Cooking up a storm

Food, greenhouse gas emissions and our changing climate

SUMMARY

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INTRODUCTION

The subject of this report is food and its impact on the climate. Our purpose is to set out what we know about the food system's contribution to 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 some conclusions and recommendations for action.

The context is climate change. Emerging research suggests that the UK and other developed countries need to reduce their GHG emissions by at least 80% by 2050[1] if we are to keep the concentration of GHG emissions below a critical 450 ppm.[2] It is important to emphasise that climate change is just one of many major environmental and ethical problems affected by the way we produce and consume food; others include water use, biodiversity, other forms of air, soil and water pollution, animal welfare, international development and food security. This report focuses largely on climate change, simply because the food-climate relationship is complicated enough as it is. We do nevertheless highlight where tensions and synergies with other social and environment concerns exist, particularly with nutrition, food security, and animal welfare; and we plan to adopt a more integrated approach in future work.

1. Food and its overall contribution to climate changing emissions: some calculations

When calculating food's GHG impacts, the food system can be bounded or defined in different ways. We can, for example, consider the impacts of all the food that is produced in the UK; alternatively we can consider the impacts arising from all the food that is consumed. We call these two perspectives the *production-oriented* and the *consumption-oriented* approaches and in each case we look at food's impacts in their entirety, from the process of and inputs to agricultural production through manufacturing, transport, retailing, consumption in the home and waste disposal.

Taking a production-oriented approach we consider the impacts arising from the production of food within UK borders and its consumption in the UK. No deduction is made for emissions attributable to food production that is destined for export; equally no addition is made for the embedded emissions associated with food imported for our consumption here (over half of all the food we consume).[3] Food's contribution is calculated as a proportion of total UK-generated emissions as stated in the UK's Greenhouse Gas Inventory.[4] This figure, currently 178MTCeq, itself estimates emissions generated by all activities undertaken within UK borders. It does not include the embedded emissions from imports, nor those associated with international aviation and shipping. As Figure 1 shows, food-related emissions by this system of measuring, generate 33MTCeq and constitute around 18.5% of total UK GHG emissions.

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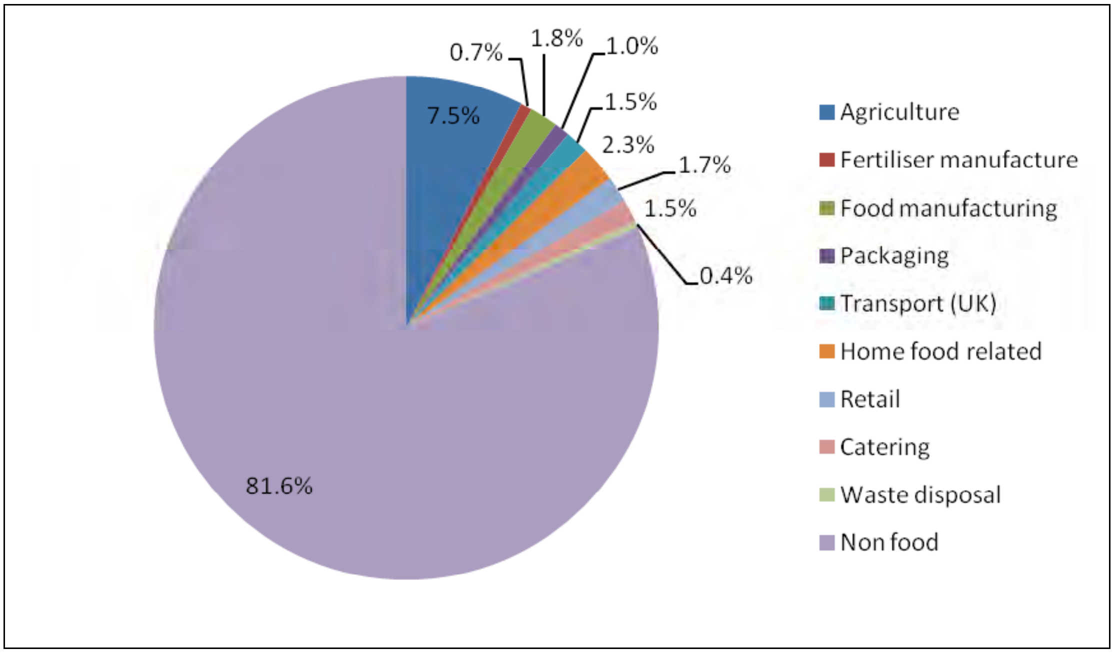
[1] Government proposals for strengthening the Climate Change Bill, Defra, February 2008 http://www.defra.gov.uk/environment/climatechange/uk/legislation/pdf/govt-amendment-package.pdf.

[2] Hans Joachim Schellnhuber, Wolfgang Cramer, Nebojsa Nakicenovic, Tom Wigley, Garey Yohe (Eds). *Avoiding Dangerous Climate Change*, Cambridge University Press, 2006.

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

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

Figure 1: Food and its contribution to UK GHG emissions – a production-oriented approach



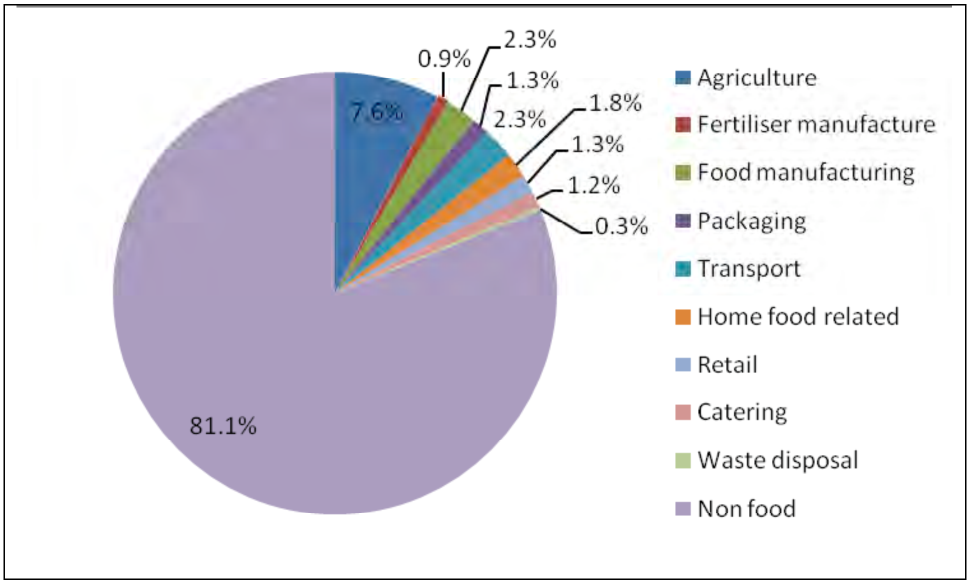
Source: Garnett T, 2008, author's estimates –see Appendix for data sources

Our second estimate takes a consumption-oriented approach; this in our view more accurately captures the actual impacts of UK activities. A consumption-based calculation quantifies all emissions arising from a nation's consumption and use of all goods and services, whether indigenously produced or imported. 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. Various attempts have been made to estimate the UK's total consumption-related emissions; the one we use here is 229 MTCeq although these figures are currently being revised upwards.[5] The emissions associated with our consumption of food in this country (one that includes the embedded emissions in the foods we import and excludes those from food we export) amount to some 43.3 MTCeq, or around 19% of total consumption –generated emissions. While the relative proportion is similar to the production-based figure, the absolute emissions are, of course, higher. Both the production and consumption based estimates are, we emphasise, highly provisional, but they give a sense of the magnitude of the contribution. Preliminary analysis by Defra using slightly different data sources and assumptions yields a very similar figure.[6]

[5] Based on carbon only estimates in Druckman, A., Bradley, P., Papathanasopoulou, E., Jackson, T. (2008) Measuring progress towards carbon reduction in the UK, *Ecological Economics* Volume 66, Issue 4, 594–604. The paper gives a CO_2-only figure of 199MTC and 15% is added on top to take account of methane and nitrous oxide, in proportion to their contribution to UK production- based GHG emissions.

[6] Preliminary analysis by Defra (2007), pers. comm. August 2007.

Figure 2: Food and its contribution to UK GHG emissions – a consumption-oriented approach



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

Food's significance is evident at the EU and global scales too. One EU study finds that food accounts for over 30% of the EU's emissions. [7] And while no global-level estimates of food's total emissions have (as far as we know), yet been undertaken, there are estimates for agriculture, as we shall see below.

2. How and why do impacts arise? The contribution of different stages in the supply chain

Agriculture

Figures 1 and 2 both show that agriculture accounts for around half of all food-related GHG emissions, or about 8.5% of the UK emissions total. While fossil fuel-derived CO_2 emissions contribute to the bulk of UK (and indeed global) GHG emissions, agriculture's impacts are largely attributable to methane (CH_4) and nitrous oxide (N_20). Both gases, while present in the atmosphere at lower concentrations than CO_2, are far more potent GHGs. Agricultural CH_4 emissions in the UK are generated almost entirely by livestock rearing, particularly from enteric fermentation in cattle and sheep and, to a lesser extent from manure. N_20 emissions cut across the arable and livestock sectors, and result from soil chemical processes taking place both in arable and grazed soils as well as from manure and urine deposits. Fertiliser production and direct energy use play smaller roles, with their contribution accounting for about 1% each of all UK GHG emissions, but their contribution is perhaps deceptively low. Surplus nitrogen fertiliser applications, help produce soil N_2O – the same is true of excessive manure applications since both contain nitrogen. Fossil fuel inputs for farm machinery use, fertiliser production and so forth perform a vital catalytic function: they make possible the scale and intensity of production that in turn generates these significant quantities of CH_4 and N_20. In effect, fossil energy sources seed-fund production systems that contribute significantly to global warming.

[7] 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.

Agriculture also contributes to GHG emissions through its role in changing land use. The latest report by the Intergovernmental Panel on Climate Change (IPCC) calculates that global agricultural activities contribute some 10–12% to the global GHG total.[8] While this, clearly, is a significant contribution, the calculation only captures direct emissions – methane from livestock rearing and rice paddies and soil N_2O.

A subsequent study,[9] using the IPCC figures, sought to calculate not only *direct* agricultural emissions but also those arising from agriculturally induced land use change – that is, the release of carbon into the atmosphere resulting from deforestation or the conversion of savannah or pasture land to arable land, or from overgrazing and subsequent soil erosion. Inclusion of these carbon losses puts agriculture's contribution at 17–32% of all anthropogenic GHG emissions. Clearly the difference between these two figures in the estimate reflects a huge element of uncertainty, much of which results from the difficulty of estimating emissions from land use change. Both figures show, however, that agriculture's true impacts are substantially greater than the figures for direct impacts would suggest.

Importantly, neither our, nor the Defra, nor the EU figures, 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.

While agriculture is the single most GHG life cycle stage, other elements of the supply chain are also significant and taken together account for the remaining 50% of food-related GHG emissions as the figures above have shown. A few supply chain stages in particular are worth highlighting.

Transport

The food miles debate has performed a vital service by raising the whole issue of food and its contribution to GHG emissions. However, a growing body of research has questioned transport's significance in the food GHG life cycle, and in particular the 'common sense' assumption that the further a product travels, the greater its GHG intensity will be.[10,11,12,13] Studies have shown that some imported products will have been grown or manufactured in less GHG-intensive ways than their UK counterparts, with the savings from this greater efficiency outweighing the negative impacts of the additional transport.[14] In addition, the mode and efficiency of transport need to be considered; mile for mile, shipping is a far less GHG-intensive

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[8] 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.

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

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

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

[12] Saunders, C. and Barber, A. (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

[13] 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.

[14] 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.

mode of transport than road and a food shipped in from the Southern Hemisphere may have the environmental edge over one trucked in from France.

These analyses have been extremely useful in highlighting the need to tackle the food life cycle as a whole – and in particular, the agricultural stage – rather than fixating on one particular issue. But in challenging the food miles assumption, there is a risk that we throw the baby out with the bathwater. Food transport is still a concern for several reasons. One is that as supply chains continue to globalise, there will be more transport and so emissions (in the absence of a clean fuels revolution) will grow in absolute terms. This is a problem given the need to make drastic cuts in our overall emissions. Importantly however, this growth will bring with it infrastructural, systemic changes that carry 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, such as roads, ports, runways, air freight handling facilities, as is clearly being seen in the emerging economies.[15] These construction activities will produce their own environmental (including GHG) impacts but more importantly, they engender a situation wherein 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, closer to home sources may be less economically attractive because labour costs are higher. As a result, local enterprises go out of business, leaving no alternative choice available.

While there are feelings that recent oil price rises may start to dampen the global sourcing impetus[16] it is important to bear in mind that oil price rises affect not just the cost of the transport leg but other stages in the supply chain too. Commodity prices as a whole have been rising and the costs are played out along the whole of the chain. Hence 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), 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.

Finally for transport, there is the 'what if?' question to consider. While it may be that UK grown products such as tomatoes may be more GHG-intensive to produce, in a greenhouse, than their sunnier-climed counterparts, 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 greenhouses than there is to moving capital – transport vehicles. What if, coupled with this, growing 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 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 may increase.

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[15] 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.

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

Food 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. Roughly speaking, we estimate that food refrigeration contributes about 3–3.5% of the UK's GHG emissions[17] – thereby accounting for around 15% of total food chain emissions.[18] Note that refrigeration does not feature in Figures 1 and 2 since its emissions are included in the figures we give for all post-farm gate food chain operations, from manufacturing through to the home.

While models predict that, thanks to gains in efficiency, refrigeration-related emissions are set to decline,[19] such technological improvements should 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.[20] 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 is worth noting that what is true for refrigeration may also be the case for the other energy-using technologies we now rely upon. 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.

Finally, 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.

Waste

Clearly refrigeration prevents food from going bad and, as such, plays a role in avoiding food waste. However, the relationship between food waste and refrigeration is a complex one and may have as much to do with our lifestyles and our attitudes to food as it does to the physical capacity to store food fresh.[21] And, refrigeration notwithstanding, around 18–20 million tonnes of food are wasted in the UK each year, with household food waste making the single largest contribution at 6.7 million tonnes.[22]

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

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[17] 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.

[18] 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.

[19] *Sustainable Products 2006: Policy analysis and projections,* Market Transformation Programme, 2006

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

[21] 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

[21] 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.

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

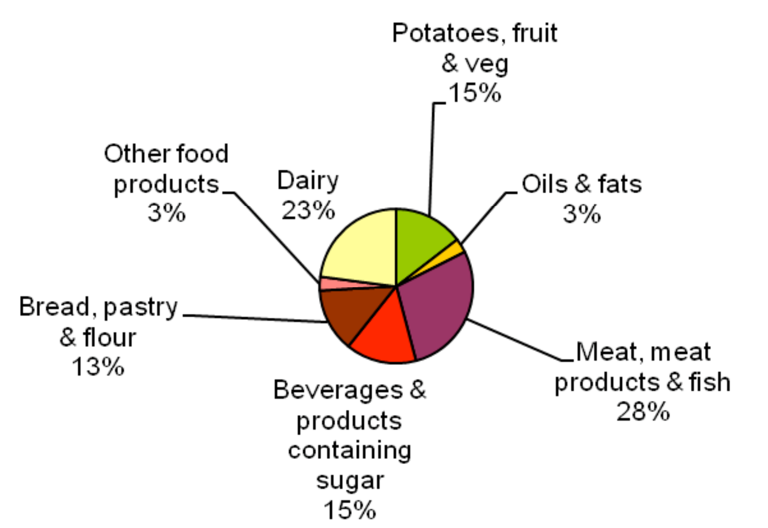
generate CH_4. Based on published data[23] we find that that degrading waste in landfill sites accounts for about 0.3% of the UK's GHG emissions. In theory, however, using anaerobic digestion (AD) systems, this waste could actually become a source of energy, offsetting the need to use fossil fuels.

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 arises at the household stage, 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.[24] Hence, a significant proportion of the food we produce 'emits in vain' so to speak, since it is not eaten. We discuss below what effect reductions in the amount of food we waste might have on overall GHG emissions, and the importance of addressing individual issues within a broader framework.

3. The contribution to GHG emissions by food type

There is another way of cutting up the emissions cake – by considering different food types. Figure 3 shows how the various foods eaten in the typical Dutch diet contribute to food GHG emissions.

Figure 3: 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 (1999) 203–216.

Meat and dairy products clearly dominate, together accounting for over 50% of food emissions. This dominance holds true in the UK too and we estimate that these foods contribute around 8%

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[23] 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.

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

of our GHG total.[25] Hence the major contribution made by agriculture itself reflects the GHG intensity of livestock rearing. We discuss the GHG implications of a growing global demand for animal source foods below.

While we have not attempted a full analysis of all the foods we eat and drink, we have undertaken calculations for fruit and vegetables, and for alcoholic drinks.

With regard to fruit and vegetables, we estimate that fruit and vegetables account for around 2.5% of GHG emissions.[26] Trends in the kinds of fruit and vegetables we eat are moving in more GHG-intensive directions. Such foods include those that are air freighted (such as berries and beans), are produced in heated greenhouses (the ratatouille vegetables), require precise temperature control (bagged salads, pre-cut fruit), or are prone to spoilage (soft berries).

Alcoholic drinks contribute around 1.5% of total UK GHG emissions[27] with little difference (from the partial data we have obtained) between wines, spirits and beers. As with fruit and vegetables, our drinking habits are moving us in more GHG-intensive directions, with growing preference for drinking in the home (meaning individual cans and bottles) and for chilled and ultra-chilled drinks. Alcohol is an example of a food (alongside, sweets, chocolates and fizzy drinks) that possesses little nutritional value. As we discuss below, we may need to reduce consumption of such foods if we are to reduce the GHG intensity of what we consume.

4. The flip side of the coin: climate change and its impacts on our food supply

Our food system not only produces climate-changing gases, but it in turn is influenced by them. The relationship between the food system and GHG emissions is a dynamic one. 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.

Broadly speaking, high latitude regions, such as North America and Northern Europe (including the UK) may initially benefit from temperature rises. 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) that are currently not viable. Water shortages will, however, increasingly pose problems, and towards the middle of the century, the harmful impacts – excessively high temperatures and drought – will outweigh any gains. In low latitude regions – Africa, parts of Asia, South America and Australasia – the negative effects 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.[28] Planning for gradual temperature increases will be made harder

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[25] 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.

[26] 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.

[27] 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.

[28] 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*

by the challenge of contending with 'wildcards' – unpredictable events such as floods, droughts and hurricanes.

The impacts of climate change on major commodities will 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.[29,30] Yields may also become more variable,[31] making it harder to predict availability from one year to the next.

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. 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, will be most vulnerable to such impacts. Violent weather could also affect fertiliser producing plants and manufacturing sites. Rising temperatures place greater demands on refrigeration, with subsequent implications for energy use.

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 pace 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.

As a final comment, it is vital to emphasise that adaptation and mitigation strategies for the food system need to be developed in tandem. Measures aimed at adapting to climate change must be compatible with, rather than developed without regard to, the goals of GHG reduction.

5. Reducing food impacts: the role of technological change and management

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

There is, in fact, a great deal that can be done, both at the farm stages and further along the supply chain. Table 1 summarises some of the options and the issues these may raise. Some of these measures are already being put in place, particularly by some of the larger manufacturers and retailers. The implementation of others relies on a more favourable policy context and progress here is patchy and inadequate.

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.

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

30 Gay, C., Estrada, F., Conde, C., Eakin, H., 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, December 2006, pp. 259–288(30).

31 Jones, P.D., Lister, D.H., Jaggard, K.W. and 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, May 2003 , pp. 93–108(16).

Table 1: The technological and managerial options

Pre-farm gate	Efficiency	Renewables	Other	Comments and issues raised
Energy use	Scope for better efficiency, CHP	Anaerobic digestion, 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	Anaerobic digestion, manure and legumes are all renewable	anaerobic 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: anaerobic digestion, 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	One off benefits; buys time. Improves soil quality

equilibrium

Post-farm gate	Efficiency	Renewables	Other	Comments and issues raised
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, anaerobic digestion 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

Achieving cuts from the agricultural sector presents particular challenges; while much can be achieved through greater nutrient use efficiency, the recycling of wastes (through AD, for instance), and breeding strategies, the options are ultimately limited by climatic and geological factors, and basic biochemistry.

N_2O emissions, one of the major agricultural GHGs, vary according to differences in soil quality, climate and even the vagaries of day to day weather. This makes both predicting, and taking steps to manage emissions very hard indeed. As regards emissions from livestock, the dairy industry aspires (but is not formally committed) to reducing milk chain emissions by 20–30% by 2020.[32] While many of the measures the industry suggests make sense, some, such as optimising feeding strategies (leading to greater output per unit of methane or nitrous oxide produced), may have negative indirect effects, particularly by fostering land use change elsewhere (for the production of feedstuffs), thereby causing releases of CO_2. Other measures may also affect other areas of concern, such as animal welfare and biodiversity. Of course, by 2050 the reduction in livestock-related emissions will need to be far higher than 30%.

Importantly, while there is much that can and should be done for the food chain as a whole, and while cleaner technologies and better supply chain management can achieve major emission reductions, these changes do not help us address the bigger picture. The food industry may be taking steps to improve its operational infrastructure, but this ultimately has little influence on its intended direction of growth. The measures put in place 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, those that require rapid modes of transport, and the unquestioned availability of virtually everything, at all times, in all locations.

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 habits and desires – behavioural norms which may lead ultimately to greater energy use. Smart technologies can 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.

6. Reducing food impacts: the role of behaviour change

Table 2 sets out what a less GHG-intensive way of eating might look like and highlights a few of the challenges these may pose for other areas of concern, including international development, attitudes to our bodies and quality of life.

[32] *The Milk Road Map*. Produced by the Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce, Defra May 2008.

Table 2: Less GHG-intensive eating patterns

Priority	Action	Impact area addressed	Comments
High	Eat fewer meat and dairy products	N_2O 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	This is dangerous territory if individual people are victimised. Moralistic attitudes towards body weight are unhelpful and often destructive. Overconsumption of food is part and parcel of a society in which consumption and consuming is its raison d'être. The eating-less agenda should be seen as part of a broader requirement to consume less overall
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	'Robust' foods are less prone to spoilage. Local is more problematic because the mode and efficiency of the transport system will influence the outcome. Measures to reduce air freighted foods may clash with objectives of supporting economic development in poor countries
Medium	Prepare food for more than one person and for several days	Efficiencies of scale – reduced energy use	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. Trends in how people actually live (more single person lifestyles etc) make this approach difficult

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).[33]
Medium, possibly high	Don't waste food / manage unavoidable waste properly eg. through anaerobic digestion	Embedded emissions – in theory lower levels of production permitted	Wasted food represents a waste of embedded emissions. The waste issue raises structural, system questions that are linked to the whole *consuming less* 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 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.

The table gives a sense of the general direction of change but we are not able at this stage to quantify the degree of change needed. It is clear though that very substantial reductions in meat and dairy consumption will be needed and we discuss this below.

[33] http://www.greenlogistics.org/PageView.aspx?id=97&tid=97 accessed 25 March 2008.

We stress that campaigns encouraging us to change *voluntarily* what we eat are unlikely to achieve much. Food is important to us in a great many cultural and symbolic ways, and our food choices are affected by cost, time, habit and other influences. Study upon study has shown that awareness-raising campaigns alone are unlikely to work, [34,35] particularly when it comes to the more difficult changes.

The *context* within which people consume must therefore change. People do not change in themselves – but they do adapt to changed circumstances. People will do things differently when their social, economic, political and cultural surroundings require it.[36] Creating these new surroundings will require the use of both regulatory and fiscal instruments.

Even with the right context however, changes in *particular* types of behaviour create wider systemic challenges. Behaviour change is as much vulnerable to the rebound effect as is technological change,[37] as the issue of food waste illustrates. 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 less food, how would retailers respond? Would they expand overseas with renewed vigour? Tesco, for example already has over 1,200 stores across Europe and Asia.[38] Would food retailers extend their non-food range even further?

This is not to say that behaviour change is ineffective or unnecessary. On the contrary, it is vital as we shall see in the case of meat and dairy production and consumption. But policies and campaigns that are put in place to tackle one issue must be mindful of the knock-on effects on emissions elsewhere. As long as consumption *per se* is deemed essential and promoted as such through macro-economic policy, changes in one aspect of behaviour will simply shift the problem around. We need to consume less 'stuff' overall.

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[34] *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.

[35] 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.

[36] *I will if you will*: *Towards sustainable consumption*, Sustainable Development Commission, London, 2006.

[37] Alcott, B. (2008) The sufficiency strategy: Would rich-world frugality lower environmental impact? *Ecological Economics* 64 pp.770–768.

[38] *Annual review and summary financial statement*, Tesco, 2007.

7. Global production and consumption: the livestock challenge

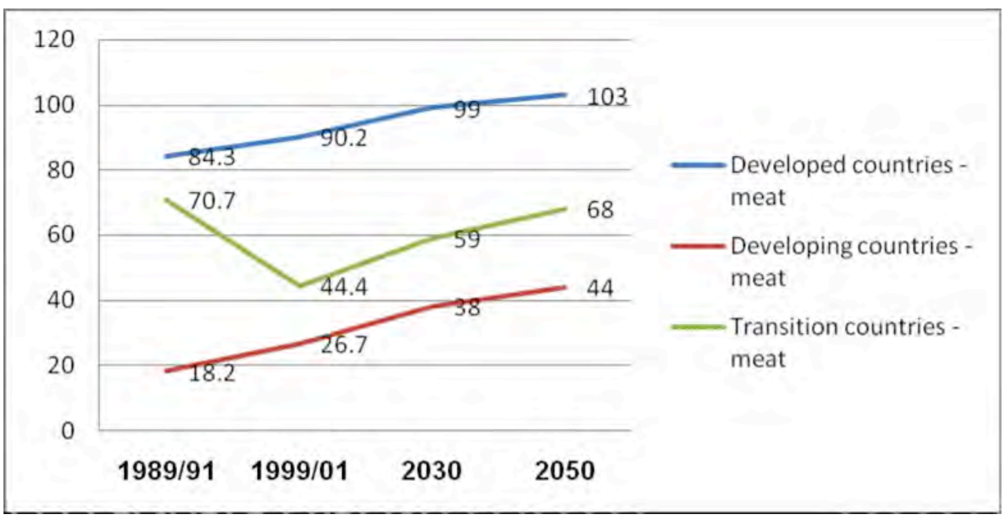
By 2050, demand for meat and dairy products is set to double as Table 3 shows. This is not only because there will be more of us on the planet but also because we will, on the whole, be eating more animal-derived foods.

Table 3: Meat and dairy demand in 2000 and predicted demand in 2050

	2000 (population 6 bn)	2050 (population 9 bn)
Average *per capita* annual global demand – meat (tonnes)	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

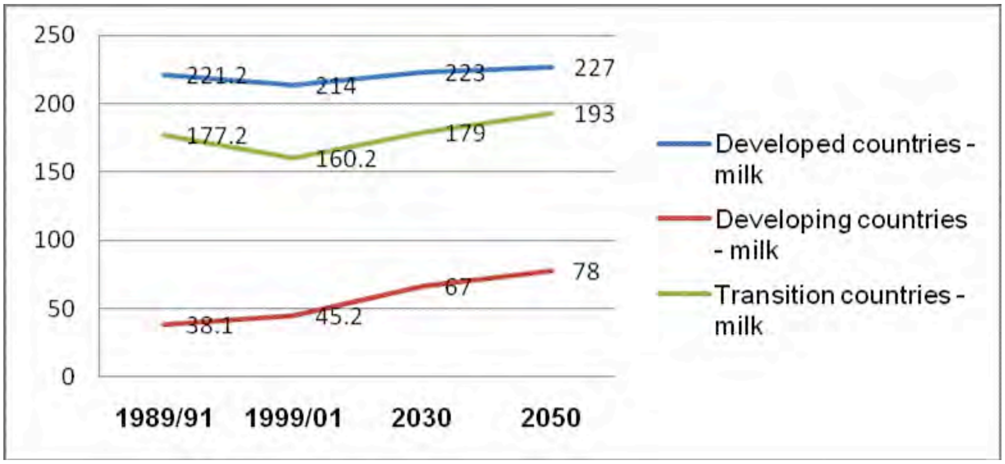
These average figures disguise huge global inequalities of consumption. Figures 4 and 5 show the difference in what the rich and the poor are anticipated to consume.

Figure 4: 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 5: 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*, while the figure for milk consumption is lower still, at a third.

Even if technological and managerial approaches 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[39,40] and NGOs,[41,42] not to mention the Chair of the IPCC,[43] have argued that to reduce GHG emissions we need to eat fewer animal-source foods (note that a lacto-vegetarian diet is not necessarily less GHG-intensive than a meat-based one).

But by how much? One place to start is to consider the very high levels of animal foods eaten by people in developed countries and to calculate what would happen if they reduced their consumption. For example, what would happen to global meat and milk volumes and ensuing emissions if people in the developed and transition economies were to reduce 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 and it also allows people in poor countries to increase the amount they eat. Per capita intakes for the developing world in 2050 are anticipated to be 44 kg of meat and 78 kg of milk annually. This represents a 62% and 73% increase on poor people's meat and milk consumption levels today but a very significant cut for the peoples of the rich world. Consumption at these levels 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

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[39] Goodland, R. (1997) Environmental sustainability in agriculture: diet matters, *Ecological Economics*, 23 189–200.
[40] Gerbens-Leenes, P.W. and Nonhebel, S (2002) Consumption Patterns and Their Effects on Land Required for Food *Ecological Economics* 42 S. 185–199.
[41] Gold, M. (2004) *The global benefits of eating less meat*, Compassion in World Farming Trust, Petersfield, Hampshire.
[42] 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.
[43] *Global Warning – The impact of meat production and consumption on climate change*. Speech given by Dr Rajendra Pachauri at the Peter Roberts Memorial Lecture organised by Compassion in World Farming, London, 8 September 2008.

more drastic two-thirds. The reduction in our *anticipated* 2050 consumption levels would be greater still.

The problem is that there are far fewer people living in the developed and transition economies than there are in the developing world. And so, even if the 1.4 billion of us living in these wealthier countries were to reduce our consumption by this amount, the consequences would be only a 15% and 22% overall reduction in *projected* world meat and milk production in 2050. As noted, meat and milk production is expected to double by 2050. Hence even with rich world reductions, global meat and dairy volumes for meat and milk would still respectively be 70% and 45% *higher* in 2050 than they are today. All other things being equal, the consequences will be a very great increase in global livestock GHGs.

Clearly reductions at this level and for this number of people 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 year 2000 levels, so as to avoid a rise in livestock GHG emissions? Assuming there will be 9 billion people in 2050, per capita consumption of meat and milk would need to be as low as 25kg and 53 kg a year respectively. This is approximately the average level of consumption of people in the developing world *today* and amounts to half a kilo of meat and a litre of milk per person a week.

This roughly translates into a 4 oz portion of meat every other day – equivalent to a quarter pounder hamburger or two sausages or 3–4 rashers of bacon. For milk a litre a week allows just about enough for cereal in the morning *or* for 100 g cheese – say three modest cheese sandwiches a week.

These figures are strikingly low – they imply drastic declines for the rich and allow for no increase by the poor. The nutritional implications are discussed below. Note that even at these low levels of consumption, we will not see a decline in livestock-related GHG emissions but merely no growth. We need the good management and technological innovation too.

8. How far can we reduce emissions in the UK? A back of the envelope calculation

We cannot state with any rigorous accuracy what food-related reductions might be possible for the UK through a mix of technological measures and behaviour change but, just for the record, we have produced 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 appears currently to be 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 emission cuts at the farm stage are likely to come from a change in what we grow because of changes in what we eat; in other words, changes in consumption will substantially dictate farm level emissions. While agriculture is the life cycle stage responsible, on average, for the greatest GHG emissions, it is also the most challenging, since we are dealing with a living dynamic system. Post-farm gate, technological improvements have strong potential for bringing emissions down, although changes in behaviour, such as reducing waste, will also play their part.

To calculate possible farm-related emission 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 (a more modest cut than what may actually be needed). 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% to 50% reduction (the latter very optimistic) in on-farm emissions through good farm management. These together could approximately speaking cut agricultural emissions by 50–70% by the middle of the century.

Post-farm gate onwards, actions by individual companies have shown that savings of up to 70% are possible given the will to invest in renewable alternatives[44] 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 throughout the supply chain will also help. This means that post-farm gate emissions would only be 30% of what they currently are.

Adding the pre- and post-farm gate savings together, food-related emissions are reduced to between a third and a half of what they are today – a cut of 50–67%. This would be equivalent to reducing today's overall UK's overall GHG emissions by a fairly substantial 9–12%.

9. Healthy diets and fewer emissions? Both or either?

Interestingly, the changes set out in Table 2 above suggest that the goals of reducing GHG emissions and of improving our diets may be compatible. On the whole, eating no more than we need to maintain a healthy body weight, basing our diets largely on plant-origin foods (vegetables, legumes, fruits and cereals), substantially reducing intakes of meat and dairy products, and cutting down on foods with little nutritional value (such as sweets, alcohol and fizzy drinks) all make reasonable nutritional sense. It will of course always be perfectly possible to find examples where these goals clash – but broadly speaking in this country, the GHG reduction and health improvement goals can go together.

However, the situation obviously depends on who you are in the world and where you live. A billion or more people worldwide are overweight;[45] but 840 million people[46] – including one in four children[47] – do not get enough to eat. The nature of the relationship between nutrition and climate change mitigation demands particularly close attention when we consider the role of meat and dairy products in our diets. The arguments here tend to be politically charged and polarised between those promoting vegetarian/vegan diets[48] and those advocating the merits of meat consumption.[49] While a considerable body of research shows that a varied diet of plant foods is in fact perfectly able to provide us with the full range of nutrients needed to maintain a healthy diet,[50,51,52,53,54] meat, eggs and dairy products provide a range of essential nutrients (iron, calcium, protein, fat) in usefully concentrated and culturally acceptable form.

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44 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.

45 *Global Strategy on Diet, Physical Activity and Health*, World Health Organisation http://www.who.int/dietphysicalactivity/publications/facts/obesity/en/.

46 *The State of Food Insecurity in the World 2006*, Food and Agriculture Organisation, 2008.

47 *The Millennium Development Goals Report 2008*, United Nations, New York, 2008.

48 http://www.vegansociety.com/html/food/nutrition/iron.php.

49 *Are you getting the balance right?* Information sheet, Meat Matters, http://www.meatmatters.com/sections/health/index.php.

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

51 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.

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

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

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 many nutrients but in many cases we consume 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.[55]

In short, nutritional wellbeing and less GHG-intensive ways of eating *can* be compatible but the challenge of doing so goes to the heart of the food security dilemma. The problem as ever is not about technical possibilities (How much food?) but about implementation (Where? Who? How?). The value of meat and dairy products needs to be considered in context of what else people are eating; in terms of what policy-makers are doing to ensure that people have 'access to sufficient, safe and nutritious food.'[56]

10. Observations, conclusions and recommendations

GHG emissions are rising dangerously. The global population is also increasing and there could well be nine 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.[57]

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 GHG-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

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[54] 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.
[55] Neumann, C, Harris, D.M. and 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.
[56] *Rome Declaration on World Food Security*, World Food Summit, FAO Rome, November 1996, FAO Rome.
[57] Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK.

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.

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 this 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,[58] 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,[59] and will also help enable it fulfil the (future) legal obligation to reduce the UK's carbon

[58] Pacala, S., and Socolow, R. (2004) Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science* 305: 968–972.
[59] *Food Matters: Towards a Strategy for the 21st Century*, Strategy Unit, July 2008.

(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.

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, it 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 CO_2 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 N_2O. Livestock products are high in 'embedded nitrogen' (since they have first consumed plants that contain nitrogen and that have receive 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.