nottingham University for the Home-Grown Cereals Authority, English Beef and Lamb Executive and British Pig Executive.

¹⁹⁸ *Agriculture in the UK 2006 – 2005 figures*: figures derived from tables 5.1, 5.2, 5.3, 5.4.

¹⁹⁹ *World Agriculture: towards 2015/2030. Summary report*, FAO, 2002.

http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/004/y3557e/y3557e00.htm

²⁰⁰ World Resources Institute: *Food Security: Grain fed to livestock as a percent of total grain consumed* 2003/4 data <http://earthtrends.wri.org/>.

²⁰¹ Keyzer, M.A., Merbis, M.D., Pavel, I.F.P.W. and 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* Volume 55, Issue 2, Pp 187–202.

efficiently consumed directly by people.^{202,203,204} We define efficiency here as fewer GHG emissions per unit of nutrition, although efficiency can also refer to, for example, water use.

Various authors have calculated the feed energy required to produce a calorie of animal protein. This, the 'feed conversion efficiency,' has a major bearing on the emission of GHGs since losses of nutritional energy through the production chain – from plant to animal nutrients – means that more GHGs are emitted for a given quantity of nutritional output. For broiler chickens reared in conventional farm systems, feed efficiency is high at 1.8 (finishing stage).²⁰⁵ In other words, 1.8 kg of grain is used to produce 1 kg of chicken. For eggs the conversion ratio is around two²⁰⁶ while for finishing pigs it is now 2.75.²⁰⁷ The efficiency of beef cattle is far harder to estimate since much will depend upon the breed and the feeding regime. Also, as we discuss later in this section, ruminants can consume grass and fibrous by-products that cannot be eaten directly by humans. Roughly speaking, the feed conversion ratio can vary between five and ten.²⁰⁸ In the developing world, feed conversion rates will be much lower due to differences, among other things, in the breed of animal and in the feeds consumed.

Nonetheless, notwithstanding differences between livestock types, the protein conversion efficiency of animal based foods is significantly lower than that of plant based foods (expressed in terms of the energy required to produce a gram of protein).^{209,210} On the other hand, a simplistic comparison ignores differences in the type of protein and in the other nutritional properties of different types of food. We explore this later in the section.

When distinguishing between livestock types, it appears, on the face of it, that poultry and pigs are much more efficient converters of plant energy into animal energy and, moreover, as monogastrics, they produce far less by way of CH₄ emissions. From a GHG perspective then, policies to encourage a switch to consumption of these products would seem to make sense and this is indeed the way consumption trends are heading.²¹¹

However, it is also the case that the monogastric diet is cereal-dependent to a far greater extent than that of ruminants. More so than ruminants, pigs and poultry consume grains that humans could eat directly and therefore they are inherently more implicated in land use change and the subsequent CO₂ impacts. This said, in industrialised systems of production and for current expectations of productivity, cereal feeding is essential to the diets of all livestock types; cattle in fact consume large volumes of cereals. Thus, while a diet of grass alone would support ruminants and not monogastrics, the overall numbers that could be fed in this way would be very considerably lower.

²⁰² Goodland, R. (1997) Environmental sustainability in agriculture: diet matters, *Ecological Economics*, 23 189–200.

²⁰³ Gold, M. (2004) *The global benefits of eating less meat*, Compassion in World Farming Trust, Petersfield, Hampshire.

²⁰⁴ Gerbens-Leenes, P.W. and Nonhebel, S. (2002) Consumption Patterns and Their Effects on Land Required for Food *Ecological Economics* 42 S. 185–199.

²⁰⁵ *Poultry UK*, Biffaward, 2006

²⁰⁶ Chen, Y.C., Nakthong, C. and Chen, T.C. (2005) Improvement of Laying Hen Performance by Dietary Prebiotic Chicory Oligofructose and Inulin *International Journal of Poultry Science* 4 (2): 103–108.

²⁰⁷ *Pig Year Book 2007*, British Pig Executive, 2007.

²⁰⁸ Meat and Livestock Commission, pers. comm., September 2007.

²⁰⁹ Pimentel, D. and Pimentel, M. (2003) Sustainability of meat-based and plant-based diets and the Environment *American Journal of Clinical Nutrition*;78(suppl):660S–3S.

²¹⁰ Reijnders, L. and Soret, S. (2003) Quantification of the environmental impact of different dietary protein choices. *American Journal of Clinical Nutrition*;78(suppl):664S–8S.

²¹¹ *Prospects for food, nutrition, agriculture and major commodity groups. World agriculture: towards 2030/2050* Interim report Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations, Rome, June 2006.

Note that feed conversion efficiency accounts only for the edible outputs of the livestock sector. The calculation does not take into account the non-edible outputs such as manure, leather, wool and so forth, which we discuss further below. If these are considered, the relative efficiencies between livestock types might look quite different. Cattle produce leather whereas chickens do not – although they do produce feathers that can be used in a number of ways. The gap between plant and animal foods might also narrow a little (although plants also provide non edible goods, such as thatching materials, and residues can be composted to provide a soil improver).

By-products

In addition to cereal and oilseeds, a wide range of by-products from other agricultural sectors is also used as animal feed. These include molasses cake, spent hops and brewers grains, vegetable residues, citrus pulp, straw, rice husks, bagasse and so forth. By making use of these, livestock can be seen as resource efficient, yielding food out of unwanted leftovers. By consuming meat and milk we are indirectly consuming ‘waste’ and in so doing obviate the need to grow alternative foods, the production of which would of course generate GHGs. This can be seen as a second order benefit of livestock, translating into avoided GHG emissions.

To understand how far livestock are GHG-efficient in their use of by-products, however, we need to consider two questions. First, how much livestock production do such by-products actually support? And second, are there, or could there be, alternative uses for these by-products which might lead to GHG reductions (the opportunity cost)?

Regarding the first question, Fadel²¹² quantifies the volume of by-products available globally in 1993 and concludes that in theory their nutritional content is sufficient to provide for the production of 80% of that year’s total milk output. If soymeal and other oilseed cakes are excluded (and we have argued that soy cake is not a by-product) the volume of available by-products drops by about 25%.

This would support the resource efficiency argument. But Fadel does not address several issues that might modify the conclusions. Firstly, he does not consider the proximity of the by-products to the livestock and whether the environmental impacts of transporting by-products might actually outweigh the benefits of by-product utilisation. Importantly, too, Fadel considers only dairy cows and does not address the feed requirements of cattle produced primarily for meat (modern dairy cows have little flesh on them), pigs, and poultry. Clearly there are not nearly enough by-products available to feed all the animals that we want to eat.

In short, ruminants do indeed make use of crop residues and other by-products. However, current levels of production cannot be sustained on by-products alone and there may at times be trade-offs between transport impacts and the goals of utilising by-products.

As to the second question: what is the opportunity cost of using by-products for livestock? Could there be alternative uses that yield greater GHG benefits? For example, might there be scope for using them as an energy source – perhaps in a biogas plant? There is enormous interest in food waste-derived anaerobic digestion and a number of commercial projects are either being developed or are running in the UK. The opportunity cost of using by-products to feed animals versus using by-products as a feedstock needs careful examination and the ‘right answer’ is likely to be very context specific. However, it is clear that there could be competition between the use of by-products as a fuel source and as an animal feed.

²¹² Fadel, J. (1999) Quantitative analyses of selected plant by-product feedstuffs, a global perspective. *Animal Feed Science and Technology* 79, 255–268.

Land

Land, both for grazing and for feed production, is the third major input to the livestock system.

What is the opportunity cost of using land for animal rearing? We have argued in the context of wheat production that growing cereals to feed animals that are then eaten by people is inefficient in terms of GHGs, since more nutrition can be generated per given quantity of land if we eat the crops directly.

However, not all land is good enough for arable farming and livestock tend to make use of this poorer quality land. Indeed in some parts of the world – the grasslands of Mongolia for instance – grass is more or less all that grows. There is a case then for saying that livestock rearing can be resource efficient – a GHG avoidance argument similar to that given for by-products. This is true, but only in part. For a start, many grasslands are not a ‘free’ resource. In the UK, while some sheep and cattle are indeed left simply to graze on the uplands, lowland pastures can be heavily fertilised (although this is not the case on organic farms) leading to N₂O and CO₂ emissions, the latter from the fertiliser production process. In all, some 66% of the grassland area in the UK receives nitrogen fertiliser applications.²¹³ In the winter, dairy and beef cattle also eat grass in its fermented form as silage, the production of which requires some energy.

Moreover, when land is overgrazed the combination of vegetative loss and soil trampling can affect nutrient cycles, soil properties and water flow, leading to soil carbon losses and the release of CO₂.²¹⁴ Overgrazing is a significant problem in many parts of the developing world and it has been estimated that 20% of land globally is degraded – up to 73% in drylands.

The problem exists in the UK too, although the picture is mixed and highly locality-specific, as discussed further below. However the UK is also implicated in overgrazing-related carbon losses overseas. Our demand for major agricultural commodities (often grown to feed livestock) pushes livestock farming onto increasingly marginal and vulnerable pasture lands where soils can be quickly degraded. Alternatively, forest land is cleared and this, too, leads to major CO₂ releases.²¹⁵ Demand for biofuels, an additional competitor for land, is likely to exacerbate the problem.²¹⁶

Note that these effects are not attributable to livestock alone but are a consequence of global demand for a whole range of commodities, many of which are eaten directly by humans. The point here is that we may not physically be able to meet our demands for meat, for cereals, for biofuel and for carbon sequestration: something has to give.

This is very much the view of Keyzer *et al.*²¹⁷ They argue that compared with other factors that are generally expected to affect the future world food situation, notably the impact of climate change, the significance of rising demand for meat will be greater still. They cite a study by

²¹³ Table B.10 *The British Survey of Fertiliser Practice: Fertiliser Use on Farm Crops for Crop Year 2007*, Defra.

²¹⁴ Abril, A., Bartfeld, P., and Bucher, E.H. (2005) The effect of fire and overgrazing disturbances on soil carbon balance in the Dry Chaco forest. *Forest Ecology and Management*, Volume 206, Issues 1-3, 15 February 2005, Pages 399–405.

²¹⁵ de Haan, C., Steinfeld, H. and Blackburn, H. (1997) *Livestock grazing systems & the environment: Finding a balance*. Paper presented at the *Livestock Systems and the Environment* conference, organised by the Commission of the European Communities, Food and Agriculture Organization of the United Nations, World Bank, 1997.

²¹⁶ Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T.-H. (2008) Greenhouse Gases Through Emissions from Use of U.S. Croplands for Biofuels Increases Land use Change *Science* 319, 1238.

²¹⁷ Keyzer, M.A., Merbis, M.D., Pavel, I.F.P.W. and 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* Volume 55, Issue 2, Pp 187–202.

Fischer *et al.*²¹⁸ that estimates the potential losses of cereal production to projected livestock in 2030 to be nearly 20 times greater than the losses resulting from climate change.

Regarding the specific UK context, while livestock may be reared on terrains that are unsuited to other agricultural purposes, in some cases this situation reflects the economic *status quo* rather than actual biological incapacity. Alternative agricultural uses may be possible given the right economic context. There may be scope to investigate the diversion of some pastureland to forestry or other biomass production, activities which not only sequester carbon but also substitute for fossil fuels. It is against these possibilities that the carbon sequestering and resource efficiency benefits of livestock rearing need to be weighed. While biomass crop yields, and hence income, are likely to be low, if increasing demand for non-fossil fuel alternatives pushes up the price of biomass, so the minimum yield needed to make the crops profitable will fall. On the other hand, with low yields, the GHGs emitted during the course of harvesting and transporting the biomass might outweigh the gains from avoided fossil fuel use. Once again, as for by-products, the alternatives merit exploration and the environmentally optimal answer is likely to be highly context specific.

4.a.ii. Outputs

Animals provide us not only with food, but with non-food goods such as leather, manure, and wool. They can also yield benefits such as soil quality, species diversity and landscape aesthetics – although in intensively farmed areas their effects here are often negative. These genuine and potential benefits need to be born in mind when assessing the GHG intensity of livestock production. Some of the key questions we may need to consider include:

- Are the full benefits of livestock products, including non-food goods, accurately accounted for in LCA (second order impacts)?
- We have to eat – would plant based substitutes be any better (opportunity cost)?
- Can we define how much livestock production we ‘need’ and does our production fall short of, or exceed them (needs)?

The following paragraphs look at the outputs from livestock production, and consider them in the context of these three questions.

Are the full benefits accounted for?

The short answer here is no. The LCAs we have reviewed attribute all emissions to the edible outputs of livestock production. Properly speaking, however, the GHGs arising from livestock production should be divided among all its various outputs. This would make GHG emissions per kg of milk or meat lower than current calculations have them to be since the non-food outputs will take a share of the emissions. One LCA of leather production²¹⁹ includes a proportion of the livestock rearing emissions in its quantification, assuming, based on an economic allocation, that 7.7% of all agricultural impacts should be attributable to the leather itself. This, if the logic were carried to its natural conclusion, would reduce the burden of the edible output by 7.7%. Attributing a share to other outputs would reduce the burden further. Put simply, if the other benefits ensuing from the livestock process are taken into account the consumption of meat and dairy products does not look quite so bad - although in the case of

²¹⁸ Fischer, G., Shah, M., van Velthuis, H. and Nachtergaele, F.O. (2001) *Global agro-ecological assessment for agriculture in the 21st century*. International Institute of Applied System Analysis, Laxenburg.

²¹⁹ Milà i Canals, L., Domènech, X., Rieradevall, J., Puig, R. and Fullana, P. (2002) Use of Life Cycle Assessment in the Procedure for the Establishment of Environmental Criteria in the Catalan Eco-label of Leather *Int J LCA* 7 (1) 39–46.

leather, tanning itself generates other considerable environmental impacts.²²⁰ This again illustrates how the second order impacts of livestock production (avoided need to produce alternatives) may alter the conclusions of classic LCA, this time by reducing per-output impacts slightly. *Overall* / livestock emissions will of course stay the same. There can, however, also be multiple non-food benefits ensuing from the production of plant foods; in the developing world, for example, straw is used for thatching and flooring. A fuller analysis would need to compare the full outputs of both plant and animal systems.

Other intangible outputs from livestock production need to be considered too. For example, one important function of upland livestock production in the UK is that it gives economic value to grasslands; these act as sinks for carbon. While established grasslands (as with forests) do not continue to take carbon out of the atmosphere to any significant degree, the point is that any *changes* in land use that disrupt the soil (ploughing, say, or construction), will cause releases of stored carbon into the atmosphere. Hence livestock, by giving grassland a monetary value, have an important role to play in maintaining pastureland and, as such, in preventing it from being used for another purpose. This said, if we decided to assign environmental value to land, maintain it undisrupted as a public good and pay farmers for doing so then, whether or not the livestock were there, the same effect would be achieved.

One study finds, however, that the carbon sequestering role of grazing animals is undermined by their responsibility for N₂O fluxes over and above those that would have occurred on ungrazed pasture.²²¹ Hence there are both environmental costs and benefits associated with livestock grazing.

Grazing livestock can also play an important role in sustaining the biological diversity of grasslands. At the right stocking density, grazing livestock can enhance grassland species diversity. Their constant nibbling, chomping and stamping controls the vigour of dominant or invasive species, allowing other less robust plants to thrive. Different livestock species will also graze in different ways and at different levels and this variety too is beneficial to species diversity. Hence land that is grazed by different kinds of livestock, providing it is not over-grazed, will lead to a varied and diverse biological landscape. On the other hand a monopoly by one grazing species on a particular area – as is often the case in the UK – can create a landscape with limited biodiversity.

Moreover, livestock grazing can not only enhance the landscape, but also harm it. As highlighted above, in developing countries particularly, overgrazing is a serious problem.

In the UK too, overgrazing has been one of the main contributors to organic soil degradation,²²² accounting for 36% of all reductions in soil quality. While sheep are the main cause, cattle also contribute to, and exacerbate, the problem.²²³ The area of eroded land in the uplands (not just

²²⁰ Nazer, D.W., Al-Sa'ed, R.M. and Seibel, M.A. (2006) Reducing the environmental impact of the unhairing–liming process in the leather tanning industry, *Journal of Cleaner Production*, Vol 14, Issue 1.

²²¹ Flechard, C.R., Ambus, P., Skiba, U., Rees, R.M., Hensen, A., van Amstel, A., van den Pol-van Dasselaar, A., Soussana, J. F., Jones, M., Clifton-Brown, J., Raschi, A., Horvath, L., Neftel, A., Jocher, M., Ammann, C., Leifeld, J., Fuhrer, J., Calanca, P., Thalman, E., Pilegaard, K., Di Marco, C., Campbell, C., Nemitz, E., Hargreaves, K.J., Levy, P.E., Ball, B.C., Jones, S.K., van de Bulk, W.C.M., Groot, T., Blom, M., Domingues, R., Kasper, G., Allard, V., Ceschia, E., Cellier, P., Laville, P., Henault, C., Bizouard, F., Abdalla, M., Williams, M., Baronti, S., Berretti, F. and Grosz, B. (2007) Effects of climate and management intensity on nitrous oxide emissions in grassland systems across Europe *Agriculture, Ecosystems and Environment* 121 135–152.

²²² Organic soils include peat, stagnopodzols, stagnohumic gleys, humic-alluvial gleys, humic sandy gley and humic gleys.

²²³ *Vulnerability of organic soils in England and Wales* (2006) Defra project SP0532 undertaken by the Universities of Leeds, Manchester and Durham.

organic soils) is reported to be increasing at a rate of 500 ha per annum, and it has been estimated that 2.5% of the total upland area is now eroding.²²⁴

Overgrazing is listed as the major agricultural reason for 'unfavourable conditions' on Sites of Scientific Interest. Of the area not meeting the PSA (Public Service Agreement) target, 36.16% has been classified as such because of overgrazing.²²⁵ With the wetter winters that are expected as our climate changes, excessive grazing could lead to a vicious cycle of environmental degradation.

By contrast, undergrazing accounts for only 5.94% of areas whose conditions are deemed 'unfavourable'. This said, while at present this is less of a problem than overgrazing, one might speculate that were livestock numbers to be reduced, the problem of undergrazing would increase. English Nature notes that, following the introduction of the Single Payment Scheme, farming in many hill areas is no longer commercially viable, meaning that livestock numbers may decline.²²⁶ Hence the problem of undergrazing could well grow.²²⁷ On the other hand, it has been observed that as climate change brings with it an increase in the frequency of droughts, some parts of the UK may become less suited to grazing,²²⁸ and as such will be vulnerable to overgrazing. This will be all the more true for the already dry, southern latitude countries.

It is also worth pointing out that much of our grazing land in the UK does not have high levels of biodiversity and this is the consequence of high fertiliser application levels and the sowing of very simple grass-clover mixes. According to one 2002 report, over 95% of semi-natural grasslands no longer have any significant wildlife conservation interest.²²⁹

much depends on how the farm is managed. One study points out that while grass monocultures grown to feed intensively reared cattle are of limited botanical and biodiversity value, extensive dairying plays an important role in the preserving of landscapes and biodiversity in marginal areas.²³⁰ Another study, however, finds that biodiversity status is poor both for intensively and extensively grazed grasslands.²³¹

Manure is another non-food output of livestock farming, and it too is a mixed blessing. On the one hand, it can improve the quality and fertility of soil and it has been shown that soil fertilised with manure is more biologically active and fertile than soil fertilised by mineral fertilisers alone.²³² Manure can also build the carbon storage potential of the soil and so help take carbon out of the atmosphere. As a natural source of nitrogen and other mineral inputs, manure helps avoid the need to produce and use energy intensive synthetic fertilisers. One does however, need to consider the extent to which substitute materials (such as compost or anaerobic

²²⁴ Ibid.

²²⁵ The Government's Public Service Agreement (PSA) target is to have 95% of the SSSI area in favourable or recovering condition by 2010.

²²⁶ *The importance of livestock grazing for wildlife conservation*, English Nature, 2005.

<http://www.english-nature.org.uk/pubs/publication/PDF/LivestockGrazing.pdf>

²²⁷ <http://www.defra.gov.uk/rural/uplands/grazing.htm>

²²⁸ *Conserving biodiversity in a changing climate: Guidance on building capacity to adapt*, Defra 2007

²²⁹ Hopkins, A. and Tallowin, J. (2002) *Enhancing the biodiversity and landscape value of grasslands*, IGER Innovations, Institute of Grassland and Environmental Research.

²³⁰ The implications of the CAP reform agreement for the dairy sector: An environmental perspective, Institute for European Environmental Policy, London, March 2004.

²³¹ Tallowin, J.R.B, Smith, R.E.N., Goodyear, J. and Vickery, J.A. (2005) Spatial and structural uniformity of lowland agricultural grassland in England: a context for low biodiversity, *Grass and Forage Science*, 60, 225–236.

²³² Fließbach, A., Oberholzer, H.-R., Gunst, L. and Mäder, P. (2007) Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming, *Agriculture, Ecosystems & Environment* Volume 118, Issues 1–4 .

digestion digestate²³³ from non-animal sources) also have these properties and what the environmental impacts of any such substitution might be.

On the downside, as it breaks down in the soil, manure emits N₂O and CH₄. The FAO report highlighted earlier calculates that N₂O and CH₄ emissions from animal manure alone contribute to more than 5% of total anthropogenic GHG emissions, with N₂O the main culprit.²³⁴ Manure is particularly problematic when overly abundant, as can be the case in intensive livestock systems.

Moreover, as already observed, a third of all cereals grown worldwide are used to feed animals. With fewer livestock, the need for fertilisers might actually fall since we would not need to grow so many feed crops. On the other hand, in a context of lower livestock production we would need to grow substitute foods and their cultivation would require fertiliser inputs, either of synthetic or natural origin (such as legumes). Once these are balanced out it may be that the total quantity of cereals grown would stay more or less the same²³⁵ albeit with reduced need to fertilise grazing land. This said, within a context of a growing global population the need for food will grow, as will the need for soil inputs from whatever source.

Manure has another potential benefit as a feedstock for biogas production in anaerobic digestion (AD) plants. The benefit of using manure in AD is that the CH₄ produced actually substitutes for fossil energy. Moreover, the resulting digestate (the solid matter that remains), can be used as a soil fertiliser and conditioner that is potentially more chemically stable than untreated manure, and that can substitute for synthetic fertilisers – in turn contributing to further avoided emissions. The potential benefits of and downsides to anaerobic digestion are discussed further in Section 7 below.

What is the GHG cost of producing substitutes?

The second question – what would the GHG cost be of producing substitute products? – is ultimately linked to the first but adopts an opportunity cost perspective. We need to consider whether the impacts of the non-livestock alternatives would be any less of a GHG burden.

Clearly food is the major and most important output from livestock farming. Meat, eggs and dairy products provide a range of essential nutrients, including protein, iron, calcium, vitamin B12 and fat.

But are meat and dairy products the only adequate sources of these nutrients? Is their consumption essential? This is important when considering the substitutability of animal with plant foods.

Nutritionally speaking, the answer is no. A considerable body of research shows that a varied diet of plant foods is perfectly able to provide us with the full range of nutrients needed to maintain a healthy diet.^{236,237,238,239,240} As discussed, the GHG burden of producing plant-based

²³³ Digestate is the solid material remaining after the anaerobic digestion of a biodegradable feedstock.

²³⁴ *Livestock's Long Shadow – Environmental Issues and Options*, FAO, December 2006 – See Table 3.12.

²³⁵ Srinivasan, C.S., Irz, X., Shankar, B. (2006) An assessment of the potential consumption impacts of WHO dietary norms in OECD countries *Food Policy* 31 53–77.

²³⁶ *Position of the American Dietetic Association and Dieticians of Canada: Vegetarian diets*, Journal of the American Dietetic Association, ADA, 2003.

²³⁷ Appleby, P.N., Thorogood, M., Mann, J.I. and Key, T.J. (1999) The Oxford Vegetarian Study: an overview. *American Journal of Clinical Nutrition*; **70** (3 Suppl): 525S-531S.

²³⁸ Key, T.J. *et al.* (1999) Health Benefits of a vegetarian diet. *Proceedings of the Nutrition Society* v.58 p.271-5.

²³⁹ Sanders, T.A. (1999) The nutritional adequacy of plant-based diets, *Proceedings of the Nutrition Society*, 58,265-269.

substitutes is lower. Note that a lacto-vegetarian diet is not necessarily less GHG-INTENSIVE than a meat-based one since dairy cows will also produce CH₄ and N₂O and the beef and dairy sectors are, in any case, highly interlinked. On the other hand, eating small quantities of meat and dairy products may be the easiest and most culturally acceptable route to achieving a nutritionally balanced diet.

Moreover, the nutritional value of consuming livestock products will vary depending on who you are, your age, how rich you are, and where you live. In wealthy countries, where diets are varied, calorie intake is high and animal products feature prominently, meat and dairy foods offer a somewhat mixed nutritional blessing. These foods may be rich in essential nutrients but in many cases we consume them excessively with damaging consequences for health. We are, moreover, able to choose from and afford a wide range of readily available alternatives, such as grains, pulses, nuts, fruits and vegetables.

On the other hand, among poor societies, where diets are overwhelmingly grain or tuber based, where access to varied food types is limited, and where there are serious problems of mal- and under-nutrition, keeping a goat, a pig or a few chickens can make a critical difference to the nutritional adequacy of the family diet.²⁴¹

Thus, when considering global trends in meat and dairy consumption, it is important to bear in mind the difference between the anticipated consumption patterns of the rich and of the poor. We discuss what might be considered to be a sustainable level of consumption in Section 8 below.

Regarding non-food outputs such as leather, wool and rendered products, we must ask, as with food, whether producing them by some other means (oil based substitutes for example) would produce fewer GHGs. This is a difficult area. Taking leather as an example, while there is some research which explores the GHG impacts of alternative materials,^{242,243} a proper comparison needs to consider the durability and functionality of alternative fabrics. Unfortunately there is very little research in this area.

4.a.iii. Needs versus demand

Finally to the third question: do we actually need the goods provided by livestock production in the quantities currently available?

The issue of need falls well outside the remit of LCA. However, it begs discussion for the simple reason that we live on a planet with finite resources, and collectively we consume too much. Section 8 discusses more generally the concept of need, and asks how far and whether we need to change what, and how, we consume. For now we limit the discussion to livestock products.

With regard to edible outputs, we have already argued that the inclusion of some meat and dairy products in the diet, while not biologically essential, can make a vital contribution to the nutritional status particularly of vulnerable groups. Small quantities can also liven up a plant-based diet. But what level of consumption, does 'some' imply? This is a difficult, perhaps

²⁴⁰ Millward, D.J. (1999) The nutritional value of plant-based diets in relation to human amino acid and protein requirements. *Proceedings of the Nutrition Society*, (1999) 58, 249-260.

²⁴¹ Neumann C, Harris D M, Rogers L M (2002). Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutrition Research*, Vol 22, Issue 1-2 pp 193 - 220

²⁴² Kalliala, E.M., and Nousiainen, P. (1999) Life cycle assessment: environmental profile of cotton and polyester-cotton fabrics, *AUTEX Research Journal Vol 1, No.1*, http://www.autex.org/v1n1/2264_99.pdf

²⁴³ Laursen, S.E., Hansen, J., Bagh J., Jensen, O.K. and Werther, I. (1997) *Environmental assessment of textiles. Life cycle screening of the production of textiles containing cotton, wool, viscose, polyester or acrylic fibres*. Environmental project no. 369. Ministry of the Environment and Energy. Danish Environmental Protection Agency.

impossible question to answer, particularly since so much else depends on what else is, or is not being eaten. All we can say for now is that our 'need' for meat, has to be assessed in the context of a wider discussion of the economics and politics of food security.

With respect to non-food livestock products, we consider first the example of leather. Do we need leather products? Are all leather products 'necessary?' As with all discussions about 'needs' the answers will be subjective.^{244,245} One might, though, reasonably argue that a resilient, breathable material of some sort is required for many uses and that leather fits this definition well. As to which leather products are more essential than others, judgements here will always be arbitrary. Traditionally footwear has been the main output of leather production. The FAO gives footwear and nothing else as an indicator of trends in the production and trade of manufactured leather goods.²⁴⁶ So, using footwear as a very crude marker of need, we find that the proportion of light bovine leather going into shoe uppers, still the chief end use, has levelled off at around 56%.²⁴⁷ If sheep and goat leathers are also taken into account, less than half the world's total leather production is utilised for footwear. This is a somewhat speculative argument, but it serves to indicate that the 'need' for leather is almost certainly less than the actual supply, although by exactly how much is not known. If livestock production were to fall, we would not go barefoot. Measures to reduce livestock numbers in order to cut GHG emissions would not inevitably require that we produce more leather substitutes. If leather jackets disappeared from the shelves (or became prohibitively expensive) we would not necessarily turn to buying PVC or linen jackets instead. We might not buy any more jackets at all. Demand would evaporate. Hence the argument that leather (and livestock) production helps avoid the generation of GHGs resulting from the production of substitute fabrics cannot be invoked, since some of the leather goods available are not needed and might not be produced at all from alternative materials.

Wool, at 2.4%, is a very small player on the international textiles market²⁴⁸ and therefore massive changes in numbers would be needed to affect the market in any way. There is, perhaps, scope to increase wool usage in some areas – for instance as an insulating material – and this would substitute for the use of fibreglass insulation, which requires energy to produce.

Rendered products are another non-food output but these, post-BSE, are struggling to find a role. Tallow is mainly used to fuel the rendering process while most meat and bone meal is landfilled; other rendered products face competition from plant alternatives. For manure, we have already suggested that while manure clearly has its benefits by improving soil quality it also generates costs.

In conclusion, livestock do indeed yield valuable outputs and a certain level of livestock production may help tackle climate change, by contributing to soil carbon sequestration and by making use of otherwise unproductive land (avoiding the need to plough alternative land). Livestock's ability to consume crop residues and by-products that are inedible to humans is resource efficient and leads to GHG avoidance. Manure can improve soil quality and reduces the need for synthetic fertilisers. There will, moreover, be an environmental cost to producing substitute goods and services if we did not have livestock from which to obtain them.

²⁴⁴ Jackson, T., Jager, W., Stagl, S. (2004) 'Beyond Insatiability – needs theory, consumption and sustainability', in Reisch, L. and I. Røpke (Eds), *Consumption – perspectives from Ecological Economics*, Edward Elgar, Cheltenham.

²⁴⁵ Jackson, T. and Marks, N. (1999) Consumption, Sustainable Welfare and Human Needs – with reference to UK expenditure patterns 1954–1994, *Ecological Economics* 28(3), 421–442.

²⁴⁶ *World statistical compendium for raw hides and skins, leather and leather footwear 1984–2002*, FAO 2003.

²⁴⁷ Ibid.

²⁴⁸ Wool Statistics, British Wool, <http://www.britishwool.org.uk/pdf/Factsheet4.pdf>

Nevertheless some of these benefits are open to challenge and at current levels of production and consumption – and even more so at projected future levels – the disbenefits of livestock with respect to GHG emissions and other concerns such as water and biodiversity, far outweigh the benefits. Clearly, ways of tackling the GHGs generated by livestock are urgently needed. In Section 7 we discuss some of the technological and managerial options that have been proposed or are being implemented. We also consider whether we may need to reduce the amount of meat and dairy products we consume and, if so, what level of reduction is required to achieve a measurable impact.

Finally, we emphasise that this discussion has focused almost entirely on livestock and its relationship with GHG emissions. Other environmental and health problems that have resulted from intensive livestock production systems, such as BSE, *Salmonella*, Foot and Mouth Disease, ammonia emissions and water pollution, have not been discussed. A full analysis of livestock's current contribution to sustainable food production will need to include these concerns too.

4.b. Fruit & vegetables

We have available to us a huge variety of fruit and vegetables, much of which we import – around 40% of our vegetables and 90% of our fruit²⁴⁹ – from a great number of countries which in turn represent a huge diversity of geographical and climatic conditions and farming techniques. All these variables make it very difficult to calculate the overall GHG emissions associated with our consumption of fruit and vegetables. We attempted a very rough calculation in the FCRN report on fruit and vegetables,²⁵⁰ and came to the conclusion that the emissions resulting from our UK consumption of these foods account for around 2.5% of the UK's GHG total. While a far more detailed analysis is needed to reach a more accurate conclusion, the figure may serve as a 'good enough' indication of the contribution. The figure is much smaller than that given for meat and dairy production, which is interesting since, until recently, most of the public focus (by which we mean that of the media and NGOs) has been on fruit and vegetables – partly as a result of the 'food miles' associated with these foods.

The contribution that the fruit and vegetable sector makes to food chain emissions may, however, 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 air freighted produce (berries and beans), Mediterranean-style vegetables (courgettes, tomatoes, peppers and so forth) and perishable salads and pre-prepared foods. Specifically, our expectation that these products should be available to us all year round renders necessary the use of energy intensive heated greenhouses and of rapid modes of transport, such as aviation.

With regard to Mediterranean-style vegetables, these tend to be grown in protected greenhouses in the UK or imported from other countries, including Spain, Italy and the Netherlands. The UK protected horticulture sector is energy intensive (and as such is eligible for a Climate Change Agreement, of which more in Section 7 below). According to a report produced by Warwick HRI for Defra, direct energy use in the protected edibles sector emits 149,740 tonnes of carbon,²⁵¹ a figure that allows for the fact that some horticultural enterprises have installed combined heat and power (CHP) plants and hence feed electricity into the national grid. While the volume of carbon produced by the sector is small (at around 0.1% of the

²⁴⁹ *Basic Horticultural Statistics*, Defra 2007.

²⁵⁰ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

²⁵¹ Steven Adams, University of Warwick, pers. comm based on data gathered for *Direct energy use in agriculture: opportunities for reducing fossil fuel inputs*, Final report to Defra by Warwick HRI, Defra project AC0401, May 2007.

UK's total GHG emissions and, interestingly half of what arises from the import of air freighted produce) it is important to note that the figure is for UK production only. We import the bulk of this type of produce, generally from Southern Europe and the Netherlands.

Dutch imports are 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. This is certainly not the case in the Netherlands and indeed we import roughly the same volumes of tomatoes from the Netherlands as we do from Spain. Overall volumes of fresh vegetables from the Netherlands are only slightly lower than they are from Spain.²⁵² The environmental profile of Dutch grown produce is, however, continuously improving. More than 50% of the greenhouse surface in the Netherlands uses co-generation (CHP) for heating. In addition, a growing number of horticultural developments use waste heat, and sometimes waste CO₂ from neighbouring industries. The Dutch Produce Association has committed to reducing its absolute CO₂ emission by 30% on 1990 levels by 2020.²⁵³

It is also worth noting that, while energy use in glasshouses is high, there can be other environmental advantages. For instance, the closed environment means that crops can be grown without pesticides and the water can be recycled. The UK has been looking closely at Dutch glasshouse models and in Section 7 we discuss the Thanet Earth initiative.

Transport can be, relatively speaking, another high impact stage in the life cycle of fresh produce although in terms of its absolute contribution to UK GHG emissions, the impacts are small. We have discussed the relevance of transport in Section 3 above.

Another key impact area for the fruit and vegetable sector is its reliance on refrigeration. 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. Foods that are transported long distances or stored for long periods of time will be refrigeration-intensive. We have estimated²⁵⁴ that fruit and vegetable refrigeration within the UK alone accounts for about 0.65% of the UK's production-related GHG emissions.

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, are 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 (particularly for fruit).²⁵⁵ On the upside, produce used in the pre-prepared sector may be utilising volumes that are not of Grade 1 quality (the grade that supermarkets stipulate for fresh whole produce). Their use in pre-prepared foods diverts waste from landfill - although one might add that it is only current notions of what constitutes acceptable quality that prevents these lower grade products from being sold in their natural state.

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, as we have discussed, fosters and makes possible the development of longer supply chains.

²⁵² Eurostat 2006 figures.

²⁵³ Kas als Energiebron: <http://www.kasalsenergiebron.nl/index.php>

²⁵⁴ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

²⁵⁵ *Fresh Fruit and Vegetables – UK – January 2007*, Mintel.

Cold storage notwithstanding, waste along the fruit and vegetable supply chain is a concern. We calculate²⁵⁶ that around 25% of all harvested fruits and vegetables are never eaten while the WRAP study already mentioned finds that fruit and vegetables make up the greatest overall share of household food waste.²⁵⁷ Interestingly, the study finds that salads are the most wasted food product (on average 45% by weight of all purchased salad is thrown away). Since these rank as one of the more GHG-intensive types of foods, this represents a striking waste of embodied GHG emissions.

Finally, the cooking stage merits attention. For fresh produce, the cooking stage can be very significant with respect to GHG emissions. One study found that, in the case of broccoli, the actual cooking of the vegetable can dominate all other life cycle stages.²⁵⁸ Foster *et al.* cite research showing that, for potatoes, the cooking stage accounts for over 30% of the life cycle CO₂e emissions²⁵⁹ while for carrots, the cooking stage contributes an even larger 64%.

We have tried to consider, based on very partial data, which might be the least GHG-intensive fruits and vegetables and have concluded that these are likely to be seasonal, field grown UK produce cultivated without additional heating or protection, and which are not fragile or easily spoiled. Produce grown overseas that is reasonably robust, cultivated without heating or other protection and is transported by sea or short distances by road, will also be fairly low in intensity. These terms – ‘short distances’ and ‘fairly low’ – are somewhat vague, reflecting the fact that (to our knowledge) there are no comprehensive comparisons of the GHG intensity of different food types, and the fact that the relative importance of transport will be different for different types of fruit and vegetables.

We also suggest that a useful gauge of the GHG intensity of a particular fruit and/or vegetable might be its perishability. Produce that is fairly robust and withstands storage conditions well without spoilage, is likely to have a lower GHG footprint than highly refrigeration-dependent, fragile, short shelf life produce.

Robust produce includes vegetables such as root crops, tubers and brassicas (particularly cabbages), and staple fruits such as apples, bananas and citrus fruits. Perishable produce is more likely to require finely balanced cold storage conditions. It will have a short life, which means that if it comes from outside Europe 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. For example a study by Doug Warner *et al.*²⁶⁰ notes that around 10–30% of the strawberry crop can be defined as Class II and as such is usually left to rot in the field. There will be additional losses further along the supply chain.

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, as policy could then focus on these stages. In the case of livestock products, for example, the agricultural stage is overwhelmingly significant. But the picture for fruit and vegetables is more nuanced. The two to three per cent figure we estimate for the sector’s total GHG contribution is comprised of relatively small quantities of

²⁵⁶ Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

²⁵⁷ *The Food We Waste* (2008) Waste Resources Action Programme, Banbury.

²⁵⁸ Muñoz, I., Milà i Canals, L. and Clift, R. Consider a spherical man – A simple model to include human excretion in Life Cycle Assessment of Food products, *Journal of Industrial Ecology*. In press.

²⁵⁹ Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A. and Mylan, J. (2006) *Environmental impacts of food production and consumption*. A report produced for the Department for Environment, Food and Rural Affairs.

²⁶⁰ *Sustainability of the UK strawberry crop*. A report undertaken by the University of Hertfordshire for Defra, 2005.

emissions from many different life stages (a few parts of a per cent to agriculture, to refrigeration and so forth) and given the 'bitty-ness' of the individual contributions, it is difficult to hone in on one particular impact.

This point is perhaps true of the food system as a whole. The food chain is so very complex and there are so many different life cycle stages and food types to consider, that when attempts are made to calculate the share that a particular food type, or particular life cycle stage makes to GHG emissions, the figures tend to separate out, dwindle down and look really rather small. Unfortunately this 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. This is an approach that we cannot afford, given the drastic cuts that are needed.

Additionally, our view is that the interactions among the different life cycle stages (such as transport, refrigeration and waste) may be more important than the individual stages. Working together they are more than the sum of their parts, and together they tend to ratchet up the emissions.

The challenge for a policy-maker is to know what to do with this relationship. 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). Changes in behaviour, and what they might achieve should also be added to the mix.

4.c. Alcoholic drinks

The following paragraphs are based on a detailed earlier FCRN study of alcohol and its contribution to GHG emissions.²⁶¹ The focus here is on the production and consumption of three broad categories of alcoholic drink; beer, wine and spirits. For each, we examine their contribution by life cycle stage. It should be borne in mind, however, that the analysis is based on very partial data. There is very little published academic literature focusing on the environmental (including GHG) impact of the alcohol sector and, as with fruit and vegetables, many of the alcoholic drinks we consume (virtually all the wine for example) are imported, making quantification all the more difficult.

A further discussion of alcohol consumption behaviour can be found in the Section 8 below, where we discuss whether the twin goals of reducing food-GHG emissions, and human health might be compatible.

4.c.i. Overall alcohol emissions

In our alcohol study we attempted to roughly quantify the contribution that alcohol consumption makes to UK GHG emissions, and we put the figure at around 1.5% of our consumption-related emissions. These figures are likely to underestimate alcohol's contribution for various reasons that are articulated more fully in the report itself. Perhaps most significantly, the study looked only at the three main categories of drinks; it excluded cider, flavoured alcoholic beverages, fortified wines, liqueurs, mixers and other smaller players. As regards packaging, forms other

²⁶¹ Garnett, T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

than cans and glass bottles (such as barrels, kegs and so forth) were not included, nor was transport associated with movements of the raw packaging materials. Since, as we will discuss, packaging plays a significant role in overall alcohol-related emissions, this omission could substantially affect the score.

Overall, our study did not find any significant difference in the GHG intensity of different categories of drinks – beers, wines and spirits. Such differences as there were, were slight and easily accountable for by the margins of error within the (partial) data that we were able to obtain. Moreover, variable factors such as the type of packaging (which can vary widely, especially for beer) and the place of consumption will alter the relative balance.

4.c.ii. Main impact areas

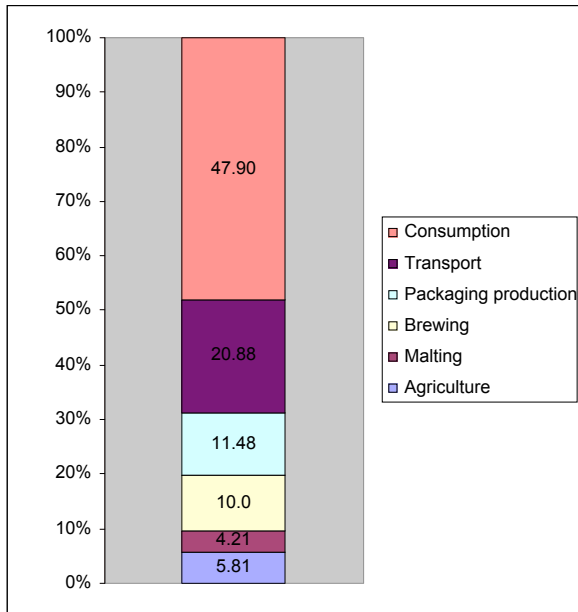
Overall, the consumption stage – by which we mean energy use in bars, pubs, restaurants, clubs and hotels – emerges as a key hotspot in the life cycle of alcohol in general and beer in particular. Emissions associated with this consumption stage are responsible for the bulk of beer-related GHGs, followed in significance by the transport stage – the reason being that beer still tends to be drunk in pubs, although the preference for at-home drinking is growing.

For wine, transport is more important than the consumption stage. Those consumption impacts that do arise, result from the refrigeration of white wine in the home, or consumption in restaurants and other premises. The impacts for spirits are fairly evenly distributed along the whole of the supply chain.

Packaging emissions for all alcohol types are significant and, in general, the smaller the volume of liquid held, the relatively more important it will be. Small bottles of beer are a case in point.

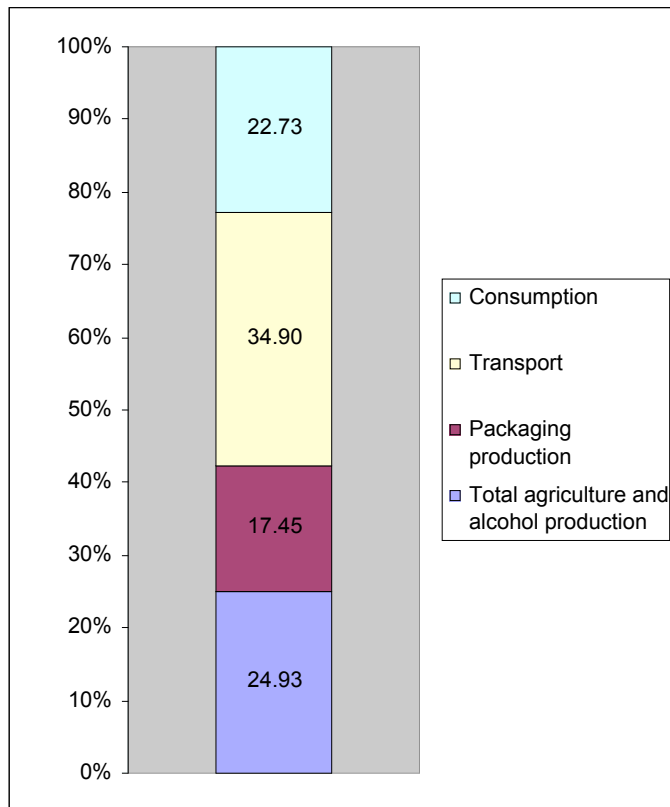
Figures 9, 10 and 11 below show the relative contribution of each life cycle stage for the different categories of alcohol (note that retail stage emissions are not included). Fuller details can be found in the FCRN alcohol paper.

Figure 9: Relative contribution of life cycle stages to beer emissions



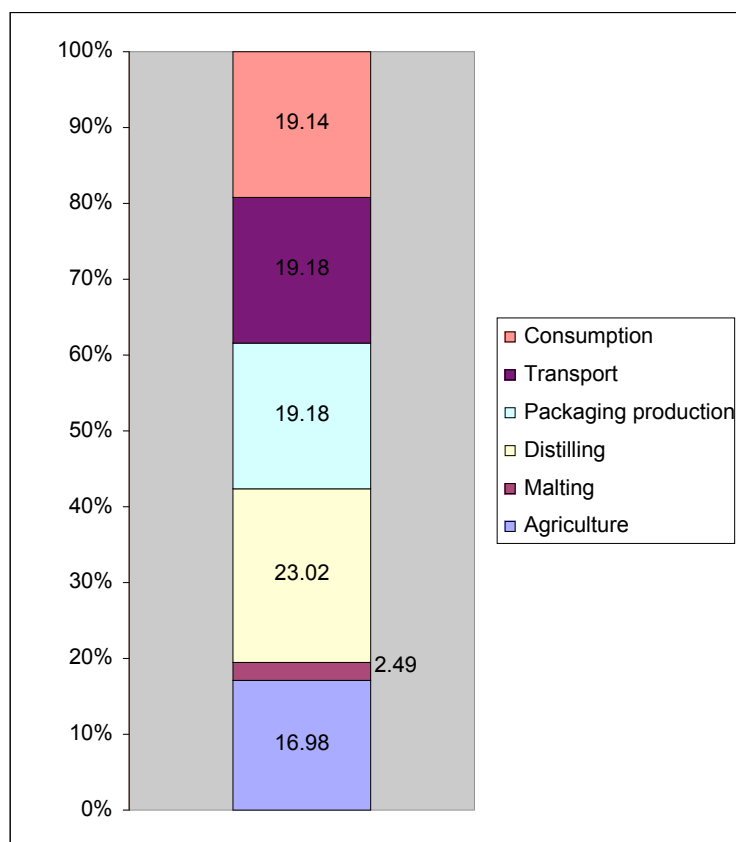
Source: Garnett, T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

Figure 10: Relative contribution of life cycle stages to wine emissions



Source: Garnett T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey

Figure 11: Relative contribution of life cycle stages to spirit emissions



Source: Garnett, T. (2006) *The alcohol we drink and its contribution to the UK's greenhouse gas emissions: a discussion paper*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey

It is important to point out that while we looked at consumption stage emissions for the alcohol sector, and found them to contribute significantly to overall life cycle emissions, we did not do so in our reports on fruit and vegetables (except for home refrigeration) and on meat and dairy products. This may give a distorted impression of the situation when in fact the consumption stage can be very important for other foods and drinks too, as in the case of fruit and vegetables, discussed above. Home food-related activities (cooking, dishwashing, refrigeration) account for around 2% of the UK's GHG emissions (see Figures 3, 4 and 5 above).

4.c.iii. Trends and their implications for GHG emissions

Certain trends in what and how we drink suggest that the GHG impacts of the alcohol sector could increase. These include the growing preference for drinking bottled and canned (instead of draught) beer, and for liking our drinks to be very cold, as in the case of white wine, lager and increasingly cider, where marketing focuses on serving it with ice. We are also seeing the development of global brands, and concentrated production and distribution structures, leading to more transport. While sector concentration means that we have fewer, larger but probably more energy efficient breweries, it is not clear whether these efficiency savings can offset growing transport-related GHGs. It is also perfectly possible to have a highly energy efficient smaller brewery, as in the case of the Suffolk based Adnams which has won awards for its low carbon practices.²⁶²

²⁶² Carbon Trust announces Adnams Brewery as winner of 2007 Innovation Awards, Press release, Carbon Trust, 27 April 2007. http://www.carbontrust.co.uk/news/presscentre/2007/270407_InnovationAwardFinalists.htm

For wines, it may also be that the growing preference for New World wines that are transported long distances is adding to the emissions burden. However, without a full LCA of Old versus New World wines (and there will also be huge variation between individual countries) it is not possible to draw conclusions.

To date, considerable energy efficiency improvements have been achieved in the malting, brewing and distilling sectors²⁶³ possibly as a result of the Climate Change Agreements that have been negotiated by these sectors, and this could suggest that overall emissions are likely to decline. However, the contribution these sectors make to overall alcohol-related GHG emissions is relatively small, as highlighted in the Figures above. While, of course, any savings that can be made are useful, they will not help cut emissions where the impacts are greatest – at the transport and consumption stages. And it is in these areas that emissions could grow.

We have already highlighted the particular problem of transport in Section 3 above, suggesting that it is one of the hardest areas of GHG impact to tackle. As regards hospitality sector emissions, one of the main challenges is simply the fragmented nature of the sector and the huge number of small and independent enterprises – over 51,000 pubs, over 47,000 hotels and over 26,000 restaurants.²⁶⁴ Policy cannot simply be made at headquarters and rolled out to all premises: there is no single HQ. Industry-led projects such as the Hospitable Climates initiative are useful steps in the right direction but they need to be expanded substantially if real cuts in emissions are to be achieved. Recently, Government has been developing a new policy tool, the Carbon Reduction Commitment, which we discuss later in Section 10 and whose focus will include the hospitality sector. This holds some promise.

Finally, we note that Government policy on alcohol and its environmental impact is the responsibility of Defra, who is also the industry sponsor. Defra deals with matters related to efficiency but does not concern itself with levels of consumption – with what and how much we drink. These matters are considered to be the responsibility of the Department of Health, who views the issue purely as a health concern. As we argue in Section 8 we may need not only to improve the GHG *efficiency* of the foods and drinks we produce, but also rethink how much of them we consume. In the case of alcohol, a reduction in consumption can yield not only environmental but also health benefits. The alcohol issue represents a particularly striking opportunity for Government to join up environmental and health policies but at present it does not appear to be choosing to do so.

²⁶³ There may be improvements at the wine production stage too but these were not explored.

²⁶⁴ *Reducing greenhouse gas emissions in hospitality*, presentation given by Peter Roberts, Institute of Hospitality at Food and Climate Policy Seminar; FCRN seminar hosted by the Sustainable Development Commission, 30 January 2008.

5. CLIMATE CHANGE – ITS IMPACTS ON OUR FOOD SUPPLY

In the sweat of thy brow shall you eat your bread
Genesis 3.19.

The relationship between the food system and climate change is a dynamic one. Our food system not only produces climate-changing gases, but it in turn is also influenced by them. A changing climate will affect what we can grow, where we can grow it, how it is distributed and consumed, and who will be at risk of hunger. The overall impact on food supply and availability will, moreover, be a consequence, not just of biophysical climatic changes, but of the social, economic, institutional, demographic and technological responses (or non-responses) to the challenge this warming poses.

We start here by looking at some of the possible biophysical impacts of climate change before examining these other framing influences. The emphasis throughout is very much on ‘could’, ‘may’, and ‘possibly’ – terms that reflect the huge uncertainty inherent in any attempt at forecasting global futures. This said, it would be misleading to give the impression that we (or rather climate experts) are simply finding shapes in the clouds. Even though we cannot be certain as to what the outcomes will be, the scientific community is increasingly able to indicate the *degree* of uncertainty we have to contend with – hence the use of quite precise definitions in the IPCC report of terms such as ‘likely’ and ‘very likely.’²⁶⁵ Some possible outcomes may be very uncertain but, if they occur, carry a high risk of causing major damage. The challenge for policy-makers is to balance these two variables: uncertainty versus risk.

5.a. Biophysical impacts on agriculture

The emerging research suggests that the impacts of climate change will affect different parts of the world in different ways. Broadly speaking, higher latitude regions, such as North America and Northern Europe (including the UK) may initially benefit from climate change. For the next couple of decades, longer periods of warmer weather may increase productivity and allow us to grow crops commercially (such as wine grapes in the UK) that are currently not viable. Water shortages will, however, increasingly pose problems, and towards the middle of the century, the negative impacts – excessively high temperatures and drought – will outweigh any gains. In low latitude regions – Africa, parts of Asia, South America and Australasia – the negative impacts of climate change are already starting to be seen and will continue to worsen. The world’s poorest and most vulnerable will be hardest hit by climate change.²⁶⁶

In addition to gradual temperature increases (something we can, to an extent, plan for), we will also have to contend with ‘wildcards’ – extreme and perhaps unforeseen weather events such

²⁶⁵ *Uncertainty Guidance Note for the Fourth Assessment Report in IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor M. and Miller H.L. (Eds.)]. Cambridge University Press, Cambridge, UK and New York, USA, p996.

²⁶⁶ Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber J. and Tubiello, F.N. (2007) *Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds.], Cambridge University Press, Cambridge, UK, 273–313.

as drought, storms or flooding. It is projected that the frequency and/or intensity of these are set to grow and these pose more serious threats to agriculture than general, slower, climatic change.²⁶⁷ Water will become scarcer in many parts of the world, although elsewhere, in low-lying parts countries such as Bangladesh and island nations, rising sea levels will increase the risk and frequency of flooding. Some agriculturally productive areas may be permanently lost to the sea. This may be the case in the UK too. Most of the Fens, for example, home to some of our most agriculturally productive farmland, lie below sea level.

In addition, changes in the temperature or distribution of water may promote plant disease, fungal infections and pest outbreaks, or change the way in which they spread. Livestock are likely to suffer heat stress in higher temperatures, which may reduce milk yields and have other detrimental impacts.²⁶⁸

Yields may also become more variable,²⁶⁹ making it harder for farmers to cope with fluctuating incomes, and, further downstream, for the food industry to secure predictable levels of supply. For other crops, quality may suffer. One study finds that by 2050, the area in Australia suitable for growing wine grapes to current quality standards may have declined by 40%.²⁷⁰ We discuss the scope for adaptation later in this section.

On the other hand, there may be a (very) limited upside to climate change. Some plants respond well to elevated levels of CO₂ in the atmosphere and indeed commercial tomato growers pump CO₂ into their greenhouses to encourage crop yields. Up to a point, higher concentrations of CO₂ in the atmosphere may boost crop productivity. Nevertheless, there is much uncertainty as to the magnitude of this effect, how long it will last for and which crop types will benefit. Other factors such as water stress²⁷¹ and higher temperatures may counterbalance the elevated CO₂ effect. Moreover, some of the world's most important crops, including maize, sugar cane, sorghum and millet, use the C4 photosynthetic pathway (rather than the C3 one – see the Glossary for definition) and will not benefit greatly under elevated CO₂ conditions.²⁷² There is also research suggesting that the protein concentration of crops may fall at elevated CO₂ levels,²⁷³ meaning that any increases in quantity may come at the expense of nutritional quality.

²⁶⁷ Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber J. and Tubiello, F.N. (2007) *Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds.], Cambridge University Press, Cambridge, UK, 273–313.

²⁶⁸ Ibid.

²⁶⁹ Jones, P.D., Lister, D.H., Jaggard, K.W., Pidgeon, J.D. (2003) Future Climate Impact on the Productivity of Sugar Beet (*Beta vulgaris* L.) in Europe, *Climatic Change*, Volume 58, Numbers 1–2, 93–108(16).

²⁷⁰ Webb, L.B. (2006) *The impact of projected greenhouse gas-induced climate change on the Australian wine industry*. PhD thesis, School of Agriculture and Food Systems, University of Melbourne.

²⁷¹ Challinor, A.J. and Wheeler, T.R. (2008) Use of a crop model ensemble to quantify CO₂ stimulation of water-stressed and well-watered crops, *Agricultural and Forest Meteorology*, 148, 1062–1077.

²⁷² Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber J. and Tubiello, F.N. (2007) *Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Eds.], Cambridge University Press, Cambridge, UK, 273–313.

²⁷³ Taub, D.R., Miller, B. and Allen, H. (2008) Effects of elevated CO₂ on the protein concentration of food crops: a meta-analysis *Global Change Biology* 14, 565–575.

The impacts of climate change on major commodities will also very much depend on where they are grown. So while wheat production may be positively affected (for a while) in the UK, this will not be the case in Australia. Commodity crops grown mainly in the lower latitudes, such as coffee, cocoa and sugar are likely to suffer from climatic change.^{274,275}

5.b. Effects further down the supply chain

The physical impacts of climate change will also affect other stages in the supply chain. For example, extreme weather events could affect transport and storage infrastructure. This puts the rural poor, who rely in a very direct way on being able to get to market (both to buy and to sell) and on facilities to store their crops, in an especially vulnerable position.²⁷⁶ Violent weather could also affect fertiliser producing plants and manufacturing sites.

Rising temperatures place greater demands on refrigeration, with subsequent implications for energy use. Where refrigeration is not available, there will inevitably be more spoilage. The variability of yields, and the occurrence of unforeseen events such as drought and flooding may also increase the volatility of supply. Supermarkets could find their expected supply source drying up and will respond by seeking supplies from elsewhere – possibly from further afield and by air. During the very wet summer of 2007, Tesco, for instance, resorted to sourcing its broccoli from the United States since European sources were under water.²⁷⁷ Hence the increased likelihood of more weather-related spoilage and failure of supply, may mean not just the waste of the emissions embedded in those failed crops but also a possible increase in transport-related emissions from the use of air freight for emergency top-ups.

What the impacts might be on supplier-retailer relationships are unclear. If retailers feel that they cannot rely on suppliers to deliver a consistent quality and volume of product, then might they be yet more reluctant to enter into long-term secure relationships, and as a result might growers be even more vulnerable? On the other hand, it is possible that disruptions in supply might hand back to the suppliers some power relative to the supermarkets. And some supermarkets might see uncertain supply as a reason for engaging in a real dialogue with suppliers to address common problems and to establish of long-term contracts.

Variability of supply will also pose challenges for our industrialised retail model. For today's supermarkets, consistency and constant availability of supply are core to their self definition. They may, however, be faced with a physical and economic climate where it is much harder to achieve these goals.

²⁷⁴ Vulnerability of agriculture to climate change- impact of climate change on cocoa production, Cocoa Research Institute Of Ghana.

²⁷⁵ Gay, C., Estrada, F., Conde, C., Eakin, H. and Villers, L.I. (2006) Potential Impacts of Climate Change on Agriculture: A Case of Study of Coffee Production in Veracruz, Mexico. *Climatic Change*, Volume 79, Numbers 3–4, 259–288(30).

²⁷⁶ Wilbanks, T.J., P. Romero Lankao, M. Bao, F. Berkhout, S. Cairncross, J.-P. Ceron, M. Kapshe, R. Muir-Wood and R. Zapata-Marti, 2007: Industry, settlement and society. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 357-390.

²⁷⁷ Personal observation – the retailer had put up a small notice up giving the reason for its sourcing decisions.

5.c. The broader implications for food supply

Food security is about more than producing enough food. It is also about access; famines arise not just where there is a lack of food but when it is unequally distributed.²⁷⁸

The FAO includes access in its definition of food security and adds on a few extra preconditions too, stating that food security exists:

*'when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.'*²⁷⁹

This definition comprises four key elements: availability, stability, access, and utilisation.²⁸⁰

The direct physical effects of climate change on food production and supply will interact with other economic, social, technological and demographic variables and these in turn will influence our food security in this broader sense. The non-physical factors include the rate of population growth; the rate of economic development and its pattern of distribution; advances in agronomy; the investment in and functioning of infrastructure; broader climate change mitigation policies – and ultimately decisions made about how land should be utilised. We discuss some of these in issues in the following paragraphs and reserve the land use issue for the report's overall conclusions.

5.c.i. Population growth and changing lifestyles

The world's population is projected to grow by about 2.5 billion between now and 2050 – to exceed 9 billion.²⁸¹ Much of this growth will take place in the developing world and for some countries who are forecast to experience strong population growth (such as China and India), this increase in numbers will go hand in hand with rapid economic development. As a result, we are likely to see a nutritional shift towards more 'Western' diets.^{282,283}

The combination of more mouths to feed and changes in what people choose to eat will considerably increase global demand for livestock products.²⁸⁴ This, in turn, will place additional pressures on land use. We discuss whether we might need to alter patterns of meat and dairy consumption further in Section 8 below.

²⁷⁸ Sen, A. (1981) *Poverty and Famines: An Essay on Entitlement and Deprivation*, Oxford University Press: Oxford.

²⁷⁹ *Rome Declaration on World Food Security*, World Food Summit, FAO Rome, November 1996, FAO Rome.

²⁸⁰ Schmidhuber, J. and Tubiello, F.N. (2007) Global food security under climate change, *Proceedings of the National Academy of Sciences*, Vol. 4 no.50.

²⁸¹ *World Population Prospects: The 2006 Revision*, Executive Summary, United Nations, New York, 2007.

²⁸² University of North Carolina *What is the Nutrition Transition?* <http://www.cpc.unc.edu/projects/nutrans> accessed 8 February 2008.

²⁸³ Popkin, B.M. (2006) Technology, transport, globalization and the nutrition transition, *Food Policy* 31 554–569.

²⁸⁴ *Livestock's Long Shadow*, FAO, December 2006.

5.c.ii. Ability to adapt; knowledge transfer and economic development

The extent to which farmers adapt to climate change will strongly influence food security projections^{285,286} and their ability to do so depends in turn on what infrastructure and support is put in place.

The number of additional people at risk of hunger as a result of climate change could, by 2080, vary between five million and 170 million – a vast range that reflects different possible pathways of socio-economic development and what steps are taken to adapt.²⁸⁷ Some adaptive measures are relatively low-key, such as adjusting sowing and harvesting times. Others are more radical (conventional breeding and biotechnology), while others, more drastically still might include abandoning certain agricultural areas. It is outside the scope of this study to examine all the possibilities. However, it is critical to note that adaptation requires a comprehensive, integrated and international policy approach – from knowledge transfer to changes in market structures, encompassing both agronomic research and socio-economic analysis.²⁸⁸ It is also critical that adaptation and mitigation measures are combined: it is counterproductive to, say, intensify agricultural production in order to improve food security if this comes at the expense of higher emissions. This – the need to balance food security with lower emission pathways – is perhaps the major challenge for decision-makers.²⁸⁹

Since climate change is likely to have a more (initially) benign effect on developed countries in North America and Northern Europe, we may see a growth in exports from rich to poor countries, in contrast with current patterns of trade. The price of food and the distribution of that food within the importing countries will critically affect the level of food security.

5.c.iii. Measures taken to address climate change – the case of biofuels

While the physical effects of climate change are already starting to hit home in some parts of the world and will hit harder still over the coming years, for the next few years the actual policy responses to the problem of climate change may have more significant impacts. The diversion of land away from food to biofuels, supported by policies and/or subsidies in the Americas and in the European Union, may affect agricultural production as much as the physical consequences of climate change itself, forcing food and input prices up and taking the best land. We have already experienced a rapid rise in the price of food, in part a result of the increase in agricultural production for fuel rather than food. If this trend continues, the negative impact it is already having on many people in the developing world will worsen.

²⁸⁵ Howden, S.M., Soussana, J.-F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H. (2007) Adapting agriculture to climate change, *Proceedings of the National Academy of Sciences*, Vol. 104 no. 50.

²⁸⁶ Schmidhuber, J. and Tubiello, F.N. (2007) Global food security under climate change *Proceedings of the National Academy of Sciences*, Vol. 04 no. 50.

²⁸⁷ Ibid.

²⁸⁸ Ibid.

²⁸⁹ Andrew Challinor, University of Leeds, pers. comm. June 2008.

6. STRENGTHS, WEAKNESSES AND CHALLENGES FOR LCA

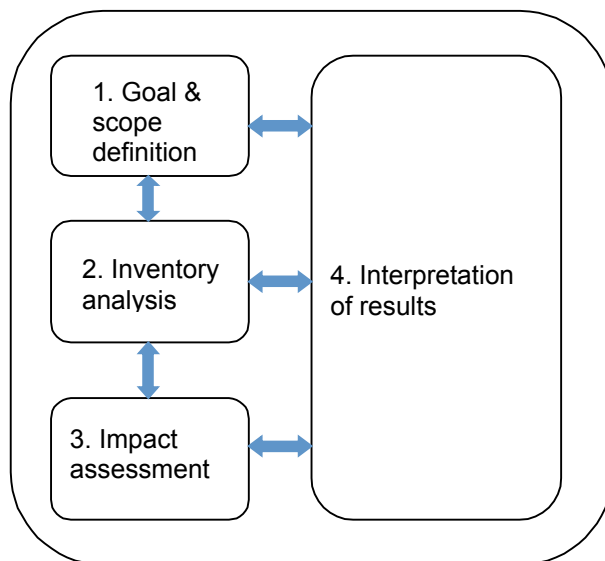
I have measured out my life in coffee-spoons
T.S. Eliot, *The love song of J. Alfred Prufrock*

The purpose of this section is to highlight some of the strengths and limitations of LCA. With the current craze for carbon footprinting and its variations, the LCA approach can sometimes be viewed as an all-encompassing solution rather than what it is – a tool. This is unhelpful, partly because it can lead to skewed policy decisions and partly because it does an injustice to the LCA approach itself.

The FCRN's work has, in fact, drawn extensively from individual LCAs, and has also adopted to an extent, a life cycle perspective. By this we mean it has tried to look at the food chain as a whole, examining how different stages fit together, and how interventions at one stage in the life cycle might affect emissions at the other stages.

While a life cycle perspective is one thing, it should be noted that formal LCA is another – far more specific – exercise altogether. Conducting a life cycle assessment comprises four main phases, as Figure 12 shows. Two ISO environmental management standards provide guidance on them; these collectively form part of the ISO 14000.

Figure 12: Stages in a life cycle assessment



In the first stage, the boundaries of the research are determined (what activities are included in the analysis and what are excluded), as is the unit against which impacts are measured (the functional unit). In the case of food, the functional unit could be one of mass (kg) or of nutrient (protein) or even of utility (a day's worth of meals).

The second phase is one of data gathering: energy and other inputs are quantified, emissions for all the individual activities obtained, and the data checked and verified.

In the third phase these data are used to evaluate the contribution that a functional unit of the product makes to various 'impact categories'. These impact categories include, for example, global warming, acidification and abiotic depletion (finite resource use).

In the fourth and final interpretative phase, the researcher discusses the results, may test their validity with a sensitivity analysis, and draws conclusions.

LCA is an invaluable tool for assessing environmental impacts. It enables its user to calculate the likely embedded impacts of a product as opposed to their apparent ones and, by identifying where the main impacts lie in the life cycle of a product, points to where remedial action is needed. It also helps dismantle apparently 'common sense' assumptions about, say, food miles. However, there are problems with the life cycle method that become increasingly apparent as one moves from calculating impacts to considering policy options, as is well-recognised by the LCA community itself.²⁹⁰ We examine some of these in the paragraphs that follow.

6.a. Detail versus the big picture

The finely grained detail of LCA can be extremely useful. For example, a Defra-commissioned study by the University of Hertfordshire²⁹¹ found a six-fold variation in CO₂e emissions among different strawberry systems. These differences reflect the wide diversity of UK strawberry production methods (the study identified 20) and the findings can provide important insights into the environmental implications, say of protected versus unprotected systems, or of different inputs or cropping durations.

On the other hand, it is not always easy to know whether the variation in emissions reflects differences in the production system or the quirks of individual farming practices. For instance, another study, this time of apple production in New Zealand²⁹² looked in detail at emissions arising from nine apple orchards, some of which were organic, and some not. The study found that the differences in the range of emissions between individual farms was greater than that between farm systems, making it difficult to draw categorical conclusions as to the merits of one farming system over another. This means that even within apparently similar farm systems, there can be huge variations. While this finding is useful in that it shows that blanket judgements of the 'system A is good and system B is bad' variety are inaccurate, it makes it difficult to know what course of policy action to advocate.

In some cases, accuracy is very hard to achieve, as in the case of agricultural products grown on soils subject to huge fluctuations in N₂O emissions, as highlighted above.

Where enough LCAs of particular sectors reach similar conclusions – such as for livestock, where the findings all point to high GHG impacts – then we may be able to draw good-enough conclusions about the environmental impacts. The process is, however, time-consuming and expensive and, importantly, the LCA approach cannot give a broad overview of whether performance trends are moving in more or less GHG-intensive directions. Here, alternative

²⁹⁰ Lundie, S., Citroth, A. and Hupples, G. (2007) *Inventory methods in LCA: towards consistency and improvement UNEP-SETAC Life Cycle Initiative Life Cycle Inventory (LCI) Programme. Task Force 3: Methodological Consistency*. Final Report, June 2007.

²⁹¹ *Sustainability of the UK strawberry crop*, Defra project HH3606, research undertaken by the University of Hertfordshire, January 2006.

²⁹² 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).

approaches such as input-output (I-O) methods, or hybrid methodologies which seek to combine LCA with I-O may be more helpful and these are currently being developed.^{293,294}

6.b. Boundary / mind-set issues

A more fundamental problem with LCA is that while it can give an accurate picture of current 'normal' behaviour, it cannot – and was never intended to – deal well with alternative consumption mind-sets. It cannot be expected to cope with the subtlety and variability of human behaviour, of the – sometimes extended – knock-on effects of behaviour change, and their structural implications.

Take food refrigeration-related energy use, for instance. Clearly the cooling and storing of food under temperature-controlled conditions is an energy-intensive process. Most LCA 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 of the length of time for which it is stored. Many studies find that for frozen food, the cold storage phase is one of the key energy intensive stages in the supply chain. An LCA 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 frozen.²⁹⁵

This, however, does not really make sense. To take the household stage only, the fact is that almost all homes have fridge-freezers and whether we choose to buy and store frozen peas 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 make no difference to my annual refrigeration energy use. The freezer will still be there, and on. Indeed one might observe that a well-stocked freezer runs more efficiently than a half empty one, per unit of food stored. At the retail and manufacturing stages, provided that the overall throughput of food remains the same, once again, the amount of time a product spends in cold storage will make no difference to overall refrigeration-related emissions.

This said, a widespread decline in household demand for frozen products will send a signal to manufacturers, who will respond by taking cold appliances out of service, thereby reducing their energy use. Domestic fridge manufacturers might also start making smaller fridges. One might, then, envisage a certain level of change in demand creating a tipping point that ultimately alters commercial behaviour, and overall supply chain energy use.

This presents an interesting methodological challenge for LCA and one that could conceivably be dealt with through 'system expansion'²⁹⁶ – the expanding of the boundaries of analysis to include the entire UK cold storage system over time – although more accurately a global level analysis might be needed. How practical and indeed useful such an exercise might be, however, is questionable. Our point is that refrigeration and its relationship with the foods we consume, and the form in which we consume them, demands a larger, more *socio-economic* perspective than that which LCA can offer. Today, food manufacturers develop, and food retailers sell, foods that are predicated on the assumption that we all have fridges and freezers.

²⁹³ Suh, S. (2004) Functions, commodities and environmental impacts in an ecological-economic model *Ecological Economics* 48, 451–467.

²⁹⁴ Lundie, S., Ciroth, A. and Huppes, G. (2007) *Inventory methods in LCA: towards consistency and improvement UNEP-SETAC Life Cycle Initiative Life Cycle Inventory (LCI) Programme. Task Force 3: Methodological Consistency*. Final Report, June 2007.

²⁹⁵ Peter Shonfield, *Energy Consumption Across the Frozen Pea Supply Chain*, Unilever, presentation given at FCRN fruit and vegetable seminar, 1 December 2005.

²⁹⁶ Weidema, B. (2000) Avoiding Co-Product Allocation in Life-Cycle Assessment, *Journal of Industrial Ecology* 4 (3), 11–33.

One needs to think only of chilled soups, sauces, breads and pastas. And as cook-chill, fresh, highly perishable or frozen foods take up increasing storage space, we are buying them more often and in larger quantities. As a result, our fridges and freezers are getting bigger. The issue here is not so much how long we store our food for, but rather how the choices we make about what size fridge to buy are shaped by how much food we put in, and for how long we store it. These choices in turn are influenced by manufacturers' and retailers' decisions although, as highlighted, the influence goes the other way too. Larger average household fridge sizes support further growth in temperature-controlled foods and perhaps in commercial cold storage infrastructure. This means that manufacturers and retailers have further incentives to develop and sell the food in order to make use of, and recoup their investment on, the storage space. And so we develop new behavioural norms (deliberately buying 'for the freezer'), which leads to increasing societal dependence on this technology. A general observation one might make is that refrigeration dependence is growing and, as it grows, so the refrigeration and associated transport and packaging infrastructure grows to provide for – and to foster – it. This is something we may need to challenge.

There is another way in which the choice of system boundaries in LCA can be problematic. For example, most LCA does not include the way in which employees to the site travel to and from work; nor what they ate for breakfast; nor whether they enjoy growing vegetables or flying bi-planes in their spare time. This is arguably a *reductio ad absurdum* of the LCA approach and there are good reasons to confine the application of LCA to the product system, rather than attempt also to include aspects which go beyond that system. The bi-plane flyer might continue to fly regardless of what job they hold; so, too, might the gardener. On the other hand, income will influence what they choose to do in their spare time. The bi-plane flyer will indulge in this expensive activity only if salary (or inherited income) permits, and so there will always be leakage, as it were, between the product and the 'human' systems.

Moreover, the human dimension, may well be relevant to the air freight debate discussed above. The chances are very high that if we take the embedded GHG emissions of employee lifestyles into account, anything produced in the developing world, whether air freighted or not, will have a considerably lower footprint than its developed world equivalent. However true this might be, it is hard to know what to do with this insight. Does one, therefore, place a higher value on employment in the developing world (a higher marginal environmental benefit)? The International Institute for Environment and Development (IIED) argues, for instance, that the ecological impacts of the average Kenyan are so low that they are in 'carbon credit' – they can afford to take on the emissions resulting from the production and air freighting of green beans and other produce.²⁹⁷ On the other hand, what if more employment in the developing world raises the standard of living and leads to an increase in the environmental footprint of that self-same employee?

The argument can go anywhere and ultimately nowhere; we raise it simply to point out that little numbers can't always tell us what to do with big issues, or capture the implications of systemic changes. Poverty in Kenya is a big problem; so is climate change. Using numbers arising from LCA (witness the recent air freight controversy highlighted in Section 3 above) to 'show' x course of action to be better than y can tragically fail to deal with either.

All of this, perhaps, constitutes not so much a criticism of LCA as a tool in itself, but of the uses to which it is put.

²⁹⁷ MacGregor, J. and Vorley, B. (2006) *Fair Miles? The concept of "food miles" through a sustainable development lens*. International Institute for Environment and Development, October 2006.

6.c. Non quantifiable impacts and the functional unit

LCA is about numbers. This makes it difficult to assess non-quantifiable impacts such as biodiversity – a simple numbers-count is fairly meaningless – although efforts are being made to develop suitable sets of indicators.^{298,299} Impacts on landscape aesthetics, quality of life, happiness³⁰⁰ and so forth, are harder still to quantify. Valiant efforts have been made to incorporate these elements into LCA, but it is perhaps wiser to acknowledge that LCA may not, ultimately, be the right tool for this particular job.

An additional problem with the LCA approach is that the findings can vary according to the choice of functional unit. Often results are expressed in terms of emissions per kg, but this is not always helpful since foods are consumed in different ways and in different quantities. A kilo of apples is consumed in a very different way – and at a very different rate – from a kilo of treacle. Some researchers have, in fact, explored impacts using different functional units (protein, vitamin C etc.), and this can be helpful when, say, assessing the nutritional adequacy of different lower-GHG diets.³⁰¹

But there are also more nebulous, less tangible functional units to think about: pleasure for instance. Food is about a great deal more than physical sustenance, and we touch upon the complexity of our relationship with food in Section 8 below. People drink alcohol not for its nutritional value, but for the pleasure it brings. If they did not consume alcohol (to save on the emissions) they might well seek out other substitute sources of pleasure – edible or inedible – and many of those will require energy. This is perhaps the territory of consequential LCA, but there is an almost infinite range of alternatives against which that pint of beer can be measured.

Moreover, sometimes a food (sugar, for instance) may have negligible nutritional value. While the stern voice of environmental rectitude may condemn sugar as a waste of embedded emissions, a spoonful of sugar helps the medicine go down: it can make a bland but nutritious low GHG impact food such as porridge more palatable. In short, if consumed in moderation, high impact foods can help along a low impact diet. How we might define moderation is, of course, another question.

6.d. Relative impacts

Linked to the porridge example is the issue of relative environmental magnitude. A given quantity of air freighted strawberries or cherries will be far more GHG-intensive than the same quantity of bananas – a more robust product that can be shipped. On the other hand, we eat far more bananas than we do strawberries – the banana is now the UK's most popular fruit³⁰² – and, in absolute terms, GHG emissions resulting from our consumption of bananas will be significantly greater than those from strawberries. Where should policy-makers focus their attention? Should policies seek to tackle the impacts of the cake or the cherry on the top? One central argument made by DfID and others against a ban on air freighted foods is that their

²⁹⁸ Scholz, R. (2007) Assessment of Land Use Impacts on the Natural Environment. Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change, *The International Journal of Life Cycle Assessment* Volume 12, Number 1 / January.

²⁹⁹ Michelsen, O. (2008) Assessment of land use impact on biodiversity : Proposal of a new methodology exemplified with forestry operations in Norway *The International Journal of Life Cycle Assessment*, Vol 13, no.1.

³⁰⁰ Hofstetter, P., Madjar, M. and Ozawa, T. (2006) Happiness and Sustainable Consumption: Psychological and physical rebound effects at work in a tool for sustainable design *Int J LCA* 11 Special Issue 1 (2006) 105–115.

³⁰¹ Carlsson-Kanyama, A. (1998) 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.

³⁰² *Basic Horticultural Statistics 2005/6* (provisional), Defra.

absolute contribution to UK GHG emissions is tiny: the implication being that we should concentrate more on areas where the bulk impacts are greater.

There are various ways of looking at this. One could say that if we allow the air freighting of foods to continue, and to continue to be seen to be acceptable, then our consumption of these foods will grow to the point that it makes a measurable, rather than purely symbolic, contribution to our emissions. There is probably truth in this argument since foods once seen as luxuries are now staples – think of satsumas (once a Christmas treat), or the now ubiquitous and entirely affordable ‘luxury’ Belgian chocolate. Raising awareness of the impact of air freighting also has an educational function, much like public exhortations to ‘Save the Whale.’ These popular foci for concern allow the real, less publicised work on conserving the supporting ecosystems to go on. Symbols can be useful.

On the other hand, life without treats is bleak. There is an argument to be made for allowing us our cakes and ale, at least in moderation, and concentrating on ‘cleaning up’ our more mainstream items of consumption. Then again, if we are to achieve an 80% cut in GHG emissions by 2050, we are unlikely to have the luxury of either-or – we will have to do both.

6.e. Land use

Policy-makers are increasingly interested in using LCA to inform their decision-making and this has led to the commissioning of substantial studies such as the University of Cranfield’s environmental analysis of major UK agricultural commodities.³⁰³ However, these studies do not accurately capture the second order land use impacts of certain forms of food production or of mitigation approaches. As discussed in the agriculture and the meat and dairy sections above, changes in land use over time can cause major releases of CO₂. The most obvious example is the razing of forestland to grow arable crops. Another might be the conversion of unploughed pastureland to ploughed cultivation. There are quality issues to bear in mind too – changes in soil quality, for instance.

The omission of the land use change dimension could lead to policy measures and recommendations which may, on a global level, actually lead to increases in GHG emissions. For example, many studies conclude that cows fed on diets higher in concentrates (cereals and proteins) emit less CH₄ and produce more milk, meaning that emissions per functional unit of outputs will decline.³⁰⁴ The UK dairy cow already consumes high levels of concentrates in her diet and so the scope for further increases is limited, but cattle in the developing world tend to receive little or nothing by way of concentrates, and it has been recommended that the proportion in their diets should increase.³⁰⁵ However, these studies do not take into account the potential second order, lost carbon sequestration impacts of dietary change. A diet richer in cereals and oilseeds may, at a global level, give further impetus to the clearance of land to grow these feedstuffs. For oilseeds, this will also improve the economic viability of growing these crops in general, since income is gained from both the oil and cake fractions. A greater diversion of cereals to feed animals may mean that more marginal land is cleared to grow food for direct human consumption. Alternatively, livestock rearing in developing countries will be shunted off land previously used for grazing into more marginal or forest land – again, with deleterious consequences.

³⁰³ Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

³⁰⁴ Weiske, A. (2005) *Survey of technical and management-based mitigation measures in agriculture* Document number: MEACAP WP3 D7a, Institute for European Environmental Policy.

³⁰⁵ *Livestock’s Long Shadow*, Food and Agriculture Organisation, December 2006.

While LCA has not yet incorporated the issue into its core, formal methodology, researchers are finding ways of engaging with the issue.^{306,307,308} For example, Kløverpris explores the possibility of developing a model to incorporate consumption-induced land use change into LCA so as to understand how changes in consumption of one particular crop, in one particular country, may ultimately affect the use to which land is put elsewhere.³⁰⁹ Ultimately, a possible outcome of his work might be to develop life cycle inventories for crops reflecting the actual land use consequences of consumption (in turn affected by price changes). Put simply, this way of thinking asks, 'What happens if country X stops growing wheat for export and uses the land to grow more oilseed? What will country Y, which has historically imported wheat from country X do? Will it grow more wheat indigenously and if so how will this change the way its land is used? Or will it import from country Z and, if so, how will country Z change the way it uses its land?'

Kløverpris argues that changes in cropping decisions can affect land use in three ways. It can lead to the displacement of other crops (wheat instead of maize); the expansion of existing croplands (often into marginal areas); or an intensification of existing production, so that a greater yield is obtained from the same area of land. Although his analysis does not explicitly explore the implications for GHG emissions, each of these could have an impact. The *displacing* crop could have a higher or lower GHG intensity than that which is displaced. The *expansion* of existing croplands into marginal areas could lead to lost carbon sequestration as, say, arable farming encroaches onto permanent grass or forestland. An *intensification* of existing production can mean higher fertiliser use and consequent increases in soil N emissions. Work by Searchinger *et al.* takes a similar approach, specifically with respect to biofuels.³¹⁰

Encouragingly, PAS 2050 (the Publicly Available Specification for the assessment of GHG emissions from goods and services) that is being jointly sponsored by the Carbon Trust and Defra, through BSI (British Standards), includes emissions resulting from land use change. At present, the draft specification only 'counts' changes in land use occurring on or after 1 January 2008, and amortizes these emissions over a 20 year period. We would argue that an earlier start date should be used so as to capture the effects of recent past land use change.

Another topic that has received only slight attention within the food life cycle literature is the concept of 'opportunity cost.' We have explored this issue in the context of agriculture in general and livestock in particular above. The opportunity cost question provides a frame for the narrower 'classic' LCA approach and also for the broader second order impact / lost carbon sequestration perspective.

For example, land now allocated to livestock production (either pasture or arable land used for feed cropping), could be used for another purpose, one that might actually lead to lower GHG

³⁰⁶ Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Friermuth Knuchel, R., Gaillard, G., Michelsen, O., Müller-Wenk, R. and Rydgren, B. (2007) Key elements in a framework for land use impact assessment in LCA. *Int J LCA* 12 (1) 5–15.

³⁰⁷ Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T.-H. (2008) Greenhouse Gases Through Emissions from Use of U.S. Croplands for Biofuels Increases Land use Change *Science* 319, 1238.

³⁰⁸ Schmidt, J.H. and Weidema, B.P. (2007) Shift in the marginal supply of vegetable oil. *International Journal of Life Cycle Assessment*.

³⁰⁹ Kløverpris, J., Wenzel, H. and Nielsen, P.H. (2008) Life Cycle Inventory Modelling of Land Use Induced by Crop Consumption Part 1: Conceptual Analysis and Methodological Proposal *Int J LCA* 13 (1) 13–21 (2008).

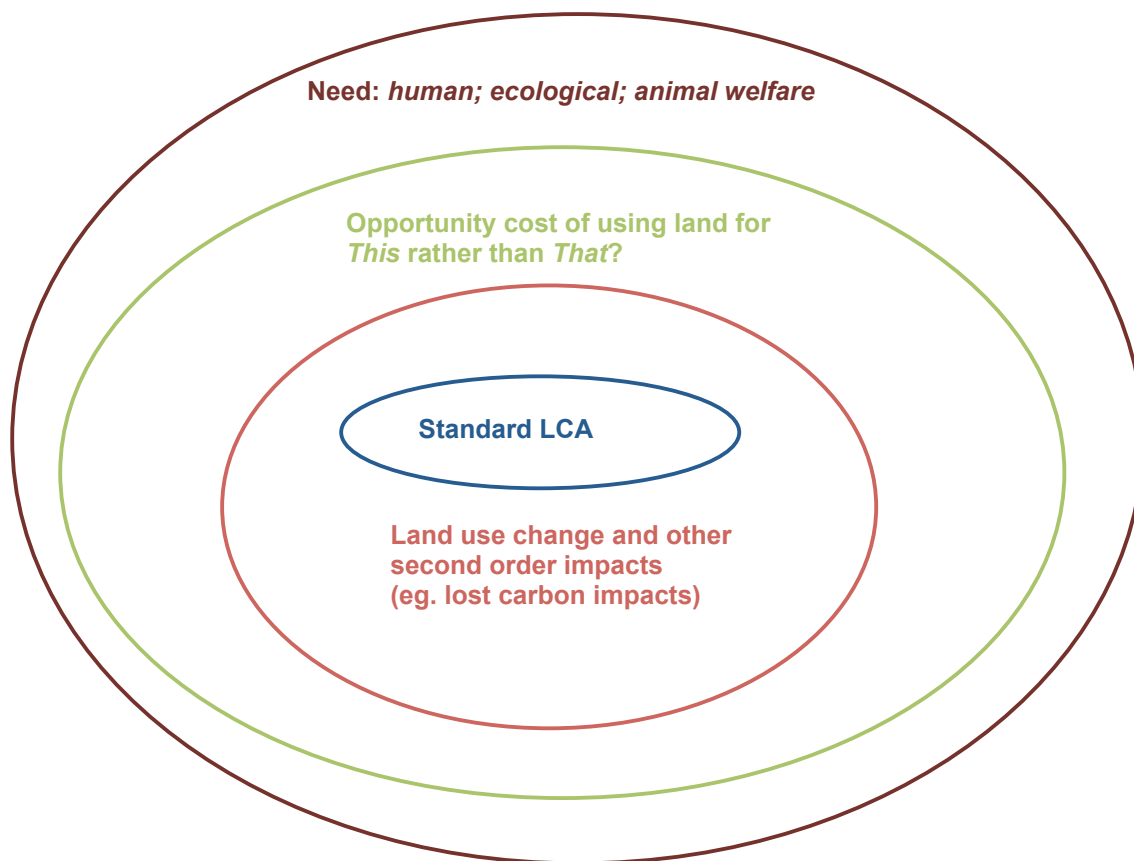
³¹⁰ Searchinger, T., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T.-H. (2008) Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land use Change, *Science*, vol 319, 29 February 2008.

emissions, or even help sequester carbon. Possibilities include using the land for biomass cultivation³¹¹ or crop production for direct human consumption, or for forestry.

When considering the opportunity cost there are many land use baselines against which impacts can be measured. For example, we can compare arable land currently used to produce feed for livestock against the use of that land to produce crops for direct human consumption. Alternatively, we can compare the use of that land for arable production against its use as permanent grazing land. A third possibility would be to compare arable feed cropping against leaving that land to revert to natural forest state.

There is no meaningful 'true' baseline, and as such there is no 'true' opportunity cost. What we need instead is to consider what, in the context of a growing population and increasing demand for food, we are currently using our land for and how we might more optimally use it to ensure that our need for food and other products are met at least environmental (including GHG) cost. What, in short, are the alternative possible options? Figure 13 below provides an illustration of the conceptual lenses through which an LCA's conclusions might be viewed.

Figure 13: A framework for contextualising food production and consumption



The results of 'classic' LCA are of limited relevance unless the second order impacts are taken into account. These, as discussed, include land use change resulting from a decision to grow a certain crop. This broader perspective is subsumed within a wider question as to what the land

³¹¹ The merits of biofuel production, some kinds in particular, are highly questionable, but are considered here as alternative possibilities to using land for livestock rearing.

should be used for, and what the consequences of using land for one purpose are with respect to other possible uses: the opportunity cost issue. Finally, land use decisions need framing in the context of non-negotiable needs – to feed ourselves adequately, to conserve and maintain the environment, and to ensure the welfare of animals reared for our use.

This leads us on to the following two sections of the report which address mitigation. The first considers what reductions technological and managerial improvements might achieve, while the second examines the role of behavioural change.

7. REDUCING FOOD IMPACTS: THE ROLE OF TECHNOLOGICAL CHANGE AND MANAGEMENT

The future is here. It's just not widely distributed yet.

William Gibson

Can we invent and manage our way out of our problems?

This question needs to be addressed in the context of the need for the UK, and other developed countries, to reduce GHG emissions by at least 80% by 2050.^{312,313} In this section we explore the potential offered by changing the way we produce food – the ‘consuming and producing smartly’ aspect of sustainable consumption and production, whose elements include both technological innovations, and good management practices. As in other sections of this paper, we take a life cycle approach, examining first the pre-farm, and then the post-farm options. We devote a separate sub-section to the GHG footprinting/carbon label issue. Note that in so doing we have categorised carbon labelling (rightly or wrongly) as a ‘smart consumption’ issue rather than one that more fundamentally challenges what and how much we consume. We conclude this section with a short summary of the technological and managerial options covered.

This overview is very brief; the other FCRN working papers provide more detailed discussion and also give references to more comprehensive overviews. The aim here is not to describe in exhaustive detail all the options on offer, but merely to sketch out the territory, identify the sorts of approaches being advocated, and offer some indication as to what these could collectively achieve.

In Section 8 we consider whether we might also need to consume both differently, and less.

7.a. Pre-farm gate: agricultural production

This sub-section looks first at direct energy use and the scope for reducing it across the agricultural sector as a whole. We then consider fertiliser production and use, and the various options on offer for reducing impacts. Following this, we look more specifically at plant-oriented reduction options and then at the scope for emission reductions in the livestock sector (basing much of this on the analysis in the livestock paper).³¹⁴ Two general discussions then follow: on carbon sequestration, and on organic farming. Finally, for this section, we look at some of the steps that the industry itself is taking to tackle climate change.

³¹²Government proposals for strengthening the Climate Change Bill, Defra, February 2008

<http://www.defra.gov.uk/environment/climatechange/uk/legislation/pdf/govt-amendment-package.pdf>

³¹³ Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK (although the Stern review takes as its threshold the higher CO₂e level of 550ppm – the adequacy of this figure has been increasingly called into question and is currently the subject of UK Government scrutiny).

³¹⁴ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

7.a.i. Energy use

Direct energy use by agriculture accounts for less than 1% of UK carbon emissions (0.67% of total GHG production-related emissions).³¹⁵ Note that direct energy use refers to on-farm activities and does not include energy used for fertiliser manufacture, transport of inputs and so forth. As highlighted above, the inclusion of fertiliser production alone would double the figure. While the figure we have given for direct energy use is small viewed from the perspective of total UK emissions, energy use and emissions are nevertheless important for particular sub-sectors of the industry, particularly horticulture and intensive pig and poultry units.

We can, moreover, not afford to pass by opportunities to reduce even small volumes of GHG emissions, and agricultural energy use is an area where significant reductions are possible using existing technology. A study undertaken by Warwick HRI for Defra³¹⁶ concludes that it should be possible to save around 15% of direct energy use in UK agriculture by 2015, through the implementation of existing, established technologies and good management practices. Importantly, much more radical savings are possible using renewable energy sources (waste biomass, wind, anaerobic digestion, solar) and indeed these have the potential to make agriculture's direct energy use carbon neutral. At present, however, renewables contribute to less than 5% of primary energy used by agriculture, and the authors warn that without government support, high costs are likely to limit uptake of the necessary technologies.

This said, there are innovative examples, particularly in the horticultural sector. We have already mentioned the Thanet Earth project. This 91 ha closed glasshouse development in Kent is due to begin production in the Autumn of 2008. The glasshouses will be heated by a gas-powered CHP system; waste CO₂ will be used to enhance crop productivity while the electricity, a 'byproduct' of the process, will be sold off to the National Grid. The amount of electricity generated should be enough to heat 50,000 homes. Note that while the Thanet Earth development is initially intended to run on gas, the developers say that they plan to incorporate renewable energy sources as the project matures.³¹⁷ The team also argue that because the electricity the development will produce is less carbon intensive than regular grid electricity, the equivalent emissions resulting from the generation and supply to those 5000 homes, in the absence of the CHP, would be more GHG-intensive. As a result, the overall contribution of the project to GHG emissions is actually negative. In our view, this argument is somewhat disingenuous: while a CHP plant that uses waste heat for horticulture is certainly a good idea, one might equally compare the carbon intensity of its electricity emissions with those produced in a district heating system that would also heat homes as well as lighting them. How one measures impacts ultimately depends on what baseline is set.

There are other well established examples in the horticultural sector. An 11 ha site at Wisington, in Norfolk, is the UK's largest producer of classic round tomatoes. Located next to the British Sugar factory refinery, the greenhouses make use of the waste heat and CO₂ resulting from the refining process. The 15 ha John Baarda Ltd tomato enterprise in Teeside makes use of waste heat and CO₂ from a fertiliser production factory.

Anaerobic digestion is a further option. It offers the potential of dealing with methanogenic waste, using that waste to generate energy, and in so doing, displacing energy that would otherwise have been produced by the burning of fossil fuels. In theory, all organic waste sources can be used, including crop residues, animal manure and slurry and commercial and municipal food waste. Defra is putting considerable energy – and £10 million – into developing,

³¹⁵ *Direct energy use in agriculture: opportunities for reducing fossil fuel inputs*, Final report to Defra by Warwick HRI, Defra project AC0401, May 2007.

³¹⁶ Ibid.

³¹⁷ Thanet Earth development team, personal communication, July 2008.

piloting and promoting the technology.³¹⁸ While in theory AD could make a useful dent in food-related emissions, the technology raises a number of challenges. Some of these are practical; the technology is still being developed, and one of the main priorities is to develop systems that can handle a wide diversity of feedstocks (from slurry to sandwiches), produce reliable outputs of biogas and a reliable, consistent quality of digestate. Consistency of the latter is very important from (among other things) an emissions perspective. Farmers need to be sure of what, and what proportion of nutrients, a given volume of digestate contains. This is partly so that it offers a viable, reliable alternative to synthetic fertilisers, and partly so they can apply the environmentally optimal amount, so avoiding the build up of nitrogen surpluses in the soil. The Environment Agency, WRAP and others are currently developing a Quality Protocol to ensure that the digestate meets consistent standards.³¹⁹

These technical problems should be solvable, given time. The other set of problems concern some of the environmental and ethical implications of biofuels. In Germany (and increasingly in the UK), arable crops are in fact grown directly as AD feedstocks, so bypassing initial consumption by animals or people. The concerns that this system raise are exactly the same as those for all first generation biofuels, namely that in a land-constrained, population-burdened world, the use of food crops for energy is environmentally and indeed morally suspect.³²⁰

A potential animal welfare concern arises when it comes to the use of manure and slurry in AD systems (note that AD systems can use a range of feedstocks, including food waste). AD works best when it has access to concentrated sources of these inputs and these are more readily found in intensive livestock systems rather than extensive ones. In the latter case the animals distribute the manure over a wide area, making it harder to collect. The possibility arises then that AD may foster further intensification of livestock farming. The welfare merits of intensive versus extensive systems are not clear-cut; they are continuously debated³²¹ and have been discussed in more detail in the FCRN livestock paper.³²² It is certainly possible to develop intensive systems that are compatible, at least with certain aspects of animal welfare, as defined by the Five Freedoms.³²³ However, intensive systems in many parts of the world (including the UK) do not always, or even often, provide acceptable standards of welfare and, to the extent that AD and the rush for 'cleaner' energy is inherently linked with such systems, it should be challenged. We note that AD is very popular in China – a country where meat production is growing, is already highly intensive, and where animal welfare is not a major priority.

7.a.ii. Fertiliser use: inorganic and organic

A general point to make about fertilisers in general, whether synthetic or organic, is that the dose needs to be optimal. No more should be applied than is necessary. Of course, how much is considered 'optimal' will depend on whether one is discussing economics or the environment. Economically optimal application levels may be different from those that are environmentally optimal, although given the recent very high cost of fertilisers, they may be becoming more closely aligned. The data in fact show that fertiliser use in the UK has declined over the years,³²⁴

³¹⁸ Defra news release: *Defra Ministers Give Boost to Biogas*, 16 July 2008.

<http://www.defra.gov.uk/news/2008/080716.htm>

³¹⁹ http://www.environment-agency.gov.uk/yourenv/consultations/2041357/?version=1&lang=_e or http://www.wrap.org.uk/composting/quality_protocol_1.html accessed 2 September 2008.

³²⁰ Doornbosch, R. and Steenblik, R. (2007) *Biofuels: Is the cure worse than the disease?* OECD, September 2007.

³²¹ Zollitsch, W., Winckler, C., Waiblinger, S. and Haslberger A. (Eds) (2007) *Sustainable food production and ethics*, Wageningen Academic Publishers, The Netherlands.

³²² Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

³²³ Farm Animal Welfare Council, <http://www.fawc.org.uk/freedoms.htm>, downloaded 21 August 2008.

³²⁴ *The British Survey of Fertiliser Practice: Fertiliser Use on Farm Crops for Crop Year 2007*, Defra.

although it has risen considerably in other parts of the world. Fertiliser prices have risen considerably in recent years, doubling in 2007 alone,³²⁵ but the trends are still in favour of more use, particularly in South and Central Asia, Latin America and Eastern Europe. World nitrogen fertiliser demand is forecast to increase at an annual rate of about 1.4% until 2011/2012, with about 69% of this taking place in Asia.³²⁶

One argument in favour of artificial fertilisers is that it is easy to know how much is being applied, and hence to match the dose with the need. The nitrogen content of manure and compost is variable, although can be known through analysis. As highlighted, the development of quality standards for digestate will help in this respect.

In addition, there is some evidence to suggest that soils fertilised with manure generate higher and longer-lived peaks of N₂O emissions than those fertilised by mineral fertilisers.³²⁷ This is because the total nitrogen inputs from the manure are more readily mobilised, added to which the carbon content of the manures helps stimulate denitrification.

However, manures require no energy to produce (other than what is already been used to rear the animal) and also improve soil quality – this is vital to the long-term sustainability of the soil, and to its ability to continue to yield productively. Synthetic fertiliser manufacture, on the other hand, is GHG-intensive, accounting, as highlighted above, for nearly 1% of the UK's total GHG emissions. Global fertiliser use accounts for a similar share of global emissions.³²⁸

Moreover, unlike synthetic fertiliser, manure is an inevitable by-product of livestock farming and farm systems that make use of it (either by applying it directly or passing it through an AD digester first) will have an environmental advantage over those that rely entirely on synthetic fertilisers, *providing* – and this is an important proviso – that the right quantities are applied. Tools that enable farmers to analyse the composition of their manures and hence apply at appropriate levels are clearly useful.

With UK arable farming located largely in eastern regions, and livestock in the west, the manure may not, however, always be located where it is needed. This barrier is a consequence of the specialised nature of the UK farming sector and it is hard to see how it might be overcome within given the current system. This said, the digestate derived from the anaerobic digestion of food waste is theoretically available more widely, provided that the technology takes off and the infrastructure develops.

Another alternative to synthetic fertilisers is the use of legumes. One paper cites a study³²⁹ that compared N₂O fluxes from a range of fertiliser- and legume-based agricultural systems. The study found there to be little difference between the two; while peak N₂O fluxes occurred in spring time in the fertiliser-based systems, fields with decomposing legume residues maintained lower peak fluxes, but sustained emissions for a longer period of time into the growing season. However, once the combined GHG output (CO₂, N₂O and CH₄) associated with a range of fertiliser- and legume-based cropping systems are all accounted for, the study finds the global

³²⁵ *Focus on fertilisers and food security*, International Center for Soil Fertility and Agricultural Development, downloaded from <http://www.ifdc.org/focusonfertilizer.html>, 21 August 2008.

³²⁶ *Current world fertiliser trends and outlook to 2011/12*. Food And Agriculture Organisation, Rome 2008.

³²⁷ Jones, S.K., Rees, R.M., Skiba, U.M. and Ball, B.C. (2007) Influence of organic and mineral N fertiliser on N₂O fluxes from a temperate grassland, *Agriculture, Ecosystems and Environment* 121 74–83.

³²⁸ Bellarby, J., Foereid, B., Hastings, A. and Smith, P. (2008) *Cool Farming: Climate impacts of agriculture and mitigation potential*. Report produced by researchers from the University of Aberdeen for Greenpeace.

³²⁹ Robertson, G.P., Paul, E.A. and Harwood, R.R. (2000) Greenhouse gases in intensive agriculture: contributions of individual gases to the radiative forcing of the atmosphere. *Science* 289, 1300–1302. Cited in Crews, T.E. and Peoples, M.B. (2004) Legume versus fertiliser sources of nitrogen: ecological tradeoffs and human needs, *Agriculture, Ecosystems and Environment* 102 (2004) 279–297.

warming potential of conventionally tilled systems to be nearly three times as great as legume-based systems. This largely reflects the fossil energy required to produce fertilisers as well as the use of lime in the fertiliser-based systems. Legume-based systems may also offer possible benefits when it comes to nitrogen leaching and ammonia volatilisation.

7.a.iii. Plant-specific options

For both plant crops and for livestock rearing, N₂O emissions account for a very significant proportion of overall emissions and as such there is considerable research activity underway. For example, much research³³⁰ focuses on improving plants' nitrogen utilisation, meaning that less fertiliser needs to be applied, and there is less residual nitrogen in the soil that can transform into N₂O. At the European level, the EU-Rotate_N³³¹ project has completed the development of a decision support tool which can help growers more accurately estimate the 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. Other mitigation measures can include: managing soils to avoid conditions that encourage denitrification (such as waterlogging); changing the form of fertilisers applied; optimising the timing of applications; and using nitrification inhibitors. All of these are useful but none offers a complete solution.

On another tack, there are breeding programmes aimed at producing fruit varieties with longer growing seasons, the idea being to extend the growing season and rely less on imports (for example Defra project HH3716SSF for raspberries³³² and HH3717STF for stone fruit³³³). While the purpose of such research is to improve the economic competitiveness of the UK industry, there could be benefits resulting from fewer transport emissions, provided agriculture-stage emissions do not outweigh the gains. This is an area which, perhaps, should be explored further.

A great deal of research focuses on breeding for reduced resistance to disease and, arguably, anything that reduces the risk of crop failure, and hence of waste, will help avoid 'wasted' GHG emissions. Research of this nature, while useful may, however, deliver only incremental improvements and gains in 'quality' (defined commercially – and as opposed to edibility) rather than breakthroughs or step change reductions.

7.a.iv. Livestock- specific options

Efforts to reduce livestock-generated emissions need to focus on CH₄ as well as N₂O, and in particular they have to contend with the risk of pollution swapping. A range of mitigation options have been discussed in the FCRN livestock paper³³⁴ and only a brief summary is provided here. The focus of our work has largely been on beef and dairy cattle, and therefore does not offer a full picture of the options. Broadly speaking, however, from the research we have reviewed, four main approaches to mitigating livestock GHG impacts emerge. These focus on the following areas: improving productivity; the management system; the outputs; and the number of livestock. These are summarised as follows:

³³⁰ Some recent Defra projects include LK0959, LK0979, LS1404, AR0714, HH1405SFV and HH3506SFV accessible from

<http://randd.defra.gov.uk/Default.aspx?Location=None&Module=FilterSearchNewLook&Completed=0> .

³³¹ <http://www2.warwick.ac.uk/fac/sci/whri/research/nitrogenandenvironment/eurotaten>.

³³² *Developing new, high quality varieties of raspberries which will crop over an extended season*, Defra project HH3716SSF.

³³³ *Extending the season of stone fruit by breeding late-ripening cherries and early-ripening plums*, Defra project HH3717STF.

³³⁴ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.

Improving productivity

- *Changing the feed*: Removing or reducing the causes of GHGs by altering the balance of what the animal consumes. This often involves improving the digestibility of what is fed by feeding more cereals and optimising protein inputs. Note that these measures do not consider the 'second order' lost carbon sequestration impacts discussed above, nor the opportunity cost of using land to grow animal feed. If these are taken into account, then this approach may well lead to increases in overall GHG emissions. An additional approach being explored is to breed grasses that have a higher sugar content, rendering them more digestible.
- *Changes to genetic make up*: Selecting traits to breed animals that can produce more milk or have more muscle (which translates loosely into more milk/meat per burp), or breeding animals which emit lower levels of CH₄ during the course of digestion; breeding for longevity or fertility; breeding for multifunctionality (livestock that can be reared for both meat and milk)
- *Changes to lifespan*: Increasing the fertility or longevity of livestock or shortening the fattening period through breeding and feeding (this means they spend less time unproductively consuming foods and emitting CH₄)
- *Feed supplements and vaccines*: For example to modify the gut flora and inhibit CH₄ production

Different management systems

- *Managing soil inputs*: Optimising nitrogen and other fertiliser inputs; exploring the benefits of legume based systems (as discussed above)
- *Mixed farming systems* that seek to maximise animal-plant nutrient cycling
- *Further investigation of organic production* and its potential benefits (see below)
- *Extensive Intensive*: Explore further the potential offered by extensive-intensive farming combinations
- *Housing*: Modifying the time spent indoors according to weather and season
- *Energy*: Improving energy efficiency; using renewable fuels

Managing the outputs

- *Manure storage and handling*
- *Anaerobic digestion*: Exploring the scope for using manure and slurries in anaerobic digestion systems, as discussed above. Note that the main source of CH₄ in the livestock system is enteric CH₄, from burping, and this cannot as yet be captured.

Changing the numbers

- *Reducing livestock numbers* over and beyond what results from increases in productivity, in combination with reductions in meat and dairy consumption – see Section 8 for a detailed discussion.

As we discuss elsewhere,³³⁵ some proposed measures may be damaging to animal welfare and raise the question of what our 'ethical non-negotiables' might be. Other actions may affect biodiversity. Tackling one type of GHG can lead to pollution swapping – increases in another GHG or in another kind of environmental pollutant, such as ammonia. Reductions in one part of the farm ecosystem can prompt increases in another. Study findings, moreover, often contradict one another. The merits of organic versus conventional farming are, in particular, hotly contested and discussed briefly in the subsection that follows.

³³⁵ Garnett, T. (2007) *Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like*. Working paper produced a part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey

The fourth option, involving a reduction in the number of livestock reared, is not a technological measure but rather requires a change in our behaviour – a reduction in the consumption, and corresponding production, of livestock products. As such we explore the issue in the Section on behaviour change below.

7.a.v. A focus on organic farming

Recent years have seen a major focus on organic farming systems, with a torrent of research arguing either in favour of or against its role in reducing GHG emissions. Our FCRN livestock paper³³⁶ reviewed the literature for the livestock sector in some detail and it concluded that in both systems there are GHG hotspots. For both systems steps will need to be taken to reduce impacts. The challenge lies in achieving reductions in ways that do not compromise other social and environmental concerns including animal welfare, soil quality and biodiversity. It is worth adding a few points to the conclusions we formed in that paper. The first relates to soil fertility and the ability of the soil to sequester carbon. Systems that place an emphasis on building soil fertility through the addition of organic inputs and the use of legumes, help build carbon in soils, thereby trapping or sequestering carbon, reducing reliance on energy intensive synthetic fertilisers, and ensuring long-term soil health. These are important if the land is to continue to be productive. While organic farming principles very explicitly emphasise the need to build long-term soil fertility³³⁷ it is important to bear in mind that there are also conventional farmers who manage their soils in this way. A second, important, point to note about organic farming is that *in so far as farms aim to be self sustaining systems*, they are not implicated in land use change and possible soil carbon losses overseas – the second order impacts that we discussed earlier. The ‘in so far’ proviso is important; many dairy farmers in the UK buy in protein feeds and, in many ways mirror conventional farming systems.

Another point to make about organic farming is that research generally finds it to be less energy intensive than conventional farming systems although there are exceptions.^{338,339,340,341}

As regards GHG intensity, the picture appears to be more mixed. Crops grown organically are often (and with exceptions) less GHG-INTENSIVE than their conventional counterparts, but many studies find that some organic livestock systems (beef, dairy and poultry) tend to be more GHG-intensive than their conventionally reared counterparts.³⁴² In the case of dairy and beef cattle this is because they tend to be associated with higher CH₄ emissions per given quantity of milk or meat, largely because output is generally lower.

The energy marker is important for the reason we have already articulated; abundant fossil energy has catalysed and enabled the development of intensive production systems. These, in turn, have enabled us to farm (and particularly to farm livestock) at a scale that has turned other ‘natural’ biological processes, such as enteric fermentation, into an un-natural, or at least human-made problem. To the extent that organic systems rely less on fossil inputs the output (meat or milk) is, by necessity, limited. This has both benefits and disbenefits. Clearly, everyone

³³⁶ Ibid.

³³⁷ *Principles of Organic Farming*, International Federation of Organic Agricultural Movements, http://www.ifoam.org/about_ifoam/principles/index.html.

³³⁸ Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

³³⁹ Cederberg, C. and Mattsson, B. (2002) Life cycle assessment of milk production — a comparison of conventional and organic farming, *Journal of Cleaner Production* 8 49–60.

³⁴⁰ Milà i Canals, L. (2003) *Contributions to LCA Methodology for Agricultural Systems. Site dependency and soil degradation impact assessment*. PhD thesis.

³⁴¹ de Boer, I.J.M. (2003) Environmental impact assessment of conventional and organic milk production, *Livestock Production Science* 80 69–77.

³⁴² Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

on the planet needs to be fed, and we have to ensure that the land available to us is able to yield the volumes we require. On the other hand, as discussed in relation to livestock, we do not need to eat the types of food (or waste the volumes of food) that we, particularly in the developed world, have become accustomed to. Energy has, in short, enabled us to leapfrog ecological limits and there is a danger that, having jumped, we may now be in freefall.

Interestingly, energy use in organic and free-range poultry systems tends to be higher than in intensive ones. Birds that are free to move about expend more energy and grow more slowly and this longer rearing process means that more energy is used for a given output of meat or eggs. There is evidently a clash here between animal welfare and energy reduction objectives. One way of resolving it is simply by eating higher welfare meat and eggs, but eating less of them – an effective solution but one that requires us to change our behaviour.

Finally, on the subject of organics, there is some research to suggest that organic and/or extensive systems produce food that contains higher nutrients, by weight, than their conventionally grown counterparts.^{343,344} In theory this means that we need to eat less organic food for a given level of nutrients and in turn this means that we don't need to grow as much of it. In practice, of course, the portions we consume are dictated by convention and appetite. If I want to eat an apple, or drink a glass of milk I am unlikely to consume half an apple or half a glass of milk simply because that will be nutritionally sufficient. On the other hand, the issue is an interesting one and should not be dismissed. As Section 8 suggests, we may need to reduce our consumption of meat and dairy products very substantially, and so it is important that those animal foods that we do consume should be as nutrient-dense as possible.

7.a.vi. Soil carbon management

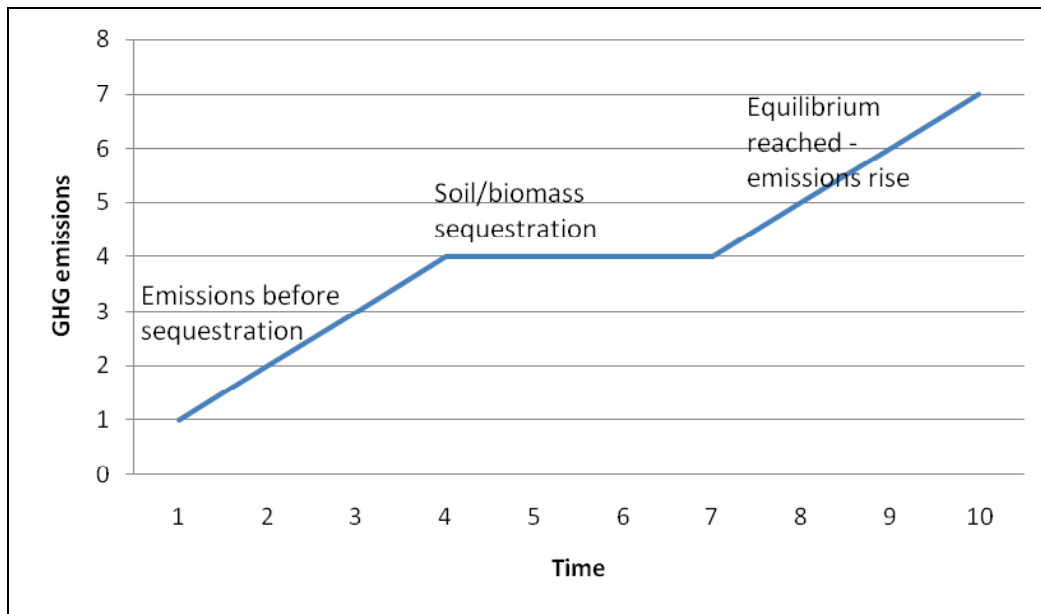
There is increasing interest in the role that soil carbon sequestration can play in reducing agricultural emissions. Soil stores carbon, so activities that enhance its ability to do so (tree planting, permanent pasture, or no-till agriculture) can potentially take carbon out of the atmosphere and lock it up.

However, soil carbon storage has its limitations. The main one is that there is only so much carbon that soil or plant matter will take up, after which a state of equilibrium is reached. After that, as Figure 14 shows, no more carbon will be sequestered. Sequestration simply buys a little time. While important in helping us meet short-term carbon reduction targets, there is a danger that in the rush to claim carbon sequestration 'credits,' longer term, permanent and perhaps more difficult measures to reduce emissions may be ignored.

³⁴³ Mitchell A, Hong Y, Koh E, Barrett D, Bryant D, Denison R & Kaffka S. (2007) 'Ten-year comparison of the influence of organic and conventional crop management practices on the content of flavanoid in tomatoes', *Journal of Agricultural and Food Chemistry*.

³⁴⁴ Pérez-López, A.J., López-Nicolas, J.M., Núñez-Delicado, E., del Amor, F.M. and Carbonell-Barrachina A.A.(2007) Effects of Agricultural Practices on Color, Carotenoids Composition, and Minerals Contents of Sweet Peppers, *Journal of Agricultural and Food Chemistry*, 55 (20).

Figure 14: Soil carbon sequestration

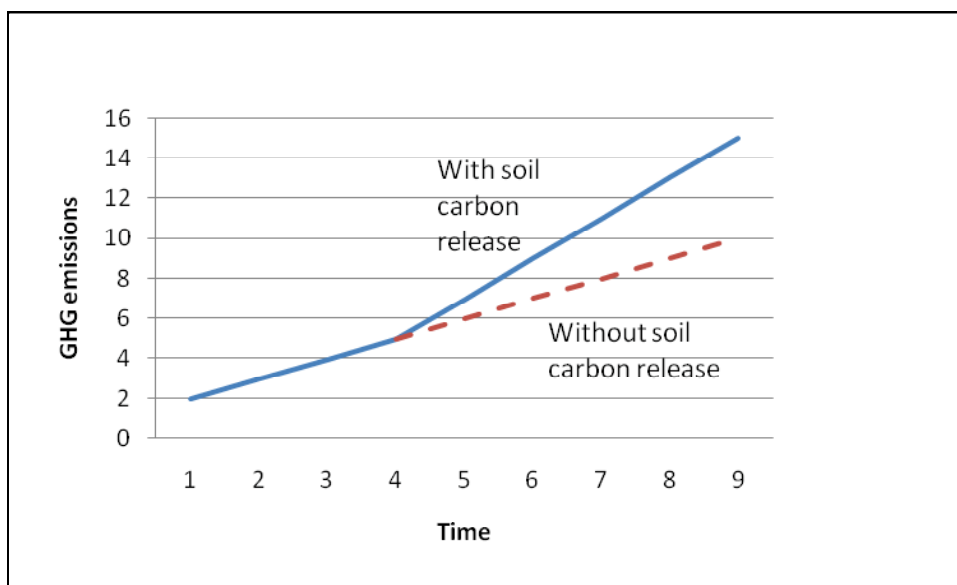


On the other hand, as Figure 15 illustrates, a change in land use that leads to the *release* of carbon (land clearance, deforestation) can produce a one off, permanent release of carbon dioxide into the atmosphere. In a sense, carbon sequestration has negative value – you only know what you had when it's gone.

There are concerns that no- or minimum-till farming can lead to higher N₂O emissions, since un-tilled soils may be prone to waterlogging, an environment that favours the formation of this gas. Evidence on the subject is mixed, with some research finding this to be the case, and other research concluding that N₂O fluxes are no greater than in conventionally tilled soils.³⁴⁵ The impacts of no-till with respect to N₂O emissions are in fact likely to vary by soil type and climate. For clay-heavy soils prone to waterlogging, N₂O fluxes may well be a problem. In sandier soils the benefits in terms of soil carbon storage probably outweigh the disbenefits.

³⁴⁵ Grandy, A.S., Loecke, T.D., Parr, S. and Robertson, G.P. (2006) Long-Term Trends in Nitrous Oxide Emissions, Soil Nitrogen, and Crop Yields of Till and No-Till Cropping Systems. *Journal of Environmental Quality*, 35:1487–1495.

Figure: 15: Soil carbon release



Note that farming practices that build up soil carbon matter (such as the addition of manure) will also improve soil quality, which in turn can improve crop productivity and help improve the biological health of the soil.

7.a.vii. New and emerging technologies

More radical technological options have also been proposed. These include breeding genetically modified plants that utilise nitrogen highly efficiently, or that are highly productive (more yield per kg of impact), or genetic modifications to inhibit CH₄ production in ruminants. These may offer possibilities. We do not discuss them here since this is an area we have not yet investigated. As with all technological options, it is important to consider whether the solution to the problem brings with it new and possibly greater costs to the environment, whether there are trade-offs with other ethical concerns such as animal welfare and, indeed, whether the technologies developed are actually appropriate to, and being developed for, the peoples and countries most in need.

7.a.viii. Actions taken by the agricultural sector

What follows is by no means an exhaustive review of what is going on in the farming sector. The situation is constantly changing – our goal here is simply to show that the sector is starting to tackle the problem, although there is a great deal more to do.

The dairy industry has recently published its ‘roadmap’ for liquid milk for England. This sets out how the dairy industry, with support from Defra, intends to reduce the negative effects of milk production, processing and distribution on the environment. The road map covers a wide range of activities including water use, packaging, waste and environmental stewardship; for GHG emissions, the goal is to reduce emissions by 20–30% by 2020 although no formal commitment has been made.

The approach the industry has taken to reducing agricultural emissions is largely one of improving efficiency, and encompasses some of the measures highlighted above: optimising inputs, better nutrient planning, improving the digestibility of feedstuffs, exploring the potential of AD, breeding programmes to increase cow longevity and so forth. It also expresses interest in an ongoing breeding programme to develop plant protein sources, such as lupins, that can be grown in the UK and so substitute for imported sources. This approach could be helpful if it helps tackle the ‘lost carbon sequestration’ issue highlighted, although we need also to consider what form of land use the lupin production would displace here in the UK.

The CALM calculator³⁴⁶ is an online tool, recently developed by the Country Land and Business Association, that allows farmers to calculate their GHG emissions. The Climate Change Task Force is also worth a mention. Jointly set up by National Farmers Union, the Country Land and Business Association and the Agricultural Industries Confederation, the Task Force produced a report³⁴⁷ highlighting how agriculture could provide 'part of the solution' to climate change and setting out where government and industry should work together.

Internationally, the private sector's GLOBALGAP initiative set voluntary standards for the certification of agricultural products, with certification undertaken by licensed third party auditors. Specifications with respect to fertiliser and pesticide use form part of the standards although there is nothing specifically relating to energy use or GHG emissions.

7.b. Post-farm gate stages

Beyond the farm gate, fossil fuel-derived CO₂ is the main gas emitted, and so in a sense the challenge is more straightforward than it is for agriculture. Measures to reduce emissions will need to adopt a combination of the following three approaches: improving energy efficiency; decarbonising the fuel source; and reducing demand for energy. While we consider each of the post-farm gate life cycle stages separately, and in turn – refrigeration, manufacturing, retailing and transport – we recognise that there is considerable overlap. For example, refrigeration is used at the manufacturing plant and at the retail outlet; transport provides the link between each life cycle stage.

7.b.i. Refrigeration

As regards energy efficiency and fuel decarbonisation, much can be done to reduce refrigeration emissions. It has been estimated that improvements in efficiency and good management such as the proper specification, use and maintenance of equipment can achieve energy savings of 20%³⁴⁸ and 50%.³⁴⁹ Further gains are possible through the use of newer technologies such as poly/tri-generation, and alternatives to hydrofluorocarbon refrigerants. A more lateral approach might be to explore the potential for packaging technologies that enable food to be stored at ambient temperature, although the embedded energy in the packaging would of course need to be lower than the avoided refrigeration emissions. From a managerial standpoint, companies investing in new equipment would benefit from taking a longer-term view on their investment, and adopting a life cycle costing perspective, rather than just buying the cheapest or 'the same as last time.' A great many organisations such as the Institute of Refrigeration, the Carbon Trust, the International Institute for Refrigeration and the Universities of Brunel and Bristol,³⁵⁰ are involved in promoting or developing technological improvements for refrigeration.

Polygeneration is a new technology that includes, but is not limited to, refrigeration, and this has been the focus of much interest at the EU level. Polygeneration is defined as the use of multiple energy inputs to create multiple energy outputs and it represents a step on from CHP in that it encompasses systems that require both heat (such as cooking) and coolness (refrigeration). A

³⁴⁶ www.cla.org.uk/calm.

³⁴⁷ Part of the solution: Climate change, agriculture and land management, Report of the joint NFU/CLA/AIC Climate Change Task Force, December 2007.

³⁴⁸ Robert Heap, Cambridge Refrigeration Technology, comment made at FCRN refrigeration seminar, Manchester, September 2006.

³⁴⁹ See, for example, *How to improve energy efficiency in refrigerating equipment*, International Institute of Refrigeration, November 2003.

³⁵⁰ Defra project AC0403 – *Fostering the development of technologies and practices to reduce the energy inputs into the refrigeration of food*.

fully integrated, low-carbon example of polygeneration would be a plant fuelled by biomass or biogas and producing heat, electricity and refrigeration.

Results from a demonstration trigeneration plant (a subset of polygeneration) in the UK show that refrigeration efficiency increased from the current norm of 38% to 76%.³⁵¹ EU-funded research suggests that the application of polygeneration to the UK food sector could reduce the sector's CO₂ emissions by about 20%,^{352,353} equivalent to 0.4% of the UK's GHG emissions. Polygeneration can, of course, be applied to other non-food areas.

7.b.ii. Manufacturing

Within the manufacturing sector, a number of companies are taking steps to reduce their manufacturing-stage impacts. Cadbury has pledged a 50% reduction in net, absolute carbon emissions by 2020. The focus will be on energy efficiency and greater use of renewables, although carbon offsetting will also be undertaken as a 'last resort'.³⁵⁴ (Note that carbon offsetting is a relatively new market and both it and the Kyoto Clean Development Mechanism have been the subject of much criticism.^{355,356,357}) McCain's, the manufacturer of chips and other potato products, aims to meet 70% of its electricity needs from wind turbines and a CHP plant running on biogas.^{358,359} The UK's food manufacturing trade body, the Food and Drink Federation, has committed to the sector achieving a 20% cut in CO₂ emissions by 2010 on 1990 levels as part of its Five-Fold Ambition.³⁶⁰ Note that the sector's emissions were 16% below 1990 levels by 2007 anyway (due to the switch to gas in the 1990s), and hence the target is highly achievable. The sugar manufacturer Tate & Lyle is installing a biomass boiler in its London refinery (the only one it owns in Europe) to replace 70% of its fossil energy use.³⁶¹

While measures to improve efficiency and to make greater use of renewable, lower carbon fuels are useful, they may not be enough to counter current unsustainable trends in the sorts of foods that are being produced and consumed – that is, they do not address unsustainable *demand*. For example, Tate and Lyle reports that it did not achieve its Group target of a 3% reduction in per-unit energy use³⁶² 'because our product mix is changing, which can make year-on-year

³⁵¹ Doug Marriott, Doug Marriott Associates, comment made at FCRN seminar, Manchester September 2006 and personal communication.

³⁵² Calculation based on estimated savings for the UK by the Optipolygen project as a percentage of current UK food manufacturing emissions as estimated by the food and drink industry (see pie chart in section 2 above).

³⁵³ *Optipolygen Final Project Results*, EIE/04/150/SO7.39553 Final project results, Intelligent Energy Europe, European Commission, 2007.

³⁵⁴ <http://www.cadbury.com/ourresponsibilities/purplegoesgreen/Pages/PurpleGoesGreen.aspx> accessed 26 September 2008.

³⁵⁵ Schneider, L. (2007) *Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement*. Report prepared for WWF by Öko-Institut E.V. Berlin, 5 November 2007.

³⁵⁶ Smith, K. (2007) *The Carbon Neutral Myth*, Carbon Trade Watch, Amsterdam.

³⁵⁷ Kollmuss, A., Zink, H. and Polycarp, C. (2008) *Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards*, WWF Germany.

³⁵⁸ Food and Drink Federation, Environmental Case Studies, <http://www.fdf.org.uk/environment/casestudies.aspx> accessed 8 February 2008.

³⁵⁹ Press release 14/08/07, McCain introduces winds of change to UK's largest chip factory. – Groundbreaking wind turbines project to cut bills by up to 60%, McCains, <http://www.mccain.co.uk/info/press-releases/wind-turbines.aspx> accessed 8 February 2008.

³⁶⁰ *The environment: Making a real difference*, Food and Drink Federation, October 2007.

³⁶¹ 26/11/2007 Press Release: *The Future's green for Tate & Lyle*, Tate & Lyle, <http://www.tateandlyle.presscentre.com/Content/Detail.asp?ReleaseID=725&NewsAreaID=2> accessed 8 February 2008.

³⁶² Tate & Lyle: *Environment* http://www.tateandlyle.com/TateAndLyle/social_responsibility/environment/default.htm accessed 8 February 2008.

comparisons somewhat misleading. As we grow our business, we are making more value added products; however, these use more energy than our traditional products.'

In similar vein, the Coca-Cola company says 'In 2006, the system experienced an increase in its energy use ratio due, in part, to certain products that are more energy-intensive.'³⁶³

In other words, while technological improvements and know-how are improving, they need to be set against business-as-usual trends which foster the development of new, often more energy intensive, products. We have highlighted this already with respect to refrigeration dependence.

7.b.iii. Transport

On the face of it, many food industry players are achieving significant improvements in their transport efficiency and all the major retailers have committed to reducing their impacts. Tesco has, for example, committed to reducing its global transport emissions per case of goods delivered by 50% between 2006/7 and 2011/12 through a mix of energy efficiency, modal shift and infrastructural change.³⁶⁴ Note that the company's target is a relative one, meaning that as the supermarket expands, so, it is likely, will its transport emissions measured in absolute terms. Measures include building new distribution centres in optimal locations, and improving the management of front haul, back haul and primary distribution networks. The company is also investing in double-deck trailers and transferring some goods from road to rail and canal. The supermarket has also committed to reducing the volume of food it brings in by air to no more than 1% of the total volume total, with a bias in favour of importing from developing countries.³⁶⁵

Other supermarkets, including Asda³⁶⁶ and Marks & Spencer³⁶⁷ have also made commitments to reduce transport emissions. McDonald's in the UK has converted its 150-strong delivery fleet to run on waste cooking oil – the mix is 85% recycled oil and 15% rapeseed oil.³⁶⁸

On a more general scale, a number of universities, coordinated by the University of Leeds, are collaborating on a major research council funded Green Logistics project,³⁶⁹ the aim being to examine ways of reducing the environmental costs of transport, including climate change, air pollution, noise, vibration and accidents.

Note that these activities are all confined to UK borders. As discussed in Section 3 above, transport's apparently modest contribution to food GHG emissions needs reconsidering in the context of its second order impacts and the fact that the trends are, globally, all going in the wrong direction. Given the food supply chain's international reach, this suggests that the impacts of food transport are growing. This is a concern that goes beyond the need to improve efficiency, and one that the food sector is not addressing.

In addition to efficiency measures, many of the supermarkets have local sourcing commitments. These may not always be helpful in reducing food-related emissions for some of the reasons already discussed in relation to food miles, above, but it is nevertheless interesting to explore *why* they have these commitments and how they 'pitch' them. As to the why, clearly consumer demand is paramount, and all supermarkets have identified a strong interest in local and/or provenance foods among an often wealthy sub-sector of the market. The pitching, however,

³⁶³ 2006 Environment Report, The Coca-Cola Company, 2007, http://www.thecoca-colacompany.com/citizenship/accountability_reporting.html accessed 8 February 2008.

³⁶⁴ Katherine Symonds, Tesco, pers.comm. March 2008.

³⁶⁵ This means that if the retailer were in danger of overshooting its 1% limit, it would cut imports from developed countries before those from developing ones.

³⁶⁶ <http://www.asda-corporate.com/environment/transport-distribution.asp>

³⁶⁷ http://plana.marksandspencer.com/?action=PublicAboutPlanDetailDisplay&pillar_id=1&cur_page=0

³⁶⁸ Environment facts and figures: Updated June 2008, McDonalds.

³⁶⁹ <http://www.greenlogistics.org/PageView.aspx?id=97&tid=97> accessed 25 March 2008.

varies from supermarket to supermarket and indeed, has evolved over time. Tesco now frames its commitment in terms of supporting smaller growers, and on quality and provenance.³⁷⁰ Indeed the company does not mention the phrase 'food miles' at all in the context of local sourcing. On the contrary, it states '*Our distribution team will be working on new local transport solutions, to ensure that working with smaller local suppliers also keeps down our carbon footprint,*' the implication being that local sourcing represents a challenge for transport CO₂ reductions rather than a solution. Sainsbury's too, does not mention food miles in same context as transport CO₂.³⁷¹ Asda, on the other hand, highlights its local sourcing³⁷² arrangements in terms of (among other things) its contribution to cutting food miles, as does Marks & Spencer.³⁷³

Whatever the angle taken, there is, however, nothing to suggest that local and regional sourcing is anything other than an add-on to the mainstream, logistical status quo. Those products that are successful on a local scale can and do get rolled out across the whole UK supply chain.³⁷⁴ We may be seeing the development of dual logistics systems: globalised systems for the bulk of the foods we eat, and 'local' (however defined) alternatives that tend to garnish, rather than substitute for, the status quo.

7.b.iv. Retail

The British Retail Consortium³⁷⁵ has made a voluntary commitment on behalf of its members to reduce emissions from buildings and transport deliveries by 15% on 2005 levels by 2013.

There is considerable scope for achieving massive improvements in store lighting, refrigeration and distribution emissions, and some of the major retailers have made fairly ambitious commitments to reduce energy use in these areas. Tesco has, for instance, stated that it will cut its store and distribution centre CO₂ emissions by 50% on a per-area basis globally by 2020.³⁷⁶ Marks and Spencer's target is to be carbon neutral by 2012 through a combination of energy efficiency, increased use of renewables and 'offsetting as a last resort'.³⁷⁷ Sainsbury's aims to reduce store CO₂ emissions per square metre by 25% against a 2004/05 baseline by 2012.³⁷⁸ As an aside, the proliferation of different types of targets and the lack of any legal requirement to report progress in the same terms makes it hard to benchmark the progress of the different retailers.

It is, moreover, not clear how their reduction targets fit with their plans for expansion – in some cases, global expansion. A distinction between the reporting of food and non-food per-area emissions would also be helpful. Non-food goods do not require refrigeration and so floor space devoted to these goods will be less energy intensive. For retailers that devote a large (and growing) area to non-food goods, this distorts their reporting of emissions.

The whole issue of overseas supermarket expansion raises serious questions, relating to emissions and to cultural-ethical concerns. With regard to the former, one needs to know whether (say) a Tesco supermarket opening in Thailand is replacing an additional business or creating additional demand. In the latter case the supermarket would be adding to overall emissions (although it is arguable that the supermarket is a meeting existing, albeit latent

³⁷⁰ *Corporate Responsibility Review*, 2007, Tesco.

³⁷¹ *Corporate Responsibility Report 2007*, J Sainsbury plc.

³⁷² <http://www.asda-corporate.com/policies/local-sourcing.asp> accessed 25 March 2008.

³⁷³ http://plana.marksandspencer.com/?action=PublicPillarCommitmentDisplay&pillar_id=1

³⁷⁴ http://www.tescocorporate.com/crreport07/04_climatechange/reducingenergyuse.html – see for example the beer case study.

³⁷⁵ *A Better Retailing Climate*, British Retail Consortium, 2008.

³⁷⁶ Tesco Corporate Responsibility Review 2008.

http://www.tescocorporate.com/crreport07/04_climatechange/reducingenergyuse.html

³⁷⁷ http://plana.marksandspencer.com/?action=PublicPillarStoryDisplay&pillar_id=1 Accessed 8 February 2008.

³⁷⁸ <http://www.jsainburys.co.uk/files/reports/cr2007/index.asp?pageid=29> .

demand). In the former case, one would need to ascertain whether the food business being replaced was more or less energy intensive than the Tesco store in question. Perhaps equally important is the concern that the encroachment of supermarkets into the developing world constitutes a form of cultural imperialism, replacing established food provisioning systems with an external model. This is an important and interesting question, and merits a separate paper in itself.

7.b.v. Food preparation and storage – domestic and catering

By the time we have carried our food home, or the food has been delivered to the catering outlet, most of the embedded GHGs have been emitted, but householders and caterers will use additional energy and generate additional emissions through their use of cookers, ovens, refrigerators, dishwashers and other kitchen appliances. The issues here relate both to the inherent efficiency of the appliances themselves, and to the way in which they are used.

With regard to the appliances themselves, steps are being taken with some products to improve the efficiency of these appliances. For example, mandatory energy efficiency labels on fridges and freezers have helped achieve considerable efficiency savings. On the other hand, smaller cold appliances such as wine and beer coolers, ice makers and ice cream makers are not included in any labelling scheme and, if uptake of these goods is strong, the energy savings in the cold appliances sector could be significantly reduced. Electric ovens also fall under the EU Energy labelling scheme but other appliances, including gas ovens, gas hobs, microwaves, kettles and other small appliances do not.

With electricity, if the source of the supply is renewable, then clearly the carbon intensity of its use drops. This raises very much broader questions to do with national energy policy and supply, which are beyond the scope of this paper.

Good management is also important. The standard ‘eco-friendly’ cooking tips are well rehearsed – not boiling more water in the kettle than is needed, putting lids on saucepans, not using the oven for individual portions and so forth. These actions can make a big difference to the overall footprint of an individual product (potatoes, for example, or tea). With domestic and commercial food preparation accounting for around 16% of overall food GHG emissions (around 3% of total GHG emissions – see Figure 4) energy efficient methods are likely to make a useful, if not dramatic dent in overall emissions.

Real time displays and ‘smart meters’ have also been proposed as a way of engaging householders in the efficiency debate. Real time displays are small units, located in a prominent position, that show people how much electricity they are using. Smart meters are more sophisticated and record both electricity and gas use. Several variants are being developed; some internet linked, some beep when electricity consumption exceeds a certain level and so forth.³⁷⁹ The main purpose of both devices is to communicate how much energy householders are using in a far more immediate and accurate way than with traditional quarterly bills. The idea is that if people know how much they are using they are motivated to reduce energy use wherever they can. The trials have been hampered by technical problems and at present it is unclear whether these devices are actually having an effect on people’s behaviour.³⁸⁰ Government at present will be undertaking further work before deciding whether to roll out smart metering to the domestic and small business sectors, although it will be doing so for larger businesses.³⁸¹

Waste is the other major impact at the household stage and has been discussed earlier. It seems perfectly possible to reduce waste levels by half through basic forward planning and

³⁷⁹ *Energy demand research report: Review of progress*, Ofgem Ref: 110/08, June 2008.

³⁸⁰ *Ibid.*

³⁸¹ <http://www.berr.gov.uk/energy/environment/smart-metering/index.html> .

good housekeeping, although various technological measures are also being explored. These include 'smart' packaging (which tells you if your food is being stored at the right temperature), resealable packaging and so forth.³⁸²

7.c. Embedded GHG emissions: the PAS GHG quantification method and carbon footprinting

In addition to the physical infrastructure – trucks and sheds, stores and fridges – the food industry has started to turn its attention to the emissions embedded in the food it manufactures and sells. The major supermarkets, together with a wide range of other stakeholders in the UK and internationally, have had the opportunity to comment on the draft carbon footprinting method, the PAS 2050, being developed by the Carbon Trust, Defra and the British Standards Institute through a stakeholder consultation process. This project will develop an agreed method for assessing the GHG emissions of goods (including food) and services,³⁸³ with the final version to be published in October 2008.

It should be emphasised that the purpose of the Carbon Trust/BSI/Defra collaboration is to develop a *method* for assessing GHG emissions; it is not to develop a consumer-facing label. Such a label is, however, being developed separately by the Carbon Trust. Indeed, as of May 2008, Tesco has packaged 20 of its products with a label showing their 'carbon footprint.' Carbon footprints can also be found on Walker's crisps while the Innocent company provides carbon footprint information for its smoothies on its website. Note that the term 'carbon footprint' is a slight misnomer since the method assesses the full range of GHGs

Retailers overseas are following suit. Migros, the Swiss retailer, will be introducing carbon labelling on five own-label product groups.³⁸⁴ The major French retailers, in association with their trade association, have announced a study to assess the embedded emissions of around 300 key items in an average French consumer's shopping basket, with labelling on packs from 2010.³⁸⁵ In Australia, the retail trade association and Woolworths Limited (the largest supermarket chain in Australia) have announced a joint study into ways of measuring the climate change impact of food, beverage and grocery products.³⁸⁶

One benefit of having a GHG assessment method is that manufacturers gain a clearer idea of the main impact 'hotspots' along the life cycle of the foods they produce and where the GHG inefficiencies lie. For example, an LCA undertaken by the Carbon Trust for Walkers crisps established that the way potatoes are sold and bought generates additional unnecessary emissions. Since farmers are paid a price per tonne, farmers store potatoes in humidified sheds to increase their water content and thus their weight. Humidifiers use large amounts of energy. At the manufacturing plant Walkers then fries the sliced potatoes to remove the moisture. It was found that the use of humidified potatoes increased overall frying time and emissions by up to 10%.³⁸⁷ Hence, in so far as energy inefficiencies translate into unnecessary costs, there is a clear incentive to reduce GHG emissions.

However, while cost may correlate with inefficient energy use, there is not the same relationship with the other sources of global warming – CH₄, N₂O and land use-related CO₂ releases. Hence

³⁸² *Survey of packaging with potential to reduce food thrown away at home. A market survey of packaging formats and other retailer and in-home solutions to help consumers manage their food inventory better.* Waste Resources Action Programme, July 2007.

³⁸³ <http://www.bsi-global.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050/> accessed 25 March 2008.

³⁸⁴ http://www.migros.ch/FR/A_propos_de_Migros/Medias/Actualite/Seiten/NewsFull.aspx?NewsID=270

³⁸⁵ <http://www.fcd.asso.fr/site/index.php?rub=accueil>

³⁸⁶ <http://www.afgc.org.au/index.cfm?id=607>

³⁸⁷ *Carbon footprints in the supply chain: The next step for business*, The Carbon Trust, November 2006.

the argument for a consumer-facing label: shoppers will be able to see what emissions are associated with particular foods. Where two similar products have different GHG impacts (all other things being equal) they may go for the less GHG-intensive choice. This in turn gives manufacturers a market incentive to reduce their emissions. Interestingly, regardless of whether the consumer understands the information being put across (or even acts upon it), the very presence of a label might spur manufacturers to take action. With respect to nutrition labelling for example, it has been argued that front-of-pack information had this race-to-improvement effect among food manufacturers.³⁸⁸ No manufacturer wants to have 'high fat, high sugar, high salt' plastered all over its packaging, and so manufacturers take action and reformulate their product. The same could (in due course) plausibly happen as a result of carbon labelling, although at the moment the public are much more aware of, and concerned about, healthy eating than of food's contribution to climate changing emissions.

Another potentially helpful aspect of the Carbon Trust label is that permission to use it is given on a 'reduce or lose' basis: a manufacturer displaying the label is required to reduce its emissions over a two year period or forfeit the right to display it. Given that there are costs involved in measuring a product's footprint, the food industry may want to turn this sign of environmental commitment to a marketing advantage – again provided that the public's interest in this issue grows.

Notwithstanding these advantages, both the PAS 2050 carbon footprinting method, and its potential use in a consumer-facing label, raise a number of concerns. Those relating to the method itself are largely practical and have been articulated by others, most formally through the formal PAS 2050 consultation process.³⁸⁹ With many supermarkets stocking over 40,000 product lines,³⁹⁰ and with individual products containing 20 or more ingredients (whose sourcing can vary from week to week) the challenge of quantifying emissions is clearly enormous. This said, the Carbon Trust has found that the task is made easier, and that costs fall, when similar products from the same company are analysed, or where inputs to multiple products are similar, and as experience of the process grows within the company. They also point out that the future development of assessment tools and the transfer of carbon footprinting information across businesses and along the supply chain, will also help. Clearly systematisation, the use of default data and gradual improvements in data accuracy and availability will indeed bring costs down and Tesco states that it has already found this to be the case. Nevertheless it has been suggested that the process is expensive and may be prohibitively so for smaller manufacturers. Once again, however, the Carbon Trust points out that the interest shown by companies in getting involved has far exceeded their expectations. Perhaps the question is not so much 'can it be done?' (to which the answer may well be: yes, ultimately) but whether this course of action represents the best use of time and money with respect to reducing food GHG emissions.

There are also concerns about the actual principle of developing a label. A general criticism is that the focus on a specific issue (climate change) can lead to consequences that may, from a broader sustainability perspective, be counterproductive. For example, fish have a lower GHG footprint than many meat products³⁹¹ but clearly, with fish stocks severely depleted, eating fish instead of meat hardly affords a solution. Spanish tomatoes may, out of season, have a lower footprint than their British counterparts but the horticultural sector in Spain is already depleting

³⁸⁸ David North, presentation given at Corporate Climate Response conference, CBI Conference Centre, London, 21 May 2008.

³⁸⁹ Details of the PAS 2050 consultation process can be found here: <http://www.bsi-global.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050/Stakeholder-Consultation/> The responses are not publicly available, but from personal communications with those responding there is a fair level of concern.

³⁹⁰ <http://www.tesco.com/talkingtesco/productChoice/>

³⁹¹ Tyedmers, P.H., Watson, R. and Pauly, D. (2005) Fuelling Global Fishing Fleets, *Ambio* Volume 34, Issue 8 pp 635–638.

scarce water resources. And a single apparently holistic 'sustainability' label would have to balance and weight all these concerns – an undertaking that is invariably subjective and very much open to question.

Critics also ask whether the label will actually prompt measurable decreases in the GHG intensity of what they consume. It may enable people to choose between two brands of yoghurt, or bread, or crisps – but any such decisions are also going to be influenced by which type of yoghurt, or bread, or crisps they actually prefer, as well as by price and other considerations. More importantly, it is highly unlikely that people are going to go around totting up the carbon content of everything they eat and then comparing it against a benchmark of ideal consumption – just as most people do not go around adding up their daily calorie intake. Arguably, if people broadly maintain their regular diets (and we are, after all, creatures of habit) and if, at the same time, manufacturers use the consumer-facing label as a means of competing with one another to get their carbon figures down (and they are also required to do so if they want to keep onto the label), then the end effect might be that the normal, typical diet that most people eat will gradually become less GHG-intensive.

This may be the case but it might be helpful here to consider nutrition labelling as an analogy. Has nutrition labelling actually had any significant effect, first on what people buy, and second on what people actually eat? This is a very difficult question to answer. Research in this area is scarce and it is, of course, very hard to disentangle the information consumers gain by reading food labels from the broader and very prevalent 'healthier eating' messages broadcast by the media.

This said, there is one interesting study³⁹² which compared people's consumption of regular potato crisps with fat-free versions made with Olestra. This found that during the 'snacking occasion' itself, fat and energy intakes were lower when people ate the Olestra-containing crisps. Over a 24-hour period, however, although fat levels were lower, overall energy intakes were not affected. In other words, people compensated by adjusting their energy intake over the course of the day. Half of the participants in the study were told that the fat-free crisps were fat-free whereas the other half were not, and interestingly, those who knew they were eating the Olestra crisps ate significantly more of them than did those who ate the regular kind. This suggests that people overcompensate for 'virtuous' consumption by eating more of the product – the rebound effect, in other words. By analogy, if, as a carbon-aware consumer, I choose to buy the lower carbon brand of crisps, I might decide to 'reward' myself with some freshly squeezed orange juice, instead of the lower-GHG UHT kind that I would normally buy. I might, or I might not – the point is, that we cannot assume that an informed consumer will necessarily make the 'right' decision.

We would also hypothesise that a highly atomised, disaggregated, accountancy-style approach to food (which is ultimately what labelling and calorie counting offer) does not encourage a relationship with food that fosters generally healthy eating habits, but rather the reverse. Arguably, the heavy emphasis on nutritional labelling does not help a society eat more healthily. The label is symptomatic of (and perhaps even exacerbates) a lost relationship with food, and a lost understanding of appetite.

One might also suggest that detailed nutritional information does not so much help consumers make informed and healthier choices as provide a way in which manufacturers can sell new products: one thinks of chocolate bars that proclaim themselves to be 'less than 100 calories' or 'lower fat' crisps. Rather than eating 'proper' versions of such foods occasionally, we are persuaded to think that we can have our cake and eat it all the time. The basic psychology of

³⁹² Miller, D.L., Castellanos, V.H., Shide, D.J., Peters, J.C. and Rolls, B.J. (1998) Effect of fat-free potato chips with and without nutrition labels on fat and energy intakes *Am J Clin Nutr*, 68:282–90.

our eating behaviour does not change and, as a result, we do not, as a nation, appear to be getting any thinner. Whether the analogy actually holds in the case of GHG labelling is unexplored territory but may be worth bearing in mind.

Finally, the carbon label prompts us to ask whether the onus should once again be placed on consumers to make the 'right' choice? Is persuading people to change how they consume fair or even effective? We discuss these questions in the Section on behaviour change below.

7.d. Can technology get us all the way?

Problematically, while agriculture makes the greatest single contribution to food chain GHG emissions, it is also the area where savings may be hardest to achieve. There are multiple gases and sources to deal with: N₂O, CH₄, CO₂ from fossil fuels, and CO₂ from land use change. Our understanding of the gases and their biochemical pathways is still developing, and there is the ever-present, complicating risk of problem swapping – a reduction in emissions of one GHG can lead to increases in another or in increases in another type of pollutant such as ammonia. The sheer numbers of individual growers (both here and overseas) all farming slightly differently, combined with differences in soil type and other geological factors, substantially magnifies the scale of the challenge.³⁹³

Most fundamentally, however, we all have to eat. We have to grow plants and rear animals and these activities are in turn subject to basic biochemical principles. Agricultural emissions can be reduced through better farm management and technological and breeding programmes, but by how much is unknown – there may only be so much slack in the system. Moreover, UK-based mitigation measures could have negative impacts on land use emissions in other parts of the world (second order impacts) and there are no signs so far that these are being taken into consideration.

The post-farm gate challenge is (in theory) more straightforward to tackle but that does not mean it is easy. The catering sector is still very fragmented, the household stage definitively so. There is greater consolidation further up the supply chain and it is no coincidence that the retailers and manufacturers are taking the lead with respect to energy efficiency.

Many of the challenges that the post-farm gate sectors face are systemic, however, and require national policy changes. Widespread reductions will not be achieved unless government is prepared to act forcefully and confidently³⁹⁴ and puts in place the right support and economic signals. These include, for example, greater support for renewables, for micro- or decentralised distribution, and a firm stance on transport fuel taxation and changes in the planning system. In the meantime the food industry can achieve reductions by shaving away at the problem, and by deploying a mix of different technologies and energy efficiency measures.

Tables 4 and 5 below summarise some of the options we have highlighted in this section.

³⁹³ 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).

³⁹⁴ *Green healthy and fair: A review of Government's role in supporting sustainable supermarket food*. Sustainable Development Commission, London, 2008.

Table 4: The technological and managerial options: pre-farm gate

Pre-farm gate	Efficiency	Renewables	Other	Comments and issues raised
Energy use	Scope for better efficiency, CHP	AD, biomass for heat, solar, wind etc.		Much depends on the policy context; impacts of biomass production need to be considered
Fertilisers	Optimising applications whether synthetic or organic	AD, manure and legumes are all renewable	AD digestate, manure, legumes as substitutes	Consistent quality of digestate needed; ditto manure; more research into scope offered by legumes needed
Crop-oriented options	As above		Breeding for improved nutrient uptake; pest resistance, extended seasons	
Livestock oriented options	Optimising feed; manure storage and handling; housing	For housing: AD, biomass for heat, solar, wind etc.	Breeding for longevity, fertility, multifunctionality; mixed crop-livestock farming to maximise nutrient recycling	Feed optimisation – potentially negative second order impacts; animal welfare implications need to be considered
Organic	Uses less energy; questions raised regarding overall GHG emissions but studies tend not to take into account second order land use change impacts	Organic systems place heavier emphasis on use of renewables		Contested benefits but in our view offers potential; non GHG benefits too; further research needed; organic systems in some ways mimic conventional (eg. breeds)
Soil carbon			Maintains carbon in soil or increases it up to point of equilibrium	One off benefits; buys time. Improves soil quality

Table 5: The technological and managerial options: post-farm gate

Post-farm gate	Efficiency	Renewables	Other	Comments and doubts
Refrigeration	20-50% savings from good housekeeping alone and specification; long-term life cycle costing	Polygeneration / trigeneration	Packaging (to keep goods at ambient temperature)	Doesn't tackle inherent refrigeration dependence of product mix
Manufacturing	Yes, potential; targets set by major manufacturers	Polygeneration; wind, AD etc.	Offsetting part of the package – questions raised about offsetting; waste reduction	Doesn't address GHG intensity of new product developments or need-to-grow
Transport	Major scope; targets set by individual companies	Limited scope for using waste cooking oils; first generation biofuels counterproductive	Modal shift to sea or rail; local sourcing; investing in logistically optimal sites for distribution centres	Doesn't address second order impacts of globalised supply chains; dual local-global supply chains developing
Retail	Yes, potential; targets set by major retailers	Yes, potential, actions taken by individual retailers	Offsetting part of the package – questions raised about offsetting; waste reduction	Doesn't address expansion especially overseas; distortive effects of non-food offer
Catering and domestic	Major scope through labelling and incentives; visible energy metering	Potential, but limited given current policies; large potential with right policy changes	Waste reduction	Huge number of individual players makes challenge harder

This brings us back to the question we asked at the outset: Can we invent and manage our way out of our problems?

The tables above show that there is certainly a great deal that can be done although it is not possible at present to put a figure on what might be possible. Certainly the example of the large

manufacturers and retailers shows that much can be achieved through improvements in energy efficiency and basic good housekeeping, as well as through investment in renewable infrastructure such as wind farms, anaerobic digesters, and polygeneration plants. Tate & Lyle's achieved 70% reduction in energy use is not very far off the 80% target.³⁹⁵

However, while cleaner technologies and better supply chain management are vital, they do not help us address the bigger picture. The food industry may be taking steps to improve their operational infrastructure, but this ultimately has little influence on their intended direction of growth. In the same way, while transport emissions per case of product are declining, overall increases in the distance goods are moved, combined with the negative second order impacts of major infrastructural investment, have a counterbalancing effect.

In short, these measures do not challenge our demand for, and the food industry's supply of, certain types of food and systems of provisioning that are inherently GHG-intensive. These include meat and dairy products, highly refrigeration intensive foods, and foods that are very perishable (and so require both refrigeration and rapid modes of transport), and the year round demand for a wide range of foods.

Technological improvements moreover do not address *trends* in how and what we consume, the demands these place on existing and emerging technology and the way in which technological developments help shape and foster new behavioural norms – norms which may lead ultimately to greater energy use. The examples of Coca-Cola and Tate & Lyle whose product mixes are becoming more energy intensive even while they take steps to improve energy efficiency, illustrate the point. Smart technologies modify the snapshot picture today – but we need to look further ahead and see how what we invent today affects what we consider to be normal tomorrow, and what the environmental implications might be.

³⁹⁵ Although note that this is for just one refinery and just one stage in the sugar life cycle.

8. CHANGES IN CONSUMPTION

*Dost thou think, because thou art
virtuous, there shall be no more cakes and ale?*
Sir Toby Belch, *Twelfth Night*, Act 2 Scene III

While major technological and managerial improvements are essential, they may not by themselves achieve an 80% GHG reduction by 2050. We need therefore to consider what changes in behaviour might achieve.

This section starts by exploring what a different, low-GHG pattern of food consumption might look like and what the implications of these changes might be on overall GHG emissions. We then look at the nitty-gritty of getting people to do things differently: what do people think about food, are people likely to change their behaviours voluntarily and how far should policy and other efforts be devoted to persuading them to do so?

Finally we go on to explore the role and effectiveness of changes in UK attitudes and behaviours, combined with technological change in the context of *global* GHG emissions – in a sense, the second order global implications of our producing and consuming differently here in the UK. What we are asking is how far changes in what we do here in the UK actually make a difference to global GHG emissions and what the implications for policy might be.

8.a. What would a less GHG-intensive way of consuming look like in the UK?

Table 6 below summarises briefly what a less GHG-intensive way of producing and consuming food might look like – note that the emphasis is on ‘might’ and further discussion and exploration is needed.

Table 6: Less GHG-intensive eating patterns

Priority	Action	Impact area addressed	Comments
High	Eat fewer meat and dairy products	N ₂ O and CH ₄ emissions; lost carbon sequestration from possible land clearance overseas	Reductions in UK production and in imports; fewer meat and dairy products consumed
High	Eat less (that is, do not eat more than you need to maintain a healthy body weight)	Obesity is a problem and is at its most basic a result of overconsumption	<p>This is dangerous territory if individual people are victimised. Moralistic attitudes towards body weight are unhelpful and often destructive.</p> <p>Overconsumption of food is part and parcel of a society in which consumption and consuming is its <i>raison d'être</i>. The eating-less agenda should be seen as part of a broader requirement to consume less overall</p>
Medium	Eat seasonal robust, field grown vegetables (preferably seasonal to the UK) rather than protected, fragile foods prone to spoilage and requiring heating and lighting in their cultivation or needing rapid modes of transport	Refrigeration, transport, food spoilage	<p>'Robust' foods are less prone to spoilage. Local is more problematic because the mode and efficiency of the transport system will influence the outcome.</p> <p>Measures to reduce air freighted foods may clash with objectives of supporting economic development in poor countries</p>
Medium	Prepare food for more than one person and for several days	Efficiencies of scale – reduced energy use	<p>Requires a measure of pre-planning – cooking in bulk for more people and/or for several days is more energy efficient than cooking lots of meals in one go. There is potential for greater waste if the food ends up uneaten.</p> <p>Trends in how people actually live (more single person lifestyles etc.) make this approach difficult</p>

Priority	Action	Impact area addressed	Comments
Lower	Shop on foot or over the internet	Reduced energy use	Research into the benefits of internet shopping is cautiously optimistic but newer studies are needed (and being undertaken as part of the Green Logistics consortium project). ³⁹⁶
Medium, possibly high	Don't waste food / manage unavoidable waste properly eg. through AD	Embedded emissions – in theory lower levels of production permitted	Wasted food represents a waste of embedded emissions but see Section 3 for a discussion of the difficulties of drawing simplistic conclusions. The waste issue raises structural, system questions that are linked to the whole <i>consuming less</i> debate
Medium	Accept different notions of quality	Embedded emissions – in theory, lower levels production permitted	Food that is edible but deemed of lower quality goes to food processing or animal feed. How much lower-quality food is actually discarded is less uncertain and merits further research
Medium	Accept variability of supply	Emergency top ups; need to source even from unsustainable sources at all costs	The current imperative to have more or less everything available all the time means that foods are available even when the environmental cost of supplying them is very high
Medium	Consume fewer foods with low nutritional value eg. Alcohol, sweets, chocolate etc.	'Unnecessary' foods – they are not needed in our diet	Raises enormous questions and accusations of nanny-state misery-guts spoil-sportism
Medium	Cook and store foods in energy conserving ways (eg. Lids on pans, use pressure cooker, minimise use of oven; judicious use of microwaves); possibly smart metering	Energy use in the home	Simple to do; saves money; impacts limited but useful

³⁹⁶ <http://www.greenlogistics.org/PageView.aspx?id=97&tid=97> accessed 25 March 2008.

Defra also gives guidelines on what a more sustainable way of eating might entail. These goals relate to a range of environmental objectives rather than GHG emissions reduction alone but are in keeping with Table 6. The five key actions are as follows:³⁹⁷

1. Switching to a diet with lower environmental and social impacts (eg. by eating fewer meat and dairy products).
2. Wasting less food in the home.
3. Avoid fish from uncertified or unsustainable stocks; buy certified fish.
4. Switching to more seasonal and local food.
5. Increasing consumption of organic or certified / assured food and drink (including Fair Trade).

Broadly speaking, eating fewer meat and dairy products and consuming more plant foods in their place is probably the single most helpful behavioural shift one can make and we discuss what level of reduction might be needed at a global level.

In addition, several recent studies have pointed out that our wealthy society, in which many of us are overweight, can collectively reduce our food GHG emissions simply by eating less.^{398,399} In theory, less food consumed means less food produced; in practice the issue is much more problematic as we have already noted with respect to food waste.

8.b. Would eating differently make much difference to the UK's emissions?

We have sketched out the eating patterns that would reduce food GHG emissions. But what level of reduction might they achieve? And do the savings compare with those achievable through technological and managerial means?

One study by Wallén *et al.* has investigated these questions from a Swedish perspective.⁴⁰⁰ The study takes as a starting point for its analysis an argument put forward by Dahlin and Lindeskog,⁴⁰¹ 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 GHG-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 to look at the detail of their arguments, but broadly speaking these recommendations accord with ours.

Wallén *et al.* go on to quantify the effect that Dahlin and Lindeskog's proposed diet would actually have on emissions. They do this by calculating average Swedish per capita annual food emissions 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.

In the 'average' Swedish diet, the GHG contribution of meat and dairy products (excluding fish and eggs) makes up about 58% of total food emissions. With a proposed 36% reduction in meat consumption, 50% in cream and 30% in cheese (but a very slight increase in milk) the contribution of the meat and dairy sector falls to 42% of a now *lower* total. Emissions from other

³⁹⁷ *Public Understanding of Sustainable Consumption of Food: A research report completed for the Department for Environment, Food and Rural Affairs by Opinion Leader, November 2007.*

³⁹⁸ Pimentel, D., Williamson, S., Alexander, C.E., Gonzalez-Pagan, O., Kontak, C. and Mulkey, S.E. (2008) Reducing Energy Inputs in the US Food System, *Human Ecology* 36:459–471.

³⁹⁹ Michaelowaa, A. and Dransfeld, B. (2008) Greenhouse gas benefits of fighting obesity. *Ecological Economics* 66 298–308.

⁴⁰⁰ Wallén, A., Brandt, N. and Wennersten, R. (2004) Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy* 7 525–535.

⁴⁰¹ 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.

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.

However, and strikingly, Wallén *et al.* find that, despite these dietary changes, overall food GHG emissions decline by only 5%. While this is a surprising conclusion, a closer investigation of the assumptions they make and the conclusions they draw lead us to question quite comprehensively the reliability of their conclusions.

The main reliability issue concerns the figures they use for meat- and dairy-related GHG emissions. For fresh beef, the per kg emissions they use are around half those presented in other life cycle studies.^{402,403,404} What is more, the figure the authors use includes post-farm gate emissions too, while the (higher) LCAs we cite calculate emissions up to the farm gate only. In other words the figure used by Wallén *et al.* is likely to be a major underestimate on several counts. Processed meat-related emissions are staggeringly low at around 1/30th of the figure they use for fresh pork, suggesting an error in the data. The authors also severely underestimate milk-related emissions, using a figure that is about a third of that given in other life cycle studies^{405,406} and underestimate cheese-related emissions by up to 50%.⁴⁰⁷

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 CO₂e emissions. In the 'sustainable' scenario they come down to 60%.⁴⁰⁸

Note that this is still likely to be an underestimate, given the exclusion of other life cycle 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).

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 consume large quantities of meat (comparable with UK levels), yet even in the proposed 'sustainable' diet these products still feature heavily – 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 the light of this one might reasonably argue that the suggested

⁴⁰² Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

⁴⁰³ Casey, J.W., Holden, N.M. (2006 in press) Quantification of GHG emissions from suckler-beef production in Ireland, *Agricultural Systems*.

⁴⁰⁴ Haas, G., Wetterich, F. and Köpke, U. (2001) Comparing intensive, extensive and organic grassland farming in southern Germany by process life cycle assessment, *Agriculture, Ecosystems and Environment* 83 43–53.

⁴⁰⁵ Cederberg, C. and Mattsson, B. (2000) A Swedish study *Life cycle assessment of milk production — a comparison of conventional and organic farming*, Department of Applied Environmental Sciences, Göteborg University, Box 464, SE-413 90 Göteborg, Sweden, *Journal of Cleaner Production* 8, 49–60.

⁴⁰⁶ Casey, J.W. and Holden, N.M. (2005) Analysis of greenhouse gas emissions from the average Irish milk production system *Agricultural Systems* 86 97–114.

⁴⁰⁷ Berlin, J. (2002) Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, *International Dairy Journal* 12 939–953.

⁴⁰⁸ Calculations available in Appendix of Garnett, T. (2006) *Fruit and vegetables and greenhouse gas emissions: exploring the relationship*, working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey, on request.

30% reduction is excessively cautious.⁴⁰⁹ The Swedes also consume 37% more milk than we do in the UK⁴¹⁰ 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 differences in how much meat and dairy produce we eat. As such, reductions to a 'sustainable' level are likely to be fairly arbitrary and based on what is considered to be 'normal' in the country of the study in question.

A sustainable diet would be very significantly lower in meat and dairy products than what is proposed in this Swedish study, and consequently much greater reductions in emissions from the food sector could be achieved. We discuss whether we can define what a sustainable global level of meat and dairy consumption and production might be in the next sub-section.

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 GHG 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 GHG-intensive consumption of foods. This may appear to be a fussy 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. It is also about shopping for, and preparing, food differently, as highlighted in Table 5 above.

What is more, 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 doesn't say whether some vegetables or 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 emissions). However, the question is relevant because changes such as these also have a bearing on trends in and future patterns of consumption. The problem is not just current emissions arising 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 GHG emissions.

Evidently changes in our behaviour will not, on their own, help us achieve an 80% cut in GHG emissions by 2050, simply because food is essential. A combination of technological improvements and behavioural change will be required. What is more, we need also to be mindful of the relationship between technological improvements and behaviour. 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. Some major technological developments might, in fact, demand of us behavioural adjustments. Other technological improvements, by assuming a behavioural status quo, can ultimately be counterproductive in that they encourage further dependence on energy-dependent technologies.

⁴⁰⁹ *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.

⁴¹⁰ *Ibid.*

8.c. A closer look at meat and dairy foods: can we define a sustainable level of production and consumption?

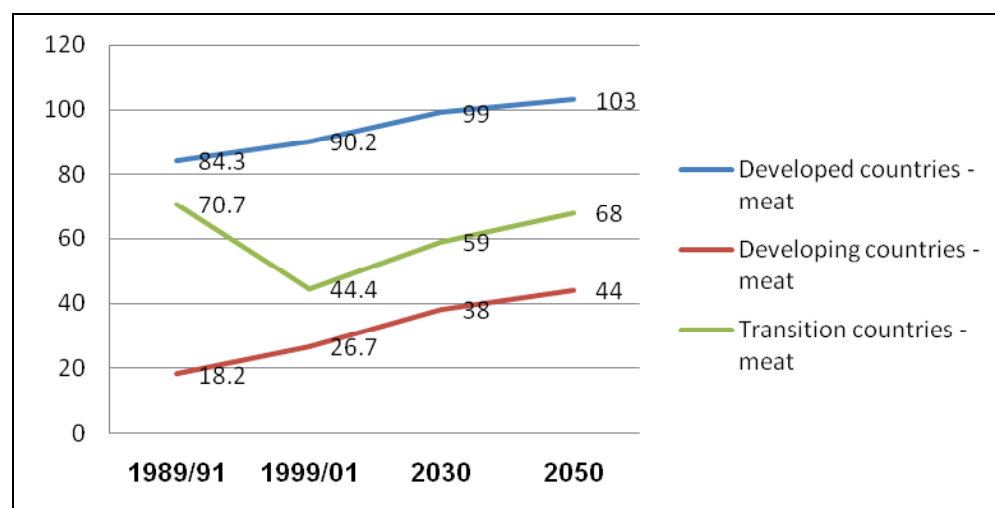
By 2050, demand for meat and dairy products is set to double as Table 7 shows. This is not only because there will be more people on the planet, but also because they will, in general, be eating more animal-derived foods.

Table 7: Meat and dairy demand in 2000 and predicted demand in 2050

	2000 (population 6bn)	2050 (population 9bn)
Average per capita annual global demand – meat (tonne)	0.0374	0.052
Average per capita annual global demand – milk (tonnes)	0.0783	0.115
Total annual demand – meat (million tonnes)	228	459
Total annual demand – milk (million tonnes)	475	883

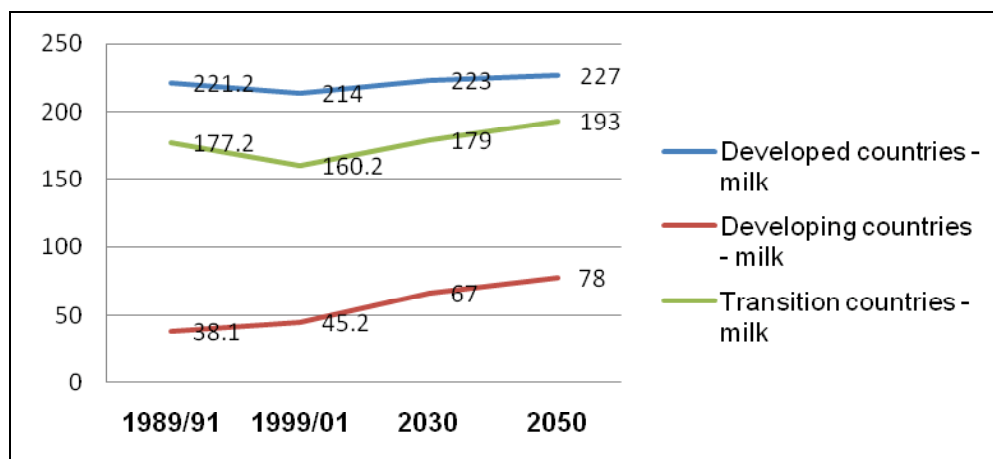
These average figures disguise huge global inequalities in consumption. Figures 16 and 17 show the difference in the projected consumption levels of the rich and of the poor for meat and milk respectively.

Figure 16: Projected trends in per capita consumption of meat products to 2050 kg/person/yr



Source: *World agriculture: towards 2030/2050* Interim report Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations, Rome, June 2006.

Figure 17: Projected trends in per capita consumption of milk products to 2050 kg/person/yr



Source: *World agriculture: towards 2030/2050 Interim report Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations, Rome, June 2006.*

The trend lines do not cross, and even by 2050 people in the developing world are projected to consume only around half as much meat as developed world populations consume *today*. The figure for milk consumption is lower still, at a third.

Even if the technological and managerial approaches identified in Section 7 above were to deliver an extremely optimistic 50% cut in global livestock-generated GHGs by 2050, the benefits would be cancelled out by the increase in demand. Various researchers^{411,412} and NGOs^{413,414} have argued that to reduce GHG emissions, we need to reduce our consumption of livestock products. But by how much?

One place to start is to take the very high levels of consumption by people in developed countries, and to consider what would happen if they were to reduce the amount of meat and dairy products they eat. For example, what would happen to global meat and milk volumes, and ensuing emissions, if developed country populations reduced their consumption to levels that people in the developing world are anticipated, in 2050, to consume? This would be in keeping with the principle of global equity, but also allows for higher consumption by people in poor countries.

Figures 16 and 17 show that by 2050 developing world peoples are projected to consume about 44 kg of meat and 78 kg of milk annually. This represents a 62% and 73% increase on their meat and milk consumption today.

For people in the developed world, however, consuming at this level would entail a very substantial change in habits. It would mean that we in the UK would halve the amount of meat we typically eat today, and reduce our milk consumption by an even more drastic two thirds. The reduction in our *anticipated* 2050 consumption levels would be greater still.

⁴¹¹ Goodland, R. (1997) Environmental sustainability in agriculture: diet matters, *Ecological Economics*, 23 189–200.

⁴¹² Gerbens-Leenes, P.W. and Nonhebel, S. (2002) Consumption Patterns and Their Effects on Land Required for Food *Ecological Economics* 42 S. 185–199.

⁴¹³ Gold, M. (2004) *The global benefits of eating less meat*, Compassion in World Farming Trust, Petersfield, Hampshire.

⁴¹⁴ Koneswaran, G. and Nierenberg, D. (2008) *Global Farm Animal Production and Global Warming: Impacting and Mitigating Climate Change*, Environmental Health Perspectives, EHPonline.org, January 2008.

However, if we multiply this reduction in per capita consumption by the number of people who are projected to be living in the developed and transition countries, and subtract this figure from the overall *anticipated* demand for meat and dairy products, we obtain a mere 15% overall reduction in projected world meat consumption, and 22% for milk, as Table 8 shows.

Table 8: Reduction achieved by developed world only reduction in consumption

	Population 2050, bn	Projected Tonnes / person / yr 2050	Total anticipated consumption (m Tonnes) 2050	Total consumption at 2050 developing world levels (m Tonnes)	% reduction
Meat					
Developed countries	1.019	0.103	105	44.8	
Developing countries	7.51	0.044	330.4	330.4	
Transition countries	0.343	0.068	23.3	151	
World meat	8.92	0.215	458.7	390	15
Milk					
Developed countries	1.019	0.227	231.3	794.8	
Developing countries -	7.51	0.078	585.7	585.7	
Transition countries	0.343	0.193	66.2	267.5	
World milk	8.92	0.498	883.2	692	22

Source: Based on data presented in *Prospects for food, nutrition, agriculture and major commodity groups. World agriculture: towards 2030/2050* Interim report Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations, Rome, June 2006.

Crucially, this lower figure *still* represents an increase on global 2000 consumption levels of around 70% for meat and 45% for milk. All other things being equal, this translates into a very great increase in global livestock-related GHG emissions.

Clearly, reductions at this level are not sufficient. Another approach is to ask how much would be available to each individual in 2050 if we keep meat and dairy production at 2000 levels, so as to avoid a rise in livestock-related GHG emissions? In the context of nine billion people in 2050, per capita consumption of meat and milk would need to be as low as 25 kg and 53 kg a year respectively. This is approximately the average level of consumption of people in the developing world *today*, and equates to half a kilo of meat and a litre of milk per person per week. For meat, this equates to a four ounce portion every other day – equivalent to a quarter pounder hamburger, two sausages, or three to four rashers of bacon. For milk, a litre a week is more frugal still – just about covering enough for cereal in the morning, with no allowance for cheese, yoghurt, and so forth. These figures are strikingly low – they imply drastic declines for the rich, and allow for no increase by the poor. As discussed earlier, animal-free, nutritionally balanced diets are possible, but are difficult to achieve and maintain without high levels of nutritional knowledge and personal commitment. Veganism would also be an environmentally counterproductive (and perhaps culturally imperialist) prescription for some peoples and cultures whose landscape is unsuited to settled arable farming. The nutritional adequacy of diets containing these quite low levels of animal products will very much depend on what else is available, and being eaten. It is clearly a priority that policy-makers develop strategies to ensure

secure access for all to nutritionally balanced, predominantly plant-based diets. We discuss the relationship between nutritional wellbeing and food GHG reduction in Section 9, below.

Note that, even assuming a zero growth in production and consumption, in order to actually reduce livestock emissions (as opposed to just stabilising them), considerable managerial and technological ingenuity to reduce per kg emissions will still be required. We have highlighted the approaches currently being developed, but ongoing research is vital.

Moreover, even these very low levels of consumption may not actually be sustainable given the other pressures our growing population are placing on our land. A third approach is to constrain consumption within the limits of ecological capacity. In other words, we need to assess how much land and how many by-products are available for livestock that are genuinely unsuited to other purposes, bearing in mind both the second order impacts of land use, and the opportunity cost of using land and by-products for livestock, instead of for something else. We need then to consider what level of livestock production such land might support without the need for external inputs, and without leading to problems of overgrazing, with the caveat that judgements as to what land is suited to what purpose can never be absolute. The number of livestock we can rear would be bound by these limits. Policy strategies would need to be put in place to manage consumer demand for livestock products – a simple sentence to write, but a much harder set of actions to deliver. At this stage we cannot tell whether this level of production, in combination with technological improvements, allows for greater or lower levels of consumption than the 25 kg and 53 kg person/year allowable under a no-growth scenario.

This course of action is somewhat stark, and it is important to bear in mind that the quality of land changes over time as does the societal balance of need for different types of land. A highly planned, command and control approach to land use is unlikely to be the way forward, even if it were politically feasible. However, land use policies can be developed, within market economies, that bear these essential principles in mind.

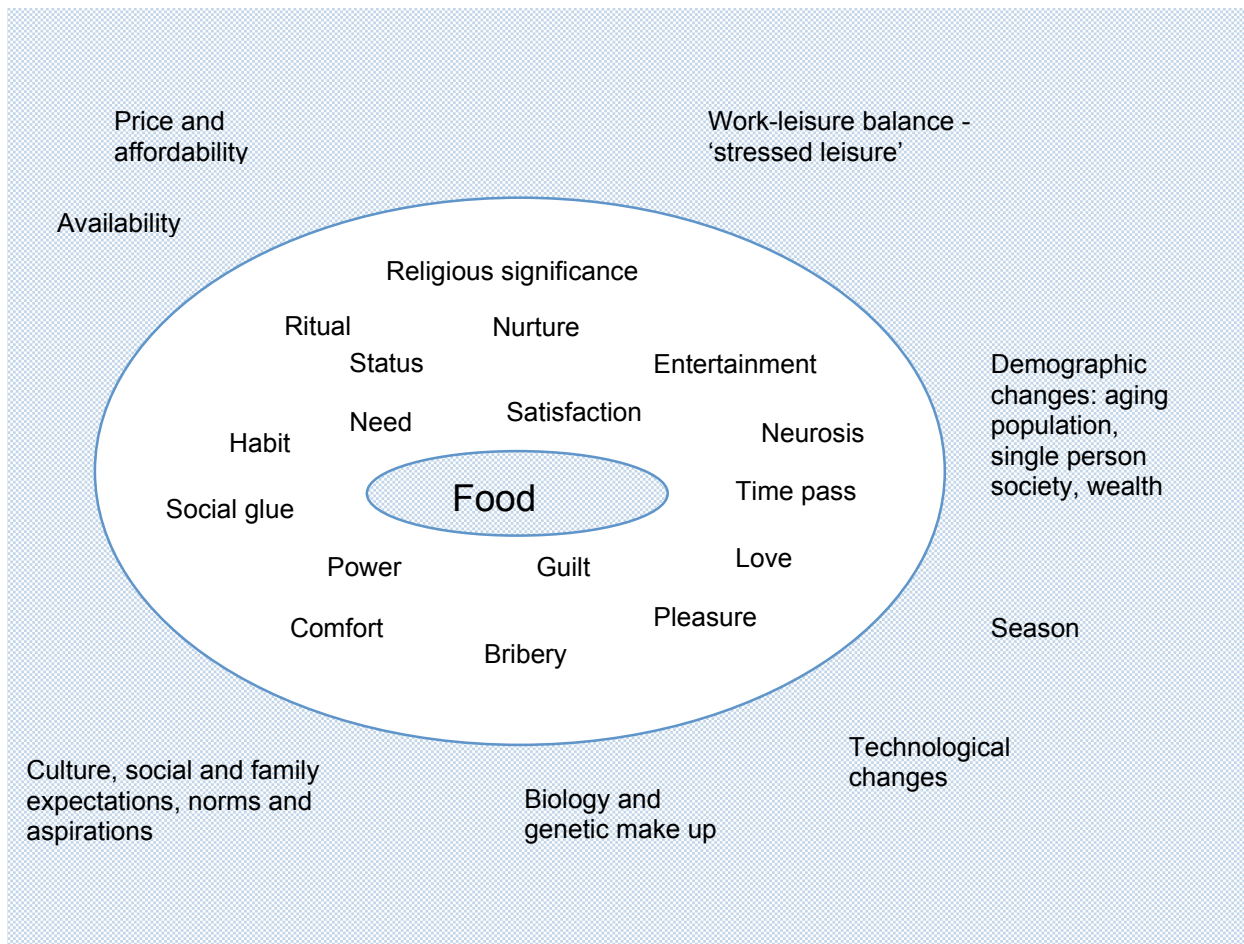
8.d. Voluntary behaviour change: how much can we expect of people?

People are motivated to consume for a wide variety of complex and frequently irrational reasons. Our relationship with food is complicated: eating 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 and because everyone else does too. This problem of 'behavioural lock-in' has been highlighted many times as a barrier to sustainable consumption.⁴¹⁵

Figure 18 highlights just a few of the meanings embedded in how, when, where and why we eat, and the broader social, economic and cultural forces that influence them.

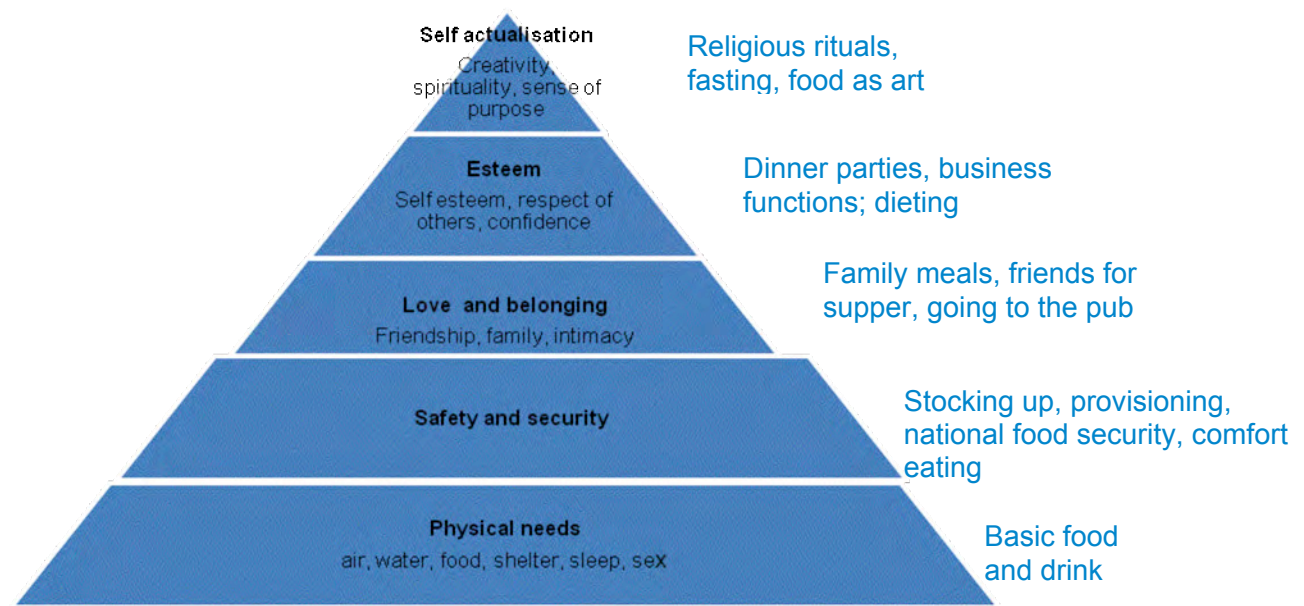
⁴¹⁵ Jackson, T. (2005) *Motivating Sustainable Consumption a review of evidence on consumer behaviour and behavioural change: A report to the Sustainable Development Research Network*, January 2005.

Figure 18: The meanings of food



As such, the function of food is to do more than just keep us alive. Taking Maslow's hierarchy of need, we can see that food has an importance at all levels of that hierarchy. Food is a basic physiological need but it is also one of the glues that bind families together. At the highest 'self actualisation' level, food and drink are bound up in the rituals and traditions of the world's major religions.

Figure 19: Food in the Maslow hierarchy of need



This has policy implications for several reasons. Because food is so important to us in so many ways, it is difficult to get us to change our diets voluntarily. The consumption patterns we set out and describe above, particularly the argument that we should be eating less meat, are very challenging. It is unlikely that awareness-raising campaigns alone will achieve much by way of behaviour change, as study upon study has shown.^{416,417} As it stands, people know little about the environmental implications of what they buy and eat. And even if they do know, a minority group excepted, they don't much care. Life is complex, life is short, life is busy.

What is more, how much of the onus of responsibility should we put on consumers anyway? Clearly, we all have to acknowledge our personal responsibilities as citizens, but in the face of strong persuasive social and economic counterforces, expecting people to 'do the right thing' is unrealistic.

The *context* within which people consume – political, social, economic – must therefore change. People change when their circumstances change. While behavioural lock-in is rightly highlighted as a barrier to sustainable consumption, it is interesting to note how varied individual habits are, suggesting that it is not the thing we do itself that is desirable (showering in the morning, tea with two sugars, sitting in a particular chair, crossing the road at a certain point), but the habitude of the habit, so to speak. People have habits almost regardless of what the habits are. It is highly conceivable that once they have broken-in their new, more sustainable patterns of being, they will settle into the same comfortable relationships with them as they had with their older, unsustainable habits.

Behaviour change is both necessary and possible. The point we make here is that it is unrealistic to expect that *conscious voluntary* behaviour change will happen, to expect people to make complex decisions and then 'do the right thing' from the good of their hearts.⁴¹⁸

⁴¹⁶ *Public Understanding of Sustainable Consumption of Food: A research report completed for the Department for Environment, Food and Rural Affairs by Opinion Leader, November 2007.*

⁴¹⁷ Jackson, T. (2005) *Motivating Sustainable Consumption: a review of the evidence on consumer behaviour and behavioural change*. A report to the Sustainable Development Research Network. London: Policy Studies Institute.

⁴¹⁸ *I will if you will: Towards sustainable consumption*, Sustainable Development Commission, London, 2006.

Obviously this is not the whole story – sales of free range chickens, or Fair Trade products, increase in response to awareness-raising campaigns, but these shifts in behaviour do not threaten to rupture the basic fabric of people’s purchasing behaviour. And, to some extent, where a sustainable course of action also brings health benefits, people modify their diets for reasons of self interest (although even here changes are small and slow). But in order for society to achieve fundamental, difficult, and wide reaching changes in how, what, and how much it consumes, strong policy action to influence the economic and social context is essential.

8.e. Voluntary behaviour change: how much can we expect of industry?

Industry is starting to engage with the concept of sustainable consumption and production (SCP) and indeed Tesco has funded a £25 million Sustainable Consumption Institute at the University of Manchester. The company’s involvement, as with that of the other supermarkets, in the Carbon Trust labelling method is part of what they see to be a step along the SCP path. Indeed, labelling has long been a core strategy in the supermarkets’ approach to sustainable food, with examples including the Fair Trade, Marine Stewardship Council, and air-freight labels.

The purpose of labelling is to provide people with information so that they can make an informed choice. It is not about managing or ‘editing’ the range of foods their customers buy. This said, some very limited choice editing, based on labels, is starting to happen. For example, many of the supermarkets now do not stock fish on the Marine Conservation Society’s ‘Fish to Avoid’ list. In Sainsbury’s and Marks & Spencer, only Fair Trade bananas are on offer (there are no ‘unfair’ alternatives). The same applies to tea and coffee in Marks and Spencer, and own-brand chocolates at the Co-op.

While this is a sort of choice editing, retailers are hardly requiring a sacrifice on the part of the consumer. The bananas, tea, coffee and chocolate available are identical to, and identically priced to, the non-Fair Trade products they replaced. Thus far then, supermarkets have edited our choices in cases where there is no need for anyone to do without.

When it comes to choice editing to reduce GHG emissions there is no evidence of action to date, but it is easy to envisage actions that manufacturers and retailers could do without much difficulty. Examples include reducing the meat content of ready meals, extending the range of meat and dairy-free ready meals relative to those with meat and promoting non-meat alternatives to whole cuts of meat. An alternative approach might be to veto the development of any new product that goes over a certain threshold of GHG intensity. Depending on their customer base, supermarkets could either advertise and promote these changes as green moves, or do so subtly and unobtrusively, so as not to rock the consumer boat.

Other options include increasing the price differential between high- and low-GHG intensity foods (a feasible move where carbon footprint labels exist), or putting a stop to cut-price or buy-one-get-one-free offers for highly GHG-intensive foods. Indeed, they could usefully do so for all foods, in so far as these offers encourage people to over-purchase and possibly to end up wasting food.⁴¹⁹ Such changes, combined with the technological improvements highlighted above, could help achieve useful reductions in the GHG intensity of the average UK food basket.

However, it is clear that other forms of choice editing, such as reducing the range of meat products on offer or the decision to mark up the price of, or even not stock ‘unnecessary’ foods,

⁴¹⁹ Speech by Joan Ruddock MP to the launch of the Waste & Resources Action Programme’s (WRAP) *The Food We Waste* report, London — Thursday 8 May 2008.
<http://www.defra.gov.uk/corporate/ministers/speeches/joan-ruddock/jr080508.htm> .

fundamentally challenge certain principles core to supermarkets' self-identity: consistency, ubiquity, availability and variety. By this we mean the need to offer consistency of appearance and quality at all times; to have the same products available in all stores across the country; to have all products more or less always available; and, of course, to continue to offer a huge variety and choice of products. These are in effect non-negotiables, to which might be added low prices, or the more subtle concept of 'value for money.'

A less GHG-intensive food system (coupled with one affected by the direct impacts of a changing climate) might, on the other hand, not be able to offer this consistency of quality and appearance. There may be absences of supply at some times, and in some locations. There may be less variety and choice. Prices – if they are to reflect the true GHG cost of products – will be higher.

It is unlikely that supermarkets will voluntarily make deeper, substantial changes in how they operate. As such, while initiatives such as the Tesco Sustainable Consumption Institute signal that retailers acknowledge the problem, there is also a danger that by taking ownership of this now well-known phrase, they may skew its meaning and end up offering up a form of reformulated '*status quo lite*', that fails to address the more difficult aspects of consumption or, indeed, trends in what, how and how much we consume.

8.f. How far can we reduce emissions in the UK? A back of the envelope calculation

Food is a basic need. It is essential to our survival in the way that televisions, say, or personal cars, or eighteen pairs of shoes are not. One might argue that those areas of our life should take on the brunt of the GHG-reduction challenge.

On the other hand, we do not have the luxury of letting one aspect of our lives off the hook, as it were, and there is enormous scope for reducing food-related emissions. In this country at least we do not need to eat as much as we do, nor all the kinds of food that we do – there is considerable leeway for change.

We cannot state with any real accuracy what level of food-related reductions might be possible through a mix of technological measures and behaviour change but, just for the record, we give a rough estimate here so as to invite comment and to challenge others to make more considered calculations. Note that we consider what is theoretically possible, not what is politically acceptable.

Put simply, while there is a strong role for better agricultural practice and the deployment of new and emerging agricultural technologies, at least half of the emissions cuts at the farm stage are likely to come from a change in what we grow because of changes in what we eat (we recognise that the argument is simplistic from the perspective of global emissions but will discuss the relationship between production and consumption in more detail below). While agriculture is the life cycle stage responsible, on average, for the greatest GHG emissions, it is also the stage where reductions might be hardest to achieve since we are dealing with a living, dynamic system.

Post-farm gate, technological improvements are likely to play a major role in bringing emissions down. We have already noted that strong interplay between the pre- and post-farm gate stages; technological developments will affect demand for certain types of agricultural products, while the type of foods produced will influence what downstream technologies are needed.

To calculate possible farm-related emissions reductions, we make a few (large) assumptions. Let us suppose that we cut our meat and dairy consumption by half, equating to an approximate halving of livestock emissions. Let us suppose, too, that 30% of these savings are offset by increases in our consumption of other substitute foods. We can also assume a 30% reduction in

on-farm emissions through good farm management. This is the upper end of the assessment by the milk road map for 2020.⁴²⁰ If we are being very optimistic, the UK might achieve a 50% reduction by 2050. Very approximately these, together, could cut agriculture-stage emissions by 50–70% by the middle of the century.

Post-farm gate, actions by individual companies have shown that savings of up to 70% are possible given the will to invest in renewable alternatives and perhaps greater savings will be possible in the coming years. In principle, given a robust policy and technology-transfer framework, we could envisage this spreading to other sectors of the food industry, even the small players. Action to reduce food waste along the whole supply chain will also help. This means that post-farm gate emissions would be only 30% of what they currently are.

Adding the pre- and post-farm gate savings together, food consumption-related emissions are reduced to between a third and a half of what they are today – a reduction of 50–67%. This would be equivalent to cutting today's overall UK GHG emissions by a fairly substantial 9–12%.

8.g. The consumption: production dilemma. What effect would changes in UK consumption and production have on global emissions?

'Think of the starving poor in Africa' many of us, as children, were told, as we contemplated our spam fritters. Many will have wondered what effect our eating habits could possibly have on world hunger.

The question is equally applicable to arguments for changing our consumption and production patterns here in the UK. Would the adoption of a low-GHG, more plant-based, less wasteful diet, in combination with more efficient technologies, make any difference at all to world emissions?

There are two answers to this question – one short, one longer. The short answer is that the UK contributes 2% to the world's GHG emissions and, of this, food accounts for a little under a fifth – that is, 0.4% of the global total. If, say, through a combination of behaviour change and technological measures we managed to reduce our food related emissions by 50–70% tomorrow, world GHG emissions would only fall by 0.2–0.25%. And, if we reached this target by 2050 (tomorrow being somewhat optimistic), in the context of massive growth in emissions from India, China and other rapidly developing countries, the overall effect on world emissions would effectively be nil.

That is the short answer. There is, however, a longer, more interesting train of thought to explore, drawing in part upon recent work by Alcott.⁴²¹ Alcott considers the current literature on sustainable consumption and the 'living lightly' philosophy. He asks whether more frugal lifestyles in the developed world would actually lower overall global environmental impact, as has been suggested, and challenges the arguments on various counts.

On the first, he looks at the consumption rebound factor. It is well known that improvements in energy efficiency are undermined by the 'rebound effect'⁴²² and he makes the case for a consumption rebound effect too. If we consume less, then this constitutes a drop in demand, so lowering the price. This means that other people, elsewhere, will take up and consume what was saved. In other words '*marginal consumers take up the slack left by the newly frugal people*

⁴²⁰ *The Milk Road Map*. Produced by the Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce, Defra May 2008.

⁴²¹ Alcott, B. (2008) The sufficiency strategy: Would rich-world frugality lower environmental impact? *Ecological Economics* 64 770–768.

⁴²² The less energy an appliance uses, the cheaper it is to run and so demand increases, so offsetting to a greater or lesser degree the savings made by increased efficiency.

who have left the market.' We have already explored this possibility in relation to waste, above, and indeed highlighted it as one of the methodological problems of LCA.

The second argument concerns the moral value of being frugal, the goals being intra-generational justice (equity for all, now); intergenerational justice (ensuring the wellbeing of future generations); and the preservation and health of non-human species and the biosphere in general. However, Alcott points out that unless explicit measures are taken to ensure that purchasing power actually goes to those who need it, now or in the future, then the benefits of your personal abstinence could just as easily accrue to wealthy people who don't need more goods. In addition *'even explicit transfers [to the poor] fall short of sustainable impact to the extent that either higher population results, or the consumption patterns of the poorer recipients are somehow environmentally more detrimental than those of the previous consumers.'*

Alcott's argument is not that changes in consumption are not necessary – they are – but rather that *voluntary* behaviour change will achieve no more than to shift around the patterns of consumption. Of course Alcott's points apply equally to technological measures – efficiencies will inevitably alter consumption patterns because of the cost-reduction effect.

In the absence of a global framework which caps overall emissions, argues Alcott, the market will not sort it all out. An attempt at a cap is of course what we already have, in the form the Kyoto protocol. But it is not only a very inadequate cap, but also a leaky one since the United States and the entire developing world, including China and India, are not subject to its restrictions. Some might say that the Clean Development Mechanism provides a get-out-of-jail-free card to Annex 1 countries⁴²³ that are struggling to reach their targets domestically.

The failings of the Kyoto Protocol are universally accepted and international negotiations are underway, culminating in the fifteenth Conference of the Parties in 2009, to develop a future global framework for emissions reduction. In addition to this formal negotiation process, academic and other institutions have proposed various possible models, all of which specify global emission caps, while seeking to achieve a balance between the need for poor countries to develop. One such proposal is the Contraction and Convergence model. This takes as its baseline the need to keep the concentration of CO₂e in the atmosphere down to 450ppm; calculates the maximum volume of global GHG emissions that can be emitted while still keeping us below this level; divides this 'safe' total by the number of people in the world; and assigns to each individual the right to pollute this amount, and this amount only. Others, such as *Baer et al.*⁴²⁴ have suggested alternatives that they argue are more equitable, since they explicitly address inequality among individuals *within* countries, and also take into account historic emissions produced by rich countries. A recent proposal by Sir Nicholas Stern also specifies a cap (higher, at 500 ppm) and sets out a framework by which developing countries can be required, over time, to make emission reduction commitments.⁴²⁵

Alcott's argument for a global cap is, then, hardly new. But it does provide a welcome counter to exhortations implying that if we all 'do our bit,' all will be well – an approach that obscures the real priority, which is for strong governance both in the national and international arena. We do not (yet) run a health system on the back of voluntary contributions by enlightened individuals or businesses. Instead, individuals and corporations are obliged to pay taxes in return for health care free at the point of use. A policy approach that relies heavily on voluntary individual action

⁴²³ Developed country signatories to the Protocol who are committed to reducing their emissions.

⁴²⁴ Baer, P., Athanasiou, T. and Kartha, S. (2007) *The Right to Development in a Climate Constrained World*. Heinrich Böll Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute, Berlin.

⁴²⁵ Stern, N. (2008) *Key Elements of a Global Deal on Climate Change*, London School of Economics and Political Science, London.

is not just weak, but it does a real injustice to people in the developing world who will suffer the worst effects of climate change.

However, while global agreements are clearly imperative, it does not follow that voluntary 'experiments' in frugality are a waste of time. They give us inklings of what a carbon-constrained world might look like in the future; how things might need to change for people; where the changes hit hardest; and how these particular impacts might be softened by readjustments elsewhere. For a government genuinely committed to developing an economic and regulatory system that ensures we reduce emissions by the required amount, this is all extremely useful since they can draw on these experiences. In addition, efforts to encourage more people to live and consume more sustainably can, if successful, help shift public opinion. This in turn can prompt government to be bolder, and less voter-fearful, both in its domestic policies and in what it brings to the international table.

Importantly too, the UK is embedded in the global economy – hence changes in how and what we consume can have larger system-wide effects as well as providing a model for change that other countries can emulate and improve upon.

9. FOOD, GHG EMISSIONS AND THE RELATIONSHIP WITH HEALTH

Never eat more than you can lift.
Miss Piggy

Is a healthier diet compatible with one that is more sustainable (including less GHG-intensive)?

While there are endless media-engendered controversies about diet, international nutritional advice is actually very consistent. A healthy diet is broadly one that is rich in fruit and vegetables, fibre-rich whole grains and cereals, contains adequate levels of protein and certain fats, and is low in saturated fats and refined sugars. By eating from these broad food groups, most people will obtain adequate levels of the key minerals and vitamins.

Table 9 below sets out UK government and WHO health recommendations, and shows how the average UK diet compares. Note that The UK Department of Health makes no specific recommendations for protein since the average British diet (see below) is not protein-limited. Protein can be scarce in other parts of the world, however, and the WHO recommends a 'safe allowance' (a higher safer quantity translating into less than 2.5% risk of deficiency for an individual) of 0.83 g protein per kg body weight per day.⁴²⁶ Protein consumption at these levels amounts very roughly to 10–15% of total daily energy intake.

The elements of a low-GHG-intensive diet have been set out in Section 8. To summarise, the main priorities are to reduce consumption of meat and dairy products, to eat no more than we need to keep ourselves healthy, to limit consumption of food that is of little nutritional value, and not to waste food.

9.a. Different ways of obtaining nutritionally balanced diets

Carlsson Kanyama (1998)⁴²⁷ presents various meals made up of differing combinations of pork, rice, dried peas, tomatoes, carrots and potatoes. She compares four sample diets made up of combinations of 'exotic' (ie. imported) and domestically produced foods, and of vegetarian and non-vegetarian ingredients, and assesses them in terms of nutritional value and GHG emissions. The four meals she classes as follows: exotic non-vegetarian (pork, rice, tomatoes); domestic non-vegetarian (pork, potatoes, carrots, peas); exotic vegetarian (rice, tomatoes, peas) and domestic vegetarian (peas, carrots and potatoes). She concludes that the domestic vegetarian diet produces the lowest level of emissions for the highest level of nutrients, followed by the domestic non-vegetarian diet. The domestic vegetarian diet is pretty dull and is unlikely to appeal to the bulk of the UK population, but her research is interesting in that it presents different pictures of how healthy eating objectives might be met. It is also worth noting that extremes can be modified, and that basic staples can be always be 'dressed up'. Legume- and vegetable-based meals (dhal and vegetable curries) are, in fact, regularly eaten and enjoyed in Indian restaurants up and down the land.

⁴²⁶ *Protein and amino acid requirements in human nutrition : report of a joint FAO/WHO/UNU expert consultation*, WHO technical report series no. 935, World Health Organisation, Geneva, Switzerland, 2002

⁴²⁷ Carlsson-Kanyama, A. (1998) Climate change and dietary choices – how can emissions of greenhouse gases from food consumption be reduced? *Food Policy*, vol 23, no.3/4, 277–293.

Table 9: UK average nutritional intakes as compared with recommended intakes

Food category	Daily nutritional recommendations	Actual UK consumption
Fruit and vegetables	Five (UK) or more (US) portions (1 portion is @90 g) >400 g a day (WHO)	3.4 portions ⁴²⁸ – lower for children
Overall fat	15–30% (WHO) 35% (UK)	37.6% (2003-4) ⁴²⁹
Saturated fat	11% (UK) < 10% (WHO)	14.7% (2003-4) ⁴³⁰
Protein	0.83 g/kg/day. For an average 65 kg British woman this is 53.95 g. For an average 80 kg man this is 66.4g. ⁴³¹	72 g plus 10 g from food eaten out = 82 g (2005–6) ⁴³²
Iron	The Referent Nutrient Intake is 8.7 mg (men) and 14.8 mg (women) ⁴³³	Average 12.7 mg ⁴³⁴
Calcium	700 mg – more for some population groups	1,002 mg ⁴³⁵
Vitamin B12	1.5 µg ⁴³⁶	6.6 µg ⁴³⁷

Another study⁴³⁸ looks at what would happen to the production, consumption, and trade of key commodities if we ate in accordance with WHO/FAO nutritional guidelines. The study looked at the production of various meats, dairy products and eggs, vegetable oils, animal fats, and cereals, and used as its basis the following nutritional recommendations: the level of fat in the diet should not exceed 30% of total energy; protein should not exceed 15% of total energy;⁴³⁹ sugar should not exceed 10%; alcoholic beverage intakes should not increase; and the total energy in the diet should not decline relative to the baseline.

The study looked at 35 countries (mostly Western Europe and North America, as well as a few Middle Eastern and Eastern European countries) whose average per capita intakes of fat contribute more than 30% to daily calorie intake. This is, of course, not a global perspective. Importantly, the study does not look at what overall food production levels might look like were the 20 countries whose fat intakes fall *below* the minimum recommended fat intake threshold to increase their consumption. It also excludes the majority of developing world countries whose fat intakes falls within the 15–30% acceptable intake range. Moreover, the report does not take into account future population growth – it is simply a snapshot of the situation today.

⁴²⁸ *Family Food*, 2002–3, Defra

⁴²⁹ Quantities of Purchases of Food and Drink and Derived Energy and Nutrient Intakes in the UK, 2003-4, DEFRA, April 2005 <http://statistics.defra.gov.uk/esg/statnot/efsuk.pdf>

⁴³⁰ Ibid.

⁴³¹ Based on average UK male and female weights : see *The Scotsman*, 2 September 2004, Hourglass figure fills out as women upsize <http://thescotsman.scotsman.com/uk.cfm?id=1027942004>

⁴³² UK household and eating out energy and nutrient intakes derived from food and drink, *Family Food*, Defra 2005/6.

⁴³³ Webb, G.P. (2002) *Nutrition: a health promotion approach*. Second edition, Arnold, London.

⁴³⁴ UK household energy and nutrient intakes derived from food and drink, *Family Food*, Defra 2005/6

⁴³⁵ Ibid.

⁴³⁶ *Risk Assessment: Vitamin B12, Expert Group on Vitamins and Minerals*, Food Standards Agency, 2003.

⁴³⁷ UK household energy and nutrient intakes derived from food and drink, *Family Food*, Defra 2005/6.

⁴³⁸ Srinivasan, C.S., Irz, X. and Shankar, B. (2006) An assessment of the potential consumption impacts of WHO dietary norms in OECD countries *Food Policy* 31 (2006) 53–77.

⁴³⁹ The authors do not explain where this recommendation comes from although it commonly used and very roughly accords with the more specific body-weight based protein recommendations set out above.

The study is nevertheless interesting. It concludes that meeting these nutritional objectives would require substantial changes in production and consumption. We would need to reduce consumption (and hence production) of meat, vegetable oils, eggs and dairy products, and eat more cereal-based products, pulses, fruits, and vegetables.

More specifically, consumption and production of vegetable oils would drop by 30%, dairy products by 28%, sugar by 24% and animal fats by 30%. Production of pig meat would fall by 13.5%; mutton and goat by 14.5%. On the other hand, cereal production for direct human consumption would rise by 31%, and fruits and vegetables by 25% and 21% respectively. For oils, volumes of the most dominant, soy, would need to decline by 28%.

Beef and poultry are interesting exceptions. Beef consumption and production could in fact rise while poultry would drop by only 1.7%. This is because the authors class these meats as low in fat (although pork from pigs reared in the UK is now leaner than beef).

Notwithstanding the rise in volumes of cereal consumed directly by humans, the paper calculates only a small increase in overall production requirements since the increase in human consumption is almost entirely offset by the reduction in demand for feed-cereals.

In short, the study suggests that to improve our diets, we should indeed be eating fewer meat and dairy products, and shifting away from growing cereals for animal feed to their production for direct human consumption. The study had no specific environmental focus but the findings are clearly relevant. The GHG intensity of livestock production and consumption has already been discussed. The paper also indicates a significant reduction in oil, particularly soy oil consumption, which has a bearing on the soy issues explored above.

It might be helpful to develop the work of this study further, this time taking a global perspective; one that considers not only nutritional global needs today, but also future needs in the context of the projected global increase in population over coming years. The paper is particularly interesting too because it looks at *needs* rather than *demand*, unlike most FAO and other food projects that take a specifically demand-oriented approach.^{440,441} We have already argued that needs-based perspectives may ultimately be more realistic.

As regards UK-specific studies, Collins and Fairchild⁴⁴² use an ecological footprint approach to assess the City of Cardiff's food footprint, to examine how it could be reduced, and what the impacts on food spending and nutrition might be. The authors assign an ecological footprint to the range of foods that typify the average diet for a man living in Cardiff, and then explore five modified versions of that diet. For each of the diets they calculate the ecological footprint, and assess the effects on household spending and nutrition. None of the diets represents a radical departure (in terms of conventional palatability) from what might normally be consumed. Three of these diets entail substituting lower footprint foods for those with higher footprints (the severity of the substitutions varying by scenario); a fourth takes the same foods but makes them all organic, while a fifth looks at the implications of an ovo-lacto-vegetarian diet. The study finds that a more or less nutritionally adequate diet can be achieved with a footprint around 23% lower than the Cardiff average, and such a diet would also be cheaper. An organic diet (differing in 'philosophy' but not substance from the standard diet) could achieve the same environmental reduction but at greater cost (31% more). The vegetarian scenario reduced the footprint by only 8%, the cost by 15%, and was no improvement from a nutritional perspective. This conclusion

⁴⁴⁰ OECD-FAO *Agricultural Outlook 2006–2015*, OECD/FAO 2006.

⁴⁴¹ Rosegrant, M.W., Paisner, M.S., Meijer, S. and Witcover, J. (Eds) (2001) *2020 Global Food Outlook: Trends, Alternatives, and Choices*. International Food Policy Research Institute, Washington D.C.

⁴⁴² Collins, A. and Fairchild, R. (2007) 'Sustainable Food Consumption at a Sub-national Level: An Ecological Footprint, Nutritional and Economic Analysis', *Journal of Environmental Policy & Planning*, 9:1, 5–30.

for the vegetarian diet is hardly surprising. Much of the meat content of the 'average' diet was replaced by cheese – all livestock products have a high GHG footprint and in any case the dairy and meat chains are inextricably linked.

A few things might be worth noting. Ecological footprinting is not the same as LCA. An ecological footprint estimates the area of land required to support the consumption demands (for food, transport, housing etc.) for a defined population, usually for one year. It does not directly measure GHG emissions. In addition, the paper's assumptions as to the relative merits of organic versus conventional production have been challenged.⁴⁴³ The organics issue is a complex one, as we have discussed. The study also assumes that poultry products are 'better' than beef, an assumption we have questioned. As far as can be made out from the report, climate change-related impacts are measured in terms of energy use, which gives a misleading impression of total GHG contributions. Finally, none of the modified diets represents a particularly radical departure from what we eat today. The aim of the paper was explicitly to develop alternative, but culturally acceptable, diets and so the scope for achieving major reductions is limited. This cautious approach to cultural flexibility and dietary change may not be up to the challenge we face from global warming.

Recent years have seen a slow increase in our consumption of fruit.⁴⁴⁴ This may be desirable from a nutritional perspective but it seems that we are increasing our consumption levels by eating more 'exotic' perishable foods – precisely those with a higher GHG footprint. The challenge for policy-makers is to see how to get people to eat more, but less GHG-intensive, fruits and vegetables. In the absence of strong price or other signals, it is doubtful that they will turn to cabbages and swedes, celebrity 'local food' chefs notwithstanding.

Climate change (and indeed other environmental concerns such as over-fishing) may force us to reconsider what our nutritional and health goals as a society should be. Are we talking about optimum nutrition for the few that can afford the cost (and time) that this entails? Or is the goal to achieve adequate nutrition for the majority, taking a more utilitarian stance that seeks to maximise our nutritional wellbeing within the context of environmental limits?⁴⁴⁵

One potentially important question we raise, but which we cannot answer, is whether there may be a correlation between the protein intensity of our diets and its GHG impacts. Nitrogen is the building block of protein, and one of its compounds, N₂O, is the most dominant GHG – at least at the agricultural stage of the food chain (beyond which carbon tends to dominate). Plants only take up around 50% of the available nitrogen in the soil, while the nitrogen use efficiency of animals can be even lower (at around 15% for cattle). Although essential for building proteins in our bodies, for every gram of nitrogen-containing protein available for our consumption, a considerable amount of nitrogen input has gone to waste, and may end up as N₂O, or in other chemical forms such as ammonia and nitrates. The nutrition transition (see Glossary) is in essence, a transition towards the consumption of more concentrated forms of protein, forms that entail greater losses of nitrogen (and also carbon, through CH₄) during their production. Thus, in the same way that animal nutritionists seek to manage the nitrogen content of the animal's diet so as to optimise nitrogen use efficiency (see Section 7 above), it may be worth exploring what effect optimising our protein consumption might have on food GHG emissions. We hope to explore this question further in future studies.

⁴⁴³ Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

⁴⁴⁴ *Family Food*, data sets 1974-2006, Defra.

⁴⁴⁵ Lang, T. and Heasman, M. (2004) *Food Wars: the battle for mouths, minds and markets*. London: Earthscan.

9.b. 'Unnecessary' foods

Some studies have already argued that we should eat no more than we need and for most people in the developed world, this means eating less. From a health perspective, this means ensuring that the foods we do eat are rich in essential nutrients.

Alcohol can hardly be said to qualify. Such benefits as there are from alcohol consumption arise from very low levels of consumption by a limited section of the population⁴⁴⁶ – men over 45 years of age, and post-menopausal women.⁴⁴⁷ The health disbenefits of excessive alcohol consumption are well known. Hence for alcohol (and perhaps for other foods too, such as sweets and chocolates), there may be a strong connection between health/societal and environmental goals. The question that then arises is this: if we were to keep our alcohol consumption at levels in line with current health recommendations, what might the effect be on the UK's GHG emissions? The following paragraphs take a closer look at this question.

9.b.i. How much should we drink?

Since 1995 the Department of Health has recommended a maximum limit of two to three units a day for women and three to four units for men. Two alcohol free days are also advised after periods of heavy drinking. Some groups, such as pregnant women and those engaging in potentially dangerous activities (such as operating heavy machinery), should drink less or nothing at all. A unit of alcohol contains around 8 g (10 ml) of pure alcohol and, roughly speaking, equates to half a pint of medium strength beer or a single pub measure of spirits. One small 125 ml glass of wine is also assumed to represent a unit but in fact normally contains around 1.5 units or more. Many wine glasses hold considerably more than 125ml.

These daily upper limits replace the previous weekly guidelines of 14 units for women and 21 for men. The rationale behind this change is to underscore the fact that drinking nothing all week and then downing the whole weekly allowance in one or two sessions at the weekend is unacceptable both from the health and the societal perspectives. However, the previous weekly limits are still relevant; the two guidelines work in combination. Those drinking regularly at the upper limits of daily consumption – 21 units a week for women and 28 units for men – and therefore exceeding the previous weekly guidelines are borderline heavy drinkers.

9.b.ii. How much do we actually drink and what are the implications for GHG emissions?

So how much do we actually drink? In 2003 (the date of analysis used in the FCRN alcohol study upon which we base this discussion) the figure was 9.1 litres of pure alcohol per person per year (2003), or 11.2 litres if the under fifteens are excluded.⁴⁴⁸ To be realistic, it is probably necessary to include underage drinkers since, of the 20–27% of children aged 11–15 who do drink, average weekly consumption is 10.5 units. Since then average per capita consumption has fluctuated slightly but the latest figures available show that they are almost identical now to what they were in 2003.⁴⁴⁹

Using the 9.1 litres a year figure, this equates to 910 units of alcohol a year, or 2.5 units per person a day. Assuming adult consumption only (15 or over) this figure goes up to an even higher three units per person per day.

This figure is much higher than the alcohol consumption figures provided by the Office for National Statistics (ONS) which report average weekly consumption for men to be 17 units and

⁴⁴⁶ Public health: the demon drink *Nature*, Volume 428 April 8 2004 Number 6983 p598.

⁴⁴⁷ White, I. R. , Altmann, D. R. & Nanchahal, K. (2002) *Br. Med. J.* **325**, 191–197.

⁴⁴⁸ *Statistical Handbook 2004*, British Beer and Pub Association, 2004.

⁴⁴⁹ *Statistical Handbook 2008*, British Beer and Pub Association, 2008.

women 7.6 units a week,⁴⁵⁰ the average being 12.3. Consumption at these levels works out at about 1.76 units a day, clearly much lower than the figure given above. However, the ONS figures are derived from a drinking survey, and underreporting is a notorious feature of all surveys involving food and drink. According to the Institute of Alcohol Studies only 60% of alcohol consumed tends to be reported, in which case the three units a day figure for over fifteens is about right.⁴⁵¹

In fact, alcohol consumption per *drinking* person is likely to be higher still, since 4.5 million people (a little under 10% of the 48 million adults in the UK)⁴⁵² do not, for religious or other reasons, drink anything at all.

If these 4.5 million teetotal adults are subtracted from the total number of adults in the UK, then average per capita alcohol consumption levels rise from 11.2 litres of alcohol per adult a year to 12.35 litres per drinking adult per year, or 3.38 units on average, a day. This equates to 24 units a week – over the recommended weekly maximum for men. Subtracting non-drinkers from the population as a whole (so including those aged 15 and under) yields a slightly lower figure of 9.8 units a week or 2.7 units a day.

By these calculations everyone in the UK is, on average, a moderate to heavy drinker. This is patently not the case, and clearly average figures mask a huge variation in drinking habits. As noted, a proportion of the population does not drink at all. Many people drink very little. Hence a considerable proportion of the alcohol consumed in the UK is drunk by a relatively small number of people.

According to the ONS/Department of Health statistics,⁴⁵³ 27% of adult men (for these purposes aged 16 or over), or 13.44 million people drink 22 or more units a week. For women aged sixteen or over the figure is 17% or 8.16 million people.⁴⁵⁴

What would happen, then, to overall alcohol consumption if we all consumed at levels in keeping with government recommendations? The calculations focus on the adult population. A fuller exploration would also need to modify the approach to include under sixteens.

As stated, 27% of men and 17% women drink too much. But there is wide variation in the degree of over-consumption, as shown in Tables 10 and 11.

⁴⁵⁰ *Statistics on alcohol England 2004*, DH/ONS, 2004.

http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalPublicHealth/StatisticalPublicHealthArticle/fs/en?CONTENT_ID=4095318&chk=vg4R24

⁴⁵¹ Andrew McNeill, personal communication, October 2005.

⁴⁵² *Statistical Handbook 2004*, British Beer and Pub Association, 2004 using 2002 ONS data.

⁴⁵³ *Statistics on alcohol England 2004*, DH/ONS, 2004.

http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalPublicHealth/StatisticalPublicHealthArticle/fs/en?CONTENT_ID=4095318&chk=vg4R24

⁴⁵⁴ This assumes a rough fifty:fifty split between men and women in the population. In fact the ratio is nearer 95:100 men:women but the figure is good enough to be getting on with.

Table 10: Alcohol intakes – men

Alcohol intake – weekly units – men	% of population
22–35 units	14
36–50 units	6
51+ units	7
Total	27

Table 11: Alcohol intakes – women

Alcohol intake – weekly units – women	% of population
15–25 units	10
26–35 units	3
36 + units	3
Total	17*

Source: Drinking: Adults' Behaviour and Knowledge in 2004, ONS <http://www.dh.gov.uk/assetRoot/04/09/79/01/04097901.pdf>

*NB: the ONS statistics give a figure of 17% due to rounding although the figures above add up only to 16%.

From these figures it is clear that most people who over-drink do so by only a glass or so extra a day. On the other hand, these weekly averages will also hide bouts of binge drinking.

The figures do not show whether those men who drink, say, between 22 and 35 units a week drink at the lower or the upper end of the spectrum and so, to make the calculation simpler, it is assumed that that most of them tend to drink at levels more or less half-way in between. So for men consuming between 22–35 units a week, it is assumed here that most drink 28 units a week. For women consuming between 15 and 25, it is assumed that they drink 20 units. And so on.

In order to calculate how alcohol consumption might decline if we kept to government recommendations, it is necessary to multiply the weekly number of units over-consumed by the number of people consuming them. We then multiply that figure by 52 (to obtain the annual sum), convert the units into litres of pure alcohol, and then deduct that figure from the total volume of alcohol consumed. The number of people who do not drink will also need to be deducted from the total population. This calculation finds that the total quantity of alcohol consumed (and therefore produced) would decline by about 14%. It also brings average daily drinking levels (using for those of the adult population who do drink) down to 9.5 litres – nearly two litres less than the norm. Once non drinking adults are excluded the average per capita levels work out at 10.5 litres, down from 12.1 litres per *drinking* adult per annum.

A sizeable number of people also drinks more than the *daily* recommended limits – in other words they binge drink. In the ONS survey, 39% of men and 23% of women binge-drank on at least one day during the week on record. If one assumes that this proportion of men and of women binge drink at least once a fortnight (a cautious estimate), the total level of alcohol consumption would increase from 14% to around 18%. This figure does not take into account the fact that the weekly over-consumption figures might need to be adjusted downwards. One might therefore argue that the 18% reduction is an overestimate. On the other hand, people who drink within the weekly guidelines also binge drink at times, and the first over-drinking calculations do not take these units into account. As such the 18% is, in our view, fairly reasonable.

A similar approach could be adopted for alcohol consumption amongst the under fifteen age group. The underreporting factor should also be borne in mind. It may be that the extent of over-drinking is higher than the reported over-drinking figures suggest. If so, drinking in line with government guidelines would lead to a reduction in overall alcohol consumption of more than 18% and in theory a corresponding decline in GHG emissions.

It should also be noted that measures to deal with the consequences of alcohol misuse, such as medical attention, police action, and the emergency services, will also have an environmental impact. These impacts have not been quantified here. Doing so is a legitimate approach, however, and one that has been adopted by, for example Defra in its publication of its *Food Miles* report.⁴⁵⁵

A reduction in alcohol consumption is not impossible to achieve. The statistics show that this is already happening in most European countries.

Once again, however, we encounter the consumption-within-a-system dilemma; it is too simplistic to make a straightforward correlation between alcohol consumption and alcohol production levels. The alcohol industry is international in its reach, and a decline in consumption here in the UK might simply lead to greater marketing efforts overseas. However, it is also true to say that there is nevertheless *some* relationship between consumption and production, as current trends in declining UK beer production and their fairly straightforward correlation with declining beer consumption demonstrate. There is also, as ever, the 'rebound' effect to consider. If people chose to drink less alcohol they may end up drinking more soft drinks instead or, instead of going to the pub, they might decide to use their saved cash on a trip to the cinema or the shops. All these alternative activities consume energy, perhaps more than that embodied in the foregone alcoholic drink. Rebound consumption is a very real possibility and one that needs to be considered, not just in the context of alcoholic drinks, but in all areas of consumption. If people were to choose not to fly abroad on holiday, for example, they may spend that money on home improvements for example, or electronic equipment – again, all with an energy and emissions 'cost'.

Of course, for almost every area of consumption, it is possible to argue that 'the alternative might be even worse'. The risk of rebound consumption is not an argument for doing nothing. On the contrary, it shows that measures to reduce public consumption of particular goods and services need to be situated in, and form part of, an overall policy context which seeks to reduce consumption in all areas of life. To date, such policy focus as exists on consumption emphasises the need to 'consume differently'. It shies away from the more contentious need to consume less 'stuff' overall. It is hard to see how the 60–80% cut in overall emissions are to be achieved unless we fundamentally reassess not just *what* we consume, but *how much*.

⁴⁵⁵ *The Validity of Food Miles as an Indicator of Sustainable Development*, report prepared by AEA Technology for Defra, July 2005.

10. POLICY: WHAT IS GOVERNMENT DOING?

It is a mistake to think you can solve any major problems just with potatoes.
Douglas Adams, *Life, the Universe and Everything*

Clearly the right policies are critical. So what is the Government doing about food and its GHG emissions? There are indeed many policies in place that concern food, and many that concern GHG emissions; some, although fewer in number, directly seek to address food-related GHG emissions.⁴⁵⁶

This section begins with a broad overview of the actions taken at the national and EU level. The two need to be discussed together since much UK legislation is EU-driven. We highlight both legislative or regulatory measures, and ‘softer’ actions such as incentives and initiatives – these often being developed with the collaboration of industry. Our focus is both on UK government activities that relate to the UK, and on those that are internationally facing. The second part of this section looks at some of the international policies – those not directly generated by the UK government or the EU – with a bearing on food.

10.a. UK and EU policies

10.a.i. Legislation and regulations

Perhaps the most major recent development has been the Climate Change Bill which, at the time of writing, is in the process of going through Parliament. This, we noted in Section 1 above, places on the UK Government a legal requirement to ensure that the UK reduces its CO₂ emissions by 60% by 2050, with an intermediate target of between 26% and 32% by 2020. Government is also required to consider whether the 60% target should be increased to 80% in keeping with the most recent scientific evidence, and whether other GHGs should be included in the target. The Climate Act, when it comes into being, will set a framework for the development of sector specific policies and targets. As such, it will certainly have an impact on food chain emissions, as it will on emissions from other sectors of society and the economy.

More specifically food-related, there are a huge number of policies aimed at the agricultural and land use sector, many of them driven by EU Directives. None of these policies overtly aims to tackle climate change, although many will have an indirect influence.

Most prominent of all is the Common Agricultural Policy (CAP) which, since major reform in 2003, is shifting the balance of agricultural support in Europe away from production-oriented agricultural subsidies, to area-based payments. Such payments are conditional on ‘cross compliance’ with minimum environmental and other standards. The intended outcome is that there will be less of an incentive to produce agricultural outputs and more focus on fostering environmental benefits.

Detailed implementation of the scheme varies in different EU member countries. In the UK, under the Single Payment Scheme, farmers receive a single flat area-based payment. The new scheme currently runs in parallel with the various older schemes it replaces, but for the period up until 2012, payments under the old schemes are being progressively reduced as payments

⁴⁵⁶ Point made by Stephen Reeson, Food and Drink Federation in his presentation given at FCRN Food and Climate Policy Seminar, event hosted by Sustainable Development Commission, January 30 2008.

under the new scheme increase.⁴⁵⁷ Since the Single Payments Scheme was only introduced in 2005 it is still too early to know what long-term effects it is likely to have on the farming sector. Additional funds are available to farmers who meet higher environmental standards under the voluntary 'Environmental Stewardship' scheme initiated in 2005. At present around five million ha (around 50% of the available farmland) is covered by this scheme and, in a 2007 review of the scheme, it was recommended, among other things, that climate change should become an overarching thematic goal of Environmental Stewardship.⁴⁵⁸

The CAP is presently undergoing a 'Health Check'. In effect, this is a review of its policies and the development of interim proposals that are intended to prepare the way for long-term reform following the EU budget review in 2009/10. The proposals have been put out to Europe-wide consultation and cover three basic themes: improving the Single Payment Scheme; improving market orientation; and 'responding to new challenges'.⁴⁵⁹ One of the challenges identified is climate change, although the proposals are short on detail. Somewhat perversely, there is also a proposal to increase milk quotas by 1% a year for 2009–2013, prior to phasing them out by 2015. The resulting likely increase in livestock numbers will lead to increases in GHG emissions.⁴⁶⁰

As regards other more specific environmental regulations, of key importance is the EU Nitrates Directive (91/676/EC), which seeks to reduce the impacts of nitrates escaping into water and air. In 2002, 55% of England was designated as a Nitrate Vulnerable Zone (NVZ) and the scheme will now be extended to cover 70% of the region.⁴⁶¹ Farmers within NVZs are required to implement various measures as regards the use of fertilisers (including manure) and the storage of manure, slurry, and silage.^{462,463}

The Water Framework Directive (WFD) 2000/16/EC is another important piece of legislation. The WFD came into force in December 2000 and requires all inland and coastal waters to reach 'good ecological' status by 2015 through the delivery of a series of environmental objectives for river basin areas. A plan for each river basin must be in place by December 2009.

To aid the achievement of this goal, in 2006 Defra rolled out its England Catchment Sensitive Farming Delivery Initiative. Forty catchments across England have been identified as priority areas for action, and farmers will be assisted in ways of improving farm practices so as to reduce water pollution from agriculture. Such practices are likely to include reduced fertiliser applications.

The EU's Integrated Pollution Prevention and Control Directive (IPPC),⁴⁶⁴ enacted in the UK as the UK Pollution Prevention and Control (PPC) Act 1999, regulates, and is intended to reduce emissions from polluting activities. These include intensive pig and poultry farms. The regulations affect aspects of a variety of farm activities including raw materials use, waste, slurry and manure management, livestock housing, energy and accident management.⁴⁶⁵

⁴⁵⁷ In the dairy sector in particular, there is still a significant guaranteed price element in support alongside the SPS. The dairy sector is also unusual in that its output is limited by production quotas.

⁴⁵⁸ *Environmental Stewardship – Review of Progress*, Defra – Natural England 2008.

⁴⁵⁹ Short Summary of the Health Check Proposals, Defra, available on

<http://www.defra.gov.uk/corporate/consult/cap-healthcheck/> accessed August 2008.

⁴⁶⁰ *Impact Assessment of 'Health Check' of Common Agricultural Policy*, draft impact assessment, Defra, June 2008.

⁴⁶¹ *Revised nitrate regulations and maps published*, Defra news release, 4 September 2008

⁴⁶² <http://www.defra.gov.uk/farm/policy/observatory/research/pdf/observatory03.pdf>

⁴⁶³ *Guidelines for Farmers In NVZs – England*, Defra, 2002.

⁴⁶⁴ Integrated Pollution Prevention and Control Directive (Council Directive 96/61/EC)

⁴⁶⁵ *IPPC Technical Guidance Note Integrated Pollution Prevention and Control (IPPC): Intensive Farming. How to comply. Guidance for intensive pig and poultry farmers*, Environment Agency, April 2006.

In 2006 the EU adopted a Soil Thematic Strategy aimed at preventing further soil degradation and restoring degraded soils. This led to proposals to establish a Soil Framework Directive,⁴⁶⁶ that would legally require Member States to take measures to protect and improve their soil. At present, however, member states have been unable to reach agreement on how to implement such a Directive. Independently of the EU, Defra is in the process of developing a Soil Strategy; this builds on the work of the first Soil Action Plan which ran from 2004–06.

As regards waste, the UK's Waste Management Regulations (2006), also known as the Agricultural Waste Regulations, provide farmers with a range of options for dealing with their farm waste. The Animal By-products regulations lay down specific requirements for the treatment of those livestock products that do not enter the human food chain. Government interest in, and support for, AD has already been noted.

Other legislation affecting farmers to a greater or lesser degree includes: the Bathing Water Directive (enacted in UK law in 2003); the 1979 Shell Fisheries Directive; and various agreements on air quality including the UNECE Convention on Long-range Transboundary Air Pollution.

Post-farm gate, policies start to become more climate-specific. One example is the Climate Change Levy (CCL), a general tax on energy use and, for particularly energy intensive industry sectors, the Climate Change Agreements (CCAs). Industry sectors eligible for CCAs receive an 80% reduction in the cost of the CCL in return for meeting energy efficiency or carbon-saving targets. Note that targets can be relative. While energy use or CO₂ must be reduced per unit of production, if the company is growing, then overall emissions may still increase. Within the food industry manufacturers, the cold storage sector, horticultural enterprises, intensive pig and poultry units and certain aspects of supermarket operations (in-store bakeries and rotisseries) are eligible for the CCA.

This phase of the Climate Change Agreement is due to end in 2012 and a new Agreement will be developed for 2013 onwards to 2017. Currently, details of how the new Agreements will work are open for negotiation and will be the subject of a public consultation. A requirement to achieve absolute, rather than relative, targets and to base targets on CO₂ emissions rather than on energy use (as is currently the case), may form part of the new agreements but this is not certain. It is also probable that emission 'milestones' will be annual rather than every two years, as is the case now. The Committee for Climate Change is likely to have an influence on the shape of the new Agreements.

In order to tackle emissions from less energy intensive but cumulatively significant sectors of industry, the Government is in the process of developing a new policy tool, the Carbon Reduction Commitment (CRC). The CRC will target emissions from energy use by large organisations such as hospitals, hotels and supermarkets – those organisations who fall outside the EU Emissions Trading Scheme and the Climate Change Agreements. CRC allowances will be issued to participants via an auction process. Within the context of the scheme cap, participants will be able to determine their own emissions targets, as with the ETS, and will be able to buy and sell permits among themselves.

10.a.ii. Other non-legislative initiatives

There are a number of other initiatives with a bearing on food and climate change although none of them have actual regulatory teeth. Perhaps the most significant development was the publication of the Government's *Food Matters* report in July 2008. This sets out in broad terms what government intends to do '*to secure: fair prices, choice choice, access to food and food*

⁴⁶⁶ Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC, European Commission, Brussels, 22.9.2006 COM(2006) 232 final http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf .

security through open and competitive markets; continuous improvement in the safety of food; a further transition to healthier diets; and a more environmentally sustainable food chain'.⁴⁶⁷ The Government will be delivering a more detailed vision and strategy in 2009.

The environmental elements of the strategy as set out in *Food Matters* include plans to develop a system to enable farmers calculate their GHG emissions, additional action on food waste and packaging, and further measures to incorporate environmental sustainability into public procurement criteria. A new Foresight project is being commissioned to explore how future food systems might evolve in a world that is adapting to, and seeking to mitigate, climate change, and what the implications might be for policy in the UK.

The *Food Matters* report strongly favours the use of market mechanisms, including carbon pricing, to improve efficiency. Notwithstanding its own analysis of the environmental impact of certain dietary behaviours (including high consumption of meat and dairy products), there is little, however, that explicitly focuses on how lower-GHG consumption patterns might be achieved. Such as there is focuses largely on government's role in providing information, and on labelling schemes.

In recent years Government has also funded a number of agricultural initiatives. These include the Rural Climate Change Forum which works to raise awareness of climate change among farmers and land managers, acts as a catalyst and coordinator of work on climate change in the rural sector, advises Defra on developing rural climate change policies, and advises on research priorities. The Farming Futures programme, a collaboration between government, the farming sector and Forum for the Future, also seeks to raise farmers' awareness of climate change, its impacts on farming, and what farmers can do to adapt to, and mitigate, its effects. Additionally, the government-funded body Natural England provides free advice to land managers.

Post-farm gate, government has set up and supports the Market Transformation Programme (MTP). The purpose of the MTP is to examine business-as-usual trends in domestic and commercial consumption of energy using products (including refrigeration, cooking appliances and so forth), and to examine how combinations of policies designed to reduce emissions might influence these trends.

Another is the Food Industry Sustainability Strategy (FISS). This process, set up by Defra, and developed in partnership with the food and drink industry and others, aims to develop a strategy for improving the environmental, social and economic performance of the food industry, from the farm gate through to the consumer. Following the publication of an initial report in 2006, seven industry-led Champions' Groups were formed, each focusing on a particular area (energy, transport, ethical trade, waste and so forth), to look at best practice, and to identify where progress can be made and the barriers to progress. The FISS itself is no longer active, but since then there have been a number of follow-on developments whose origins are FISS-inspired. These include some of the activities highlighted in Section 7 above – the Food and Drink Federation's five-point plan, the British Retail Consortium's commitments, and the PAS GHG assessment method. At the waste stage, government funds the Waste Resources Action Programme which (among other things) focuses on reducing food and packaging waste.

Defra has also been funding a series of roadmaps on products such as liquid milk and fish (both complete and published) which look at what a more sustainable supply chain for these products might look like and how (through a combination of government policies and industry action) we might get there. As discussed, the dairy industry is now aiming to reduce the GHG emissions arising from dairy farming by 20–30% by 2020.⁴⁶⁸ Note that the road map 'considers.. ways of

⁴⁶⁷ *Food Matters: Towards a Strategy for the 21st Century*, Strategy Unit, July 2008.

⁴⁶⁸ *The Milk Roadmap*. Report produced by the Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce, Defra, May 2008.

reducing the environmental impacts associated with liquid milk using *current patterns of production and consumption*. The Roadmap *does not consider alterations to the size of the dairy sector.*' [author italics]. In other words, current levels of consumption are not negotiable.

Indeed, the whole area of reducing consumption (rather than making more sustainable choices where these are available) is not one that the Government has shown a willingness to tackle. Research commissioned by government⁴⁶⁹ into what people understand 'sustainable food' to be, and the extent to which people might be prepared to consume more sustainably, reveals that understanding is low, as is willingness to change voluntarily, particularly in more difficult areas such as meat and dairy consumption.

One interpretation of these findings (and one that government has not explicitly made), is that if people are not willing to change given current circumstances, then the circumstances within which they make their choices (fiscal and legislative) must be altered. Government appears, however, to be opting for a softer approach, funding work to promote and encourage more sustainable lifestyles. It is arguable that this approach is not only likely to be too slow, but only marginally effective – marginal in the numbers it reaches and in the behaviours it changes – and indeed the Government's timidity has been noted by its very own sustainability watchdog, the Sustainable Development Commission.⁴⁷⁰ Significantly, the Government has no current plans to undertake a road map for the meat industry, although its own commissioned research highlights very clearly the major contribution that meat makes to GHG emissions.⁴⁷¹

In addition to government policies directly affecting the UK food and farming sector, there are also its food-related activities overseas to consider. The Department for International Development funds a number of projects aimed at promoting sustainable agriculture and is increasingly funding initiatives with a climate change dimension (either from the mitigation or adaptation perspective). A recent issue that has attracted significant media attention, and which we discussed in Section 3 above, has been DfID's role in supporting export horticulture in Kenya and other African countries, and this has generated major debates as to the merits of supporting poor farmers versus the environmental impacts of importing foods by air.⁴⁷²

Government is also in the process of setting up a Sustainable Agriculture Innovation Network (SAIN) in partnership with the Chinese Government. The purpose here is to assist the Chinese Government in furthering its goals of 'circular agriculture' by providing a framework for China-UK collaboration on sustainable agriculture. Given the projected growth in China's production and consumption of food and other goods, this is clearly an important initiative.

Global-facing, UK-generated sustainable *consumption* policies and initiatives, are cautiously starting to emerge; government is, for example engaging in a series of 'Sustainable Development Dialogues' with a number of emerging economies, including China, India and Brazil. Efforts to promote and assist with cleaner technology transfer are also underway. We do not yet, however, see evidence of any efforts to engage with the environmental implications of the nutrition transition.

⁴⁶⁹ Owen, L., Seaman, H, and Prince, S. (2007) *Public Understanding of Sustainable Consumption of Food: A report to the Department for Environment, Food and Rural Affairs*. Opinion Leader. Defra, London.

⁴⁷⁰ *Green healthy and fair: A review of Government's role in supporting sustainable supermarket food*. Sustainable Development Commission, London, 2008.

⁴⁷¹ Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A. and Mylan, J. (2006) *Environmental impacts of food production and consumption*, A report produced for the Department for Environment, Food and Rural Affairs.

⁴⁷² The issue is currently the subject of a Soil Association consultation process. The organisation's Standards board has defined circumstances in which recommends continuing to certify air freighted organic produce as such and is currently consulting on how it might go about implementing this.

10.b. International policies

There are few, if any, international policies that focus deliberately on reducing food GHG emissions although clearly, international trade policies and agreements, negotiated through global trade rounds, will have an important bearing on them.

A major general climate initiative is the EU Emissions trading scheme, a cap-and-trade system which targets intensive energy users, including large food companies. This scheme, while generally endorsed in principle, has been widely criticised as being ineffective since too many 'free' permits have been allocated. This means that companies can carry on doing more or less what they are already doing, and still stay within their allocation limits. The recently agreed next Phase of the ETS is more stringent and, it is hoped, will achieve useful reductions.

Emerging policies and targets on biofuels will indirectly affect food. |Up until recently, the EU target was that 10% of transport fuel should come from biofuels by 2020; in the light of growing concerns about first generation biofuels, this has now been reduced to 6% with the remaining 4% to come from other renewable sources⁴⁷³ The last few years have seen , massive investment in, and subsidies for, fuel cropping in the US and elsewhere; this has had widely publicised consequences – the key one being to push up the price of food commodities, reflecting competition for land between food, animal feed, and fuels. As discussed, this may have the effect of increasing CO₂ releases by prompting land clearance for arable cropping or, indirectly by pushing existing, less commercial agricultural activities onto more marginal or forestland.

One of the Kyoto market mechanisms, the Clean Development Mechanism (CDM), could in theory help reduce agricultural emissions. The CDM provides a means by which Annex 1 Kyoto signatories can achieve a certain percentage of their required reduction by investing in projects in the developing world that lead to GHG emission avoidance or reduction. Examples include investments in renewable energy schemes, afforestation, biogas plants and so forth. Critically, these schemes have to demonstrate 'additionality' – it has to be shown that they would not have happened had it not been for this particular investment. This is a hard thing to demonstrate and many of the CDM's critics^{474,475} have pointed out that a great many approved projects are not additional at all. At the time of writing there are very few agricultural CDM projects on the CDM register. Those there are tend to focus on the generation of energy (including AD) from animal waste, sewage, or biomass.⁴⁷⁶

Finally, there is growing international policy focus on sustainable consumption and production. The EU has recently announced a set of proposals on sustainable consumption and production that are intended to improve the environmental performance of products, increase the demand for more sustainable goods and production technologies, and encourage EU industry to innovate.⁴⁷⁷ The proposals cover sustainable procurement and eco-labelling, with food explicitly included in their focus.

⁴⁷³ Press release: *More sustainable energy in road transport targets*, European Parliament, 11 September 2008 http://www.europarl.europa.eu/news/expert/infopress_page/064-36659-254-09-37-911-20080909IPR36658-10-09-2008-2008-false/default_en.htm accessed 26 September 2008.

⁴⁷⁴ *Bad deal for the plant: Why carbon offsets aren't working... and how to create a fair global climate accord*. International Rivers, Berkeley, California, 2008.

⁴⁷⁵ Schneider, L. (2007). *Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement*. Report prepared for WWF by Öko-Institut E.V. Berlin, 5 November 2007.

⁴⁷⁶ UNFCCC Clean Development Mechanism database, accessed 10/05/08 <http://cdm.unfccc.int/Projects/projsearch.html> .

⁴⁷⁷ *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan*, European Commission, 2008.

At a broader global level, one of the key drivers is the UN's Marrakech Process.⁴⁷⁸ This was set up following the World Summit on Sustainable Development. The process seeks to assist countries in their efforts to green their economies; help corporations develop greener business models; and show consumers how to adopt more sustainable lifestyles. In response to this process, sustainable consumption and production programmes are being developed in a growing number of countries.⁴⁷⁹ Their focus tends, however, to be on resource efficiency, recycling, energy efficiency, renewable energy and so forth. Analysis that fundamentally challenges current consumption trajectories – of meat and dairy products or simply of growing quantities of 'stuff' – is thin on the ground. For example, the most strongly worded statement in China's strategy for a Circular Economy is as follows:

*'The people's government at all levels is to adopt various measures to encourage environmentally-friendly consumption, actively foster a green market system, vigorously promote green procurement and sustainable consumption, and advocate moderate consumption.'*⁴⁸⁰

10.c. Some final thoughts

This section has highlighted the wide range of national and international policies and initiatives that, one way or another, have a bearing on food. Some of its initiatives are promising and constructive, others overly cautious and probably ineffectual. Table 12 provides a summary.

The main observation we would make is that notwithstanding all these policies, they need to be seen in terms of a much larger economic and political context.

Wider policies with respect to energy demand and supply, trade, and economic development, often undermine smaller scale attempts to reduce food-related emissions. Perhaps most the most fundamental counterweight to sustainability is the assumption that continuing and growing consumption is necessary and desirable; that assumption forms the basis for all economic policies.^{481,482} At what point do we say 'We have enough?'

⁴⁷⁸ <http://esa.un.org/marrakechprocess/index.shtml> accessed 8 September 2008.

⁴⁷⁹ See the United Nations Environment Programme's Clearinghouse for national SCP programmes; <http://www.unep.fr/scp/nap/clearinghouse/> accessed 8 September 2008.

⁴⁸⁰ Policy Framework Study: Policy Reinforcement for Environmentally Sound and Socially Responsible Economic Development in China (PRODEV). *Deliverable of Activity 3 'Policy Framework Study and Identification of Areas for Policy Reinforcement'* UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP), State Environmental Protection Administration China (SEPA) and United Nations Environment Program – Division of Technology, Industry and Environment (UNEP-DTIE), 2006.

⁴⁸¹ Czech, B. (2007) The Foundation of a New Conservation movement: professional society positions on economic growth. *Bioscience* 57(1), 6.

⁴⁸² *Weathercocks & Signposts: The environment movement at a crossroads*, WWF, April 2008.

Table 12: UK and international policies affecting food and climate change

Name of policy	Who introduced?	Geographical reach	Status	Focus of policy	Comment
Climate change Bill	UK	UK	To be enacted	All areas – food bound to be affected	Will only affect emissions from food produced or manufactured in this country and not embedded emissions
EU Biofuels obligation	EU	EU	Mandatory	10% of transport fuels to come from biofuels by 2020	Calls for it to be scrapped – much criticism of the environmental impacts of first generation biofuels
Kyoto; Clean Development Mechanism	Kyoto signatories	International – North-South exchange	Market mechanism	Relevant to agriculture	Not many agricultural CDM projects – those that are largely the generation of energy eg. Through AD
Common Agricultural Policy	EU	European Union	Legal Undergoing Health Check prior to next round of reforms post-2010	Agriculture	Health Check places higher emphasis on climate change but has counter-productive elements. General shift to decoupling
Single Farm Payments	UK	UK	Legal	Agriculture	Decouples payment from production
Environmental Stewardship Schemes	UK	UK	Incentive	Area based payments – 50% UK covered	In review of the scheme it was recommended that Climate Change be an overarching goal
Nitrates Directive	EU	EU		Land based activities, especially agriculture	

Name of policy	Who introduced?	Geographical reach	Status	Focus of policy	Comment
Nitrate Vulnerable Zones	UK	UK	Required for farmers in defined zones – zones soon to cover 70% England	Land based activities, especially agriculture.	Farmers within NVZs are required to implement various measures as regards the use of fertilisers (including manure) and the storage of manure, slurry and silage. seeks to reduce the impacts of nitrates escaping into water and air
Water Framework Directive	EU	EU	Required. Good ecological status for inland and coastal waters to be achieved by 2015 and a plan for each river basin by December 2005	Affects land around all inland and coastal waters – hence affects many agricultural areas	
England Catchment Sensitive Farming	UK (results from WFD)	UK	40 catchments identified as priority areas	Affects agricultural areas	Farmers supported in developing farm practices that reduce water pollution – eg. reduced fertiliser use
Integrated Pollution and Control (IPPC)	EU	EU	Legal	Pigs and poultry, raw materials use, waste, slurry and manure management, livestock housing, energy and accident management	
Pollution and Control Act	UK (results from IPPC)	UK	Legal	Pigs and poultry, raw materials use, waste, slurry and manure management, livestock housing, energy and accident management	

Name of policy	Who introduced?	Geographical reach	Status	Focus of policy	Comment
Soil Thematic Strategy	EU	EU	Not legal – proposals to develop Soil Framework Directive currently stalled	Agriculture and land based activities	Aimed at preventing further soil degradation and restoring degraded soils. This led to proposals to establish a Soil Framework Directive
Soil Strategy	UK	UK	In development	Agriculture and land-based activities	Builds on the work of the first Soil Action Plan 2005–6
Rural Climate Change Forum, Farming Futures, Natural England advice	UK	UK/England	Voluntary initiatives, developed in partnership with farm sector	Agriculture	
Waste Management Regulations and Animal By-products Regulations	UK	UK	Legal	Farm waste	Relevant to AD too
International development policies	UK	International; developing world	Strategy/policy	Agriculture and food policy	Export development considered to be the way forward
Food Matters	UK	UK	Strategy/policy	Takes a farm – plate approach and covers social, economic and environmental aspects	Strongly market / efficiency oriented
Climate Change Levy & Climate Change Agreements	UK	UK	Regulation	Levy affects all businesses using energy; CCAs affect certain food sectors eg. manufacturing, some retail activities, horticulture, cold storage, pig and poultry units, the rendering sector, milk processors	CCAs due to end in 2012. Plans for how future agreements will work in development. Possibility that absolute reduction targets may be required

Name of policy	Who introduced?	Geographical reach	Status	Focus of policy	Comment
Carbon Reduction Commitment	UK	UK	In development – to be regulation	Will affect large but less intensive energy users – including supermarkets, catering establishments, schools, hospitals etc.	Cap and Trade scheme
Market Transformation Programme	UK	UK	Informs policy	Energy using food related appliances (eg refrigerators) affected	
Food Industry Sustainability Strategy			Informs policy;		Led to development of FdF and BRC commitments
PAS 2050	UK	UK	Product standard – to be published September 2008	Affects food and other products	Carbon Trust also developing a consumer-facing label
Milk road map	UK	UK	Dairy industry 'will strive' to reduce GHGs by 20–30% by 2020.	Milk	No plans apparent for a meat road map
Waste Resources Action Programme	UK	UK	Informs policies, develops campaigns, works in partnership with industry	Affects food waste and food packaging	
Marrakech Process	International	International	Informs policy; number of national SCP Action Plans being developed	SCP can include food	Focus largely on smart consumption rather than less
EU proposals on sustainable consumption and production	EU	EU	Informs policy; affects labelling policy etc.	Sustainable procurement and eco-labelling elements include food	Focus largely on smart consumption rather than less

Name of policy	Who introduced?	Geographical reach	Status	Focus of policy	Comment
Sustainable Development Strategy <i>Securing the Future</i>	UK	UK	Informs policy	Includes food	Emphasis on developing a One Planet Economy
Research into SCP	UK	UK	Informs strategy	Includes food	

Colour code:

Generally climate-related
Agriculture-oriented
Farm – plate approach
Post-farm gate
Sustainable consumption and production

11. OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

'Better drowned than duffers. If not duffers wont drown.'
Arthur Ransome, *Swallows and Amazons*.

Greenhouse gas emissions are rising dangerously. The global population is also increasing and there could well be 9 billion people on the planet in 2050, all of whom will need to eat. The numbers of people in absolute poverty and those who are very wealthy are both growing. Climate change will affect poor people first and worst. If we don't act now, it may be too late and very much more expensive to act later.⁴⁸³

Food contributes to a significant proportion of global GHG emissions- possibly around a third - and all stages in its life cycle play their part, with agriculture taking the largest individual share. Globally speaking, our pattern of food production and consumption is moving in more greenhouse gas intensive directions.

Technological improvements in how we grow, manufacture and distribute our food are essential and important, and many promising technologies are already available, if not commercially attractive. However, technology alone will not be sufficient to keep us to an emissions pathway that prevents a rise of more than 2°C. This is as true of the food chain as it is for transport, and for other areas of commercial and individual consumption. Therefore changes in behaviour are also essential. If we are all to eat, while keeping within required emissions limits, then we have to eat differently.

Governments worldwide are seeking to tackle climate change but their approaches are almost entirely based on developing cleaner technologies and improving efficiency. Trends in consumption are taken as given, the role of technology being to provide for this demand. Drawing on the analysis we have presented here, we suggest that a technology-only approach may lead to one of several outcomes.

One possibility is that we are unable to meet global demand for food while keeping down the ensuing GHG emissions. Instead, we will continue to try and meet growing demand for animal products, and this will lead to greater livestock emissions, incurred in part by changes in land use and the destruction of carbon-sequestering land areas. The same scenario might equally apply to, and will be exacerbated by, a continuing commitment to biofuels. The consequence will be that those living in the areas most affected by climate change and unsustainable changes in land use, will suffer most.

Another possibility is that we *do* achieve some form of technological breakthrough, enabling us to meet demand for more livestock-dominant diets while also reducing emissions – but that this will come at the expense of other ethical and environmental concerns. These might include biodiversity, sustainable water use, animal welfare and possibly new environmental problems associated with the deployment of novel technologies. There is, moreover, no guarantee that by producing enough food we achieve food security. Distribution and access are socio-economic, not biological challenges. Indeed one might argue that a more redistributive approach to meeting the food needs of the most vulnerable will be mindful of the environmental impacts - since it is the poorest who have to live most directly with the consequences of climate change.

⁴⁸³ Stern, N., *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK, 2007.

Moreover, by sustaining and catering to global trends, this business-as-usual approach continues the global trend towards further dependence on energy and GHG-intensive lifestyles, and so the challenge of trying to meet these demands will continue. By 2050, on current projections, the developing world will still, on average, be eating less than half as much meat as people do in the rich world, and only a third of the milk. There is a long way to go before they catch up with developed world levels. Do we assume that ultimately they will want to eat as much meat and milk as we do, and do markets therefore seek to supply these volumes? When is enough enough? Who decides at what level justifiable demand turns into unsustainable greed?

We are seeing the emergence of a sustainable consumption and production policy programme in the UK and there are also signs of SCP initiatives developing elsewhere. The focus of these is, however, entirely on voluntary change. While such initiatives give helpful insights into how we might consume differently, and may encourage those already open to encouragement, they will not by themselves, achieve much. Other measures to reduce the consumption of GHG-intensive foods are also needed – some market oriented, such as carbon (GHG) pricing, and some (emissions caps, for instance) regulatory. These need to work together to change the context within which people consume – what foods are available to them, for example, in shops, restaurants and canteens, and at what price.

Crucially, the problems of food and climate change need to be tackled in partnership with, rather than separately from, other pressing social, ethical and environmental problems. These include food security (access and supply), biodiversity, water use and availability, and the welfare of the animals we rear and use. Developments such as robust methods of measuring embedded GHGs, potential product labels and communications, while interesting, take an atomised view of sustainability, picking out and tackling particular concerns in isolation. The challenge of sustainable development demands a more synthetic approach.

This is not to say that specific focus on specific concerns is not needed – it is vital, otherwise there is nothing to synthesise and one descends into apple pie platitudes. Moreover, a policy approach that says ‘we can’t tackle anything unless we tackle everything’ is doomed to agonised impotence. Our point is that research and policy on food and its GHG emissions must consider how different mitigation strategies sit with other environmental concerns. Policy makers and researchers must consider both the possible synergies and the tensions. They also need to consider how measures to reduce emissions can be undermined by other core economic policies and trends. Cherry picking issues to focus on because they are politically uncontroversial (waste less food, investigate ways of breeding less methanogenic cattle) without considering wider systemic relationships could well be counter productive.

Ultimately, land is the real challenge. There is only so much to go round. In the context of nine billion people on the planet by 2050, policy makers need to consider what the best use of land might be, such that we are all fed adequately and at minimum GHG cost; stored carbon is not released; biodiversity is protected; and other ethical non-negotiables (from the rights of indigenous peoples to animal welfare) are upheld.

In other words, should we use our land to plant crops, to graze or feed animals, to store carbon, for biomass production or even (radically...) to allow other species space to live? How do decisions about land use in this country affect land use in another?

Global collaboration on land use is essential. Evidently, a Global Land Use Planning Authority does not exist, and one would probably not wish to invent one. But there are ways in which the market, combined with robust international agreements and regulations, can foster sustainable land use. We need to develop systems where biodiversity, soil carbon storage, and the production of low GHG food actually have market value and – importantly – where moral goods

that cannot be captured by dollar signs are nevertheless preserved and upheld. The pricing of GHGs and other environmental externalities may play a role, combined with stronger global agreements to protect biodiversity and to improve welfare conditions for farmed animals. Clearly all these are questions that need to be explored at Copenhagen in 2009.

Finally, to conclude our report, are some recommendations.

Our main recommendation

At the national level, we offer this main, overarching recommendation.

The UK government must commit to achieve a reduction of 70% or more in absolute food-related emissions by 2050. The UK as a whole needs to reduce its overall GHG emissions by 80% or more but since food is essential in the way that other goods and services are not, we suggest a slightly lower target for this area of our lives. This 70% reduction is, based on the evidence we have reviewed, entirely achievable and may be increased to 80% as new technological developments emerge.

Government then needs to set out how it intends to achieve these cuts. Only a consumption-oriented approach will do; that is, one that takes into account the embedded emissions of all the food we eat. Government needs to set out, perhaps using a Socolow Wedge type approach,⁴⁸⁴ roughly what percentage will come from technological improvements at each stage in the life cycle, and what percentage will come from changes in what we eat.

All this is in keeping with Government's commitment to set out a vision and strategy for our food,⁴⁸⁵ and will also help enable it fulfil the (future) legal obligation to reduce the UK's carbon (possibly GHG) emissions by 60% (possibly 80%) by 2050. It should publicly report its progress accordingly. Such a plan has global implications. If successful, it will show how a nation can achieve food security while reducing climate changing emissions. The UK should work with international bodies such as the FAO and WHO to share information, develop programmes, and aid other nations in developing their own country specific strategies.

This is not a task for one Government department alone. All of them, and not just Defra, need to be involved since reductions of this magnitude will affect all policy areas, from economic structures (BERR), to the education of our children (Department for Children, Schools and Families), to the way we engage with and assist the developing world (Department for International Development).

Some more specific recommendations

In the remaining paragraphs we set out some more specific recommendations and suggestions. We do not cover all conceivable technologies and policies. The aim rather is to suggest the general direction of travel that Government, policy makers, researchers and NGOs should take. We hope that others, perhaps via the medium of the Food Climate Research Network, will help put up the road signs, and fill in the landscape.

We direct our recommendations first to Government; next to the food industry and then to the NGO community. We conclude with some suggestions for further research, either to be undertaken independently by researchers, or commissioned by Government.

⁴⁸⁴ Pacala, S., and R. Socolow (2004). Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science* 305: 968-972.

⁴⁸⁵ *Food Matters: Towards a Strategy for the 21st Century*, Strategy Unit, July 2008.

11.b.i Government

International communication: Government should take a global lead in communicating the need for sustainable (including less GHG-intensive) food consumption and production. It seek to define and advocate principles of food security that explicitly marry the goals of nutritional wellbeing with GHG mitigation. It should communicate these goals to international bodies such as the FAO and the WHO, and through international fora such as the G8 Summit and the UN climate change conference in Copenhagen in 2009.

Carbon (GHG) pricing: A system of carbon pricing is critical. As government develops its thinking on the subject, Government needs to look at ways of incorporating food and land use change into such a system, bearing in mind the potentially negative impacts on poor people and other environmental and ethical concerns, such as biodiversity and animal welfare.

Livestock research and development: Government needs to consider the second order impacts of the livestock GHG mitigation work it funds. Among other things, it needs to consider whether projects aimed at improving livestock diets may, through their reliance on imported proteins, encourage land use change and subsequent carbon dioxide releases overseas.

Anaerobic digestion (AD): Government should consider what impacts the push to promote anaerobic digestion might have on animal welfare, given the technology's natural compatibility with intensive livestock systems. Government also needs to examine whether the expansion of AD systems may lead to competition between the use of food waste and agricultural byproducts for animal feed and its use as a feedstock for AD. Where such competition does exist, it needs to look at the environmental implications of different approaches.

Meat and dairy consumption: Government needs to reinvigorate its plans for developing a meat road map. The road map should have clear targets for emissions reduction (in line with the overarching 70% reduction target) and should be developed as a partnership project between government, the livestock sector, NGOs and the research community. It should be clear about what reductions it expects to achieve from changes in livestock management and what level from changes in consumption, how it intends to achieve these reductions and what support the livestock industry should receive.

Livestock and the economy: Government needs to consider how a move to diets lower in meat and dairy products might affect farmers. It needs to look at how farmers might be supported through existing structures (such as a more climate-focused Environmental Stewardship Scheme) to farm fewer animals and maintain viable livelihoods, as well as what new incentives and schemes might be needed.

International development assistance – reorientation: Government needs to reorient its focus towards delivering maximum development assistance at minimum GHG intensity. It needs to consider whether the projects it sets up and the aid it offers, actually help the country in question to develop and attain food security in ways compatible with the global requirement to reduce GHG emissions, or whether development is being achieved through initiatives that are GHG-intensive. In other words, DfID needs to foster low GHG impact development wherever it operates and to promote this focus to the other aid agencies with whom it collaborates.

International development assistance – adaptation with mitigation: DfID needs to ensure that the agricultural development projects it supports, combine measures to help farmers both to adapt to, and to mitigate climate changing emissions.

11.b.ii. The food industry

Support for overseas suppliers: Manufacturers and retailers who import products from the developing world need to adopt longer term, stable and sustainable patterns of association with their suppliers. A key requirement is that importers provide financial and other assistance to their agricultural suppliers to help them adapt in coming years to the impact of climate change.

Reporting: Retailers and manufacturers need to report on the impact that their growth strategies (including, for retailers, planned openings of new stores, and expansion into other countries) are likely to have on their absolute emissions. Reductions on a per-area basis do not, given their growth strategies, present the whole picture.

Choice editing – livestock products: Retailers, manufacturers and caterers (both public and private) should begin the task of ‘choice editing’ with respect to livestock products. Examples include reformulating ready meals to reduce the meat content, offering more animal-free ready meal alternatives, promoting plant foods (such as legumes and pulses) as alternatives to meat and dairy foods, educating their customers and working in a supportive manner with farmers.

Carbon cut-off thresholds: Manufacturers should set ‘carbon cut-off thresholds’ when considering new product developments. For different categories of product (bread, ice-cream, sauces etc.) they should define certain levels of GHG intensity above which plans for a new product will be rejected. The GHG intensity would take into account emissions both during the course of production and its use. The intention here is to steer the product innovation sectors away from foods that are (through, say, their reliance on refrigeration) inherently GHG-intensive.

Shopping trolley GHG intensity: Supermarkets should, in partnership with manufacturers, set targets for reducing the GHG intensity of an ‘average’ trolley of goods. Targets could be achieved by improving the production efficiency of the foods in question, and through working to shift people’s purchasing behaviours in less GHG-intensive directions so that the ‘average’ trolley’s contents actually change.

Air freight: Supermarkets and other importers should phase out imports of air freighted products from rich or middle income countries, such as the United States.

Out of stocks and substitutions: Emergency top-ups via air should be phased out. In circumstances where regular supplies have failed and an air freighted supply is the only alternative, then retailers should simply not stock the product in question, communicating to customers the reason for so doing.

Technological improvements: Manufacturers and retailers should set stringent targets to reduce absolute energy use in their buildings and transport operations, through the deployment of renewable technologies and efficiency improvements. Trade associations such as the Food and Drink Federation, the British Retail Consortium and the Food Storage and Distribution Federation should each set targets for absolute emissions reductions for their sectors by 2015 and 2020, in keeping with the overarching 70% reduction goal for food.

11.b.iii. NGOs

NGOs across interest areas (including environment, international development, consumer and animal welfare) should collaborate on a campaign aimed at pressurising Government to deliver the low GHG food vision and plan we have set out. Such a campaign could work in partnership with the food industry and the media to help raise awareness among the public as to how they can reduce the GHG intensity of the food they consume.

11.b.iv. Researchers

The UK food chain and its second order impacts: We need to understand better the effect that UK consumption has on land use elsewhere, in order to gain a greater sense of the UK's true contribution to global climate-changing emissions.

Transport, globalisation and the structural implications: Research is also needed to gain a greater understanding of the second order impacts of long distance food transport. We need to situate the food miles debate in the context of infrastructure investment and development and assess the direct GHG impacts of that development. Studies that look at whether the establishment of one particular supply chain route creates a 'snowballing effect' leading to the expansion and proliferation of other supply chains, are also needed.

Protein, our diets and GHG intensity: Research is needed to consider whether there is a link between foods that are high in protein and those that are GHG-intensive. Nitrogen is a key building block of protein and nitrogen losses lead, among other things, to the generation of N₂O. Livestock products are high in 'embedded nitrogen' (since they have first consumed plants that contain nitrogen and that have received nitrogen fertilisation) and there are significant losses throughout the system. High protein wheat receives significant applications of nitrogen fertiliser, although the situation will be different for other high protein foods such as legumes. It is also the case that in the developed world we consume far more protein in our diets than we require. Further research in this area can guide the development of a sustainable nutrition policy.

The relationship between food and non-food grocery retailing: There is a need to understand better how supermarkets' expansion into non-food retailing affects their overall GHG emissions, what the relationship is between their food and non-food offers, and how any steps to reduce their food related GHG emissions might affect their non-food expansion strategies. We also need to know how far supermarkets, in expanding, are substituting for existing supply (for example replacing other shops) and how far they are creating new demand.

Food waste and systemic change: A useful research avenue would be to investigate the effect that reductions in household food waste might have on overall supermarket sales of food and on food production and imports. Focusing on waste may help shed light on the systemic linkages between different parts of the food chain, and between the food chain and wider economic structures.

Catering and GHG emissions: More research on catering-related GHG emissions is needed. In particular an understanding of the relative impacts of large catering providers versus small ones would be helpful, and the impact split between public and private procurement. Research looking at what business-as-usual catering GHG trends might be would also be useful.

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APPENDIX 1: ABOUT THE FOOD CLIMATE RESEARCH NETWORK

The Food Climate Research Network (FCRN) has been running since the autumn of 2004. Based at the University of Surrey's Centre for Environmental Strategy it was initially funded by the Engineering and Physical Sciences Research Council (EPSRC) but, as from the summer of 2008, has been awarded a further four years' funding by both the EPSRC and Defra.

The project grew out of a research project developed at Transport 2000, *Wise Moves*, which explored the relationship between food, transport and CO₂. Among other things, *Wise Moves* concluded that while transport emissions were significant, a broader life cycle perspective was needed to tackle food related GHG emissions. In addition, to ensure breadth of perspective a collaborative approach was required, bringing together individuals across sectors (industry, government, research and NGOs) and disciplines (from the social to the biological sciences) to share information on food, climate and GHG reductions.

The FCRN undertakes the following activities:

- **Research and knowledge synthesis:** Seeks to improve our understanding of the impacts associated with the food chain and the options for emissions reduction, focusing both on the technological and behavioural dimensions. Draws together what we know, exploring how different issues fit together, and articulating these in a way that is accessible to a wider audience. So far, five reports have been produced, of which this is latest. The others have focused on: alcoholic drinks; fruit and vegetables; food refrigeration; and livestock production and consumption.
- **Working seminars:** Five seminars have been held to inform the development of the research papers (above) and to draw upon the different perspectives and expertise of stakeholders.
- **Networking and communication:** Provides a means, through seminars and the membership mailing list, by which others can come together to share and seek information. At the time of writing (September 2008) membership stands at around 1000 with around seven new members joining each week. The FCRN website www.fcrn.org.uk is a comprehensive resource of information on food and climate change and is regularly updated.
- **Momentum building:** Engages with policy-makers, business, NGOs and the research community to raise awareness of the need for action and to encourage people to work together on the issue.

APPENDIX 2: CALCULATION METHOD FOR ESTIMATING UK FOOD GHG EMISSIONS

[Food GHG impacts calculation method – click here for the Excel spreadsheet.](#)