Food and Climate change:

A review of the effects of climate change on food within the remit of the Food Standards Agency

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The views expressed in this report are those of the authors and do not necessarily reflect the views or policies of the expert panel or the Food Standards Agency

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1 Executive summary

1.1 Aims and methodology

1.1.1 The aims of this report were to identify:

- The impact that climate change may have upon nutrition
- The effects that climate change may have upon food safety
- The impact that food & food waste has as a driver of climate change
- How responses to climate change may impact on nutrition and food safety

1.1.2 The purpose of the report was to inform the Food Standards Agency (FSA) on how climate change may affect their ability to deliver safe and healthy food, and to suggest ways that the FSA may engage in climate change mitigation and adaptation. **These policy implications are highlighted in bold.**

1.1.3 A set of expert interviews were conducted, followed by a focussed and structured literature search. The report was then reviewed by the experts and FSA.

1.2 Climate change and food choice

1.2.1 Individual food choice is affected by many variables and predicting, manipulating or analysing it is not simple. Climate change may directly affect individual food choices, but there is only limited evidence of the ways in which our food and drink are affected by temperature and weather. Foods eaten more frequently in the summer, such as barbecued food, salads, and alcohol may be consumed more frequently with climate change.

1.2.2 Climate change may affect food choice through price and availability. Research suggests little change or even a reduction in world grain prices up to a global temperature rise of 3^{O}C after which prices will rise as production falls. Predicted increases in extreme weather events are likely to have negative impacts on the availability of food, but there are few assessments on this. Increases in food prices are likely to lead to some consumers choosing lower cost food.

1.2.3 Climate change may lead to initiatives to produce food with lower Greenhouse Gas (GHG) emissions. These may have large impacts upon food production, but the implications for food prices are uncertain. One mitigation measure against climate change may be an increase in the growth of biofuels, and these are associated with elevated food prices (Lock et al., 2009).

1.2.4 New models to understand the likely effects of climate change on food prices and availability in the UK are required. These should examine a range of foodstuffs and consider the likely impacts of increases in extreme weather events.

1.2.5 Studies to understand how weather and climate affect food choice, and what this means for future climates are required.

1.2.6 Better understanding of how consumers respond to food price fluctuations and rises is required. Such research should focus on low income and vulnerable groups including refugee, immigrant and homeless groups.

1.3 THE IMPACT OF CLIMATE CHANGE ON NUTRITION

1.3.1 If food prices rise then, as healthier foods are often more expensive, consumers may choose less healthy food (Cummins and Macintyre, 2006). Of particular concern is that food with a high energy density (usually more processed foods with high sugar and fat contents) is often cheaper than its less energy dense counterparts, and less affected by price rises (as the cost of the food is a smaller component of cost). This may reduce the nutritional quality of dietary intakes, lower the nutritional status of some groups and increase the risk of obesity.

1.3.2 FSA initiatives such as the "Eatwell" website to encourage healthier eating, the nutritional labelling of foods, and initiatives to reduce the saturated fat and salt content of processed foods are important to protect public health. These will become increasingly important should climate change lead to less healthy diets.

1.3.3 The FSA National Diet and Nutrition Survey will be essential in highlighting changes in nutritional intake and status resulting from climate change. This may ensure that any problems that arise can be addressed. Extending the survey to better cover vulnerable groups is essential.

1.3.4 Climate change will alter the geographical locations from which food is sourced (Easterling et al., 2007) and such shifts may affect nutritional quality, as food from varying parts of the world has different vitamin, antioxidant and amino acid compositions.

1.3.5 Agricultural adaptation to climate change will lead to the development of new crops bred to survive in different climatic conditions or in new geographical areas. These developments may also occur as agricultural systems reduce their GHG emissions. It is important to ensure that crop breeding should focus on maintenance of nutrient content and absorption as well as improved yields.

1.3.6 Changes in how foods are grown, processed, stored, prepared and cooked (all of which could alter with climate change) may affect the nutritional content of food. Higher fuel costs may reduce cooking options for poorer groups.

1.3.7 FSA statutory and non-statutory monitoring of the nutritional quality of food (as well as nutritional surveys) will play an important role in identifying whether climate change or new crop breeds are altering the nutritional content of food and affecting the intakes in the general population or vulnerable groups.

1.4 EFFECTS OF CLIMATE CHANGE ON FOOD SAFETY

1.4.1 Under climate change the UK population is likely to consume different types of food produced in different geographical areas. The safety of food varies by food type and where it is produced. For example meat carries a higher risk of food poisoning than vegetables. There is only limited evidence on how our diets will alter under climate change, making it impossible to gauge associated changes in food safety.

1.4.2 Climate change may also lead to altered chemical and pathogen inputs to food. There are multiple mechanisms through which climate change could affect existing pathogens or lead to the emergence of new ones (FAO, 2008a). The pathogens of most concern under climate change are those with those with low infective doses (e.g. *Shigella* spp., parasitic protozoa) and significant persistence in the environment (e.g. enteric viruses and parasitic protozoa) (FAO, 2008a). Pathogens with stress tolerance responses to temperature and pH (e.g. enterohemorrhagic E. *coli* and *Salmonella*) may also enhance their competitiveness (FAO, 2008a). Climate change may increase the demand for irrigation water, elevating pathogen risks. Altered use of pesticides and veterinary medicines is likely. Increased use of veterinary medicines may increase the prevalence of antibiotic-resistant pathogens (FAO, 2008a). Flooding is one mechanism for transporting pathogens and chemicals onto agricultural land and may increase (Boxall et al., 2009).

1.4.3 Elevated temperatures may increase food borne pathogens and mycotoxins in the pathway between farm and consumer. Food transport, storage and processing affect food safety risks, but there is little information on how these will alter under climate change.

1.4.4 The common theme emerging for food safety is altered risks and increasing unpredictability. Chemical and radiation levels in food are tightly regulated and controlled (FAO, 2006), so changes in UK or imported food concentrations will be within prescribed limits. The UK, represented by the FSA, plays a major role in setting standards and works with other EU institutions to mitigate the effects of chemicals and other contaminants.

Climate change may also alter the incidence of food borne infections. Through the Health Protection Agency (HPA) mechanisms are in place to detect changes in the incidence of these and to respond to protect public health.

1.4.5 Greater unpredictability suggests the need for increased horizon scanning to predict new risks, and greater speed in addressing emerging threats. Within the HPA and DEFRA there are a number of such groups. Some pathogens and chemicals are transferred from animals to humans, so monitoring of animal health in the UK and overseas may enable us to detect threats before human infection occurs. Development of rapid detection methods for pathogens and chemicals in food, and surveillance systems to report these quickly, may enable swift action to be taken.

1.4.6 Some effects of climate change may be localised. This highlights the need for targeted monitoring of food from areas that are undergoing rapid agricultural change, individuals consuming food from such areas and vulnerable groups. Risk assessment techniques may identify areas for targeting, as well as possible mitigation techniques.

1.5 IMPACT OF FOOD AND FOOD WASTE AS A DRIVER OF CLIMATE CHANGE

1.5.1 Food is responsible for 15-30% of UK GHG emissions. Most of these occur within agriculture (45%), food manufacture (12%) and transport (12%). Agricultural emissions are dominated by fertiliser production and emissions from livestock, rice and manure. Simple surrogates of GHG emissions such as "local food" or "food miles" are misleading. Only 1.5% of fruit and vegetables are air freighted but it accounts for 40% of fruit and vegetable transport GHG emissions (Garnett, 2006).

1.5.2 Meat and dairy consumption is responsible for over 50% of the GHG emissions from typical diets. Meat and dairy foods, particularly beef, lamb, pork and cheese result in 3-13 times more GHG emissions than vegetables and pulses. Other foods with large GHG footprints include sugary foods and drinks, tea, coffee and cocoa. Mediterranean style vegetables, eggs, poultry, fish, bagged salads, cooking oils and biscuits all have moderate footprints.

1.5.3 Around 30% of all food bought in the UK is wasted; a large source of GHG emissions (5-10% of UK total). From this total, 19% of the waste is unavoidable, 20% is potentially avoidable and 61% could probably have been avoided had the food been managed more effectively. Meat and salad vegetables are the food types most wasted.

1.5.4 **There is a need for systematic reviews of the GHG emissions resulting from different foods and methods of food production, processing, transport, packaging, storage, cooking and**

disposal. This would inform policy on where in the food chain GHG emissions are produced and how these may be managed.

1.6 Impact of responses to climate change on nutrition and food safety

1.6.1 There are a variety of initiatives to reduce food related GHG emissions. Many, such as improved energy efficiency in fertiliser manufacture, will have little impact upon nutrition or food safety. Others, such as changes to fertilizer, pesticide and manure applications (ADAS, 2009), may have uncertain impacts on food safety. Schemes to improve the efficiency of refrigeration systems, reduce food packaging and minimise the amount of food thrown away may cut GHG emissions but should not compromise food safety or nutrition.

1.6.2 Existing FSA work on food safety hazards across the food chain could be used to ensure such measures do not compromise food safety. The FSA is working with the Waste Resources Action Programme to reduce food waste. At the strategic level the FSA needs to continue engaging with Foresight projects on Land Use (Foresight, 2009b) and Global Food and Farming Futures (Foresight, 2009a) to ensure that issues of nutrition and food safety are considered.

1.6.3 One response to climate change may be individuals consuming diets with lower GHG emissions. These may include:

1. Reducing intake of meats (generally from ruminants) and dairy foods and replacement by meats and dairy foods with lower GHG footprints and vegetable proteins;
2. Reducing intake of sugary foods and drinks, and of tea, coffee and chocolate;
3. Reducing food waste, and composting what food waste we cannot avoid; and
4. Reducing air freighting of foods

1.6.4 Reduced meat and dairy consumption may be nutritionally beneficial in reducing saturated fat intakes, so reducing cardiovascular disease risks (Friel et al., 2009). However, it may have implications for the iron, zinc and calcium intakes of some vulnerable groups. Reduced consumption of sugary foods and drinks would help to reduce intakes of dietary sugars, and possibly energy intakes.

1.6.5 Promotion of more seasonal and local produce could adversely affect fruit and vegetable consumption in the winter and spring when local availability is limited. Ensuring adequate year round consumption of a variety of fruit and vegetables is important (World Health

Organization, 1990). GHG efficient ways of achieving this, while maintaining nutrition and food safety, need to be found.

1.6.6 The FSA will need to ensure that recommendations for a low GHG diet take account of nutrition and food safety concerns. The UK government is committed to healthy, safe and sustainable food (Strategy Unit, 2008a) and the Council of Food Policy Advisors, which includes representatives from the FSA, has been set up within DEFRA to advise on a 'strategic approach to food policy' – marrying health & environmental issues. FSA could become the source of integrated advice to consumers on food (Strategy Unit, 2008a) and websites such as eatwell.gov.uk could become a platform for such information.

1.6.7 A diet sourcing foods from a many of geographical locations averages out variations in microbial, chemical and radiation levels. Should a low GHG diet involve greater consumption of locally produced food (N.B. transport is a small component of GHG emissions) some individuals, especially in vulnerable groups, may be at increased risk of nutrient deficiencies or toxicities reflecting their local soils (Oliver, 1997).

1.6.8 If a trend towards local food occurs, the FSA will need to enhance monitoring of such food sources, especially if risk audits suggest that food from such areas are at higher risk of leading to nutrient deficiencies or food safety issues. Additionally, individuals consuming the majority of their food from local sources may be especially at risk.

1.6.9 If changes in consumer choices to lower GHG emissions are encouraged, then ways of engaging with the public to support and encourage appropriate changes need to be considered. Traditional methods of information provision plus encouragement, even where backed up by fiscal incentives, are probably inadequate. Information campaigns appear to be ineffective because individuals tend to base their behaviour on trial and error of themselves or others. Effective persuasion includes understanding the target audience and using this to make an immediate, direct, imaginative and emotional appeal. It tends to use individual commitment and buy-in, and is helped by a supportive social environment (Jackson, 2005).

1.6.10 Such strategies require a joined up approach between all government departments. The FSA can take on a major role through displaying GHG-aware behaviour in its internal practices as well as providing research-based information on diets that are GHG-friendly, nutritious and safe. Changes can be supported by providing guidelines for such diets to individuals and provision of such foods through government bodies such as schools, hospitals and the armed services. Finally it can encourage good business practices using links developed in the low salt strategy.

2 Introduction

2.1 PURPOSE

2.1.1 This review was commissioned by the FSA as part of their research programme aiming to 'look at the potential impacts of climate change on our policies and how it might affect our ability to deliver our vision of 'safe and healthy eating for all''(Wadge, 2009).

2.1.2 The review was implemented using an expert panel and rapid literature review to describe the current state of knowledge in each area and highlight relevant gaps. This includes an assessment of the likely severity of each issue as well as adaptation and mitigation possibilities. The report was then reviewed by experts within the different sectors of the FSA.

2.1.3 The report is novel as it aims to examine all interactions between climate change and food. Although there is much previous work on specific issues such as climate change and agriculture, and food choices and climate change this is one of the first reports to consider this literature in its totality.

2.1.4 The specific aims of the report were

1) To understand the impact that food and food waste has as a driver of climate change
2) To identify the impact that climate change may have upon nutrition
3) To identify the impact that climate change may have upon food safety
4) To assess how individual and societal responses to climate change may impact upon nutrition and food safety

2.2 SCOPE

2.2.1 Many factors are likely to affect food in the UK over the next 50 years, and climate change is only one of these. This is a brief literature and expert-based review. A fuller review of likely issues on the future of land use in the UK is being undertaken by the Foresight project on Global Food and Farming Futures, and is due to be published later in 2010 (Foresight, 2009b). This will address wider issues including the food needs of a growing world population, changing consumption demands of large populations in developing nations, the effects of climate change on agriculture and marine production, and scientific and technological advances to improve agricultural efficiency and productivity.

2.2.2 This report considers all aspects of the food cycle. This has been defined as the growing and production of foods, food processing and manufacturing and food wastage. It also includes the food retail sector which includes transportation, shop costs, refrigeration, environmental purchasing standards and packaging. Finally consumers and households, including how consumers get to the shops, how they store and prepare foods, what they throw away, and what happens to this (Strategy Unit, 2008b).

2.2.3 The report focuses on UK issues. There is good evidence that the effects of climate change will be more difficult to deal with in other parts of the world, compounding existing and predicted food insecurity and undernutrition (Costello et al., 2009). As the UK is not self-sufficient in food (DEFRA, 2008) issues of climate change and social unrest (a possible consequence of climate change) in the rest of the world will not be only of academic or compassionate interest. Furthermore, the UK buys food in an international market, so the way that foods are produced in other parts of the world, their relative abundance or scarcity, will directly impact on the UK and the health and wellbeing of its citizens, and so some of these issues are covered here briefly.

2.2.4 The report focuses on food and drink rather than water quality or abundance (although there is a crossover here). We note effects on food availability and safety of changes in climate that relate to water, but do not address these changes in depth or engage with availability of water for people's health, cleanliness, drinking or cooking.

2.2.5 It is not the purpose of this report to discuss the causes of climate change in detail, or to discuss agriculture, except to the extent that climate change and agriculture will determine the food we have available to eat, and the extent to which we can help mitigate climate change through changes in the food cycle.

2.2.6 Finally it is important to recognise that climate change is only one environmental issue, and a policy which has positive effects upon climate change may have adverse effects on other issues. In addressing climate change it also important to recognise the FSA's commitment to sustainable development. This is defined as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). These FSA actions are highlighted by its current Sustainable Development Action Plan (FSA, 2009b) which aims to encourage internal sustainability as well as embedding sustainable development into policy making. The later implies that the FSA need to consider the social, economic as well as environmental (including climate change) impacts of all its policies. In this report the term 'carbon' is used which is a shorthand for all greenhouse gases which contribute to climate change.

2.3 REPORT STRUCTURE

2.3.1 Section 3 describes the methods used to develop this report. Section 4 then summarises climate change projections for the world, Europe and the UK. The contribution of food production, food consumption and food waste to climate change is presented in Section 5. This demonstrates that food is an important contributor to climate change and consequently examines measures that may be implemented to reduce the carbon footprint of food. Section 6 addresses how climate change is likely to affect the diet of individual consumers, considering factors such as food prices and availability. Section 7 builds upon the results from Sections 5 and 6 to examine the likely implications of climate change for nutritional intake and status. Section 8 examines the likely implications of climate change for food safety. Section 9 develops the discussion and considers how we can engender public engagement in climate change. Section 10 details the references used. The overall themes that emerge from the report as well as links to policy are presented in the Executive Summary.

3 Methodology

3.1 METHODS

3.1.1 Our research plan was designed to fit in with the 6 week turnaround required by the FSA and consisted of a rapid review which used a variety of complementary methods to locate and summarise formally and informally published studies.

3.1.2 The first phase of the methodology included a series of interviews with a group of respected experts and a broad based literature review of the issues. The experts were chosen to cover the four topics pre-stated in the review protocol and funding bid (section 2.1.4) as well as general food safety, climate change and adaptation issues. The aim of these interviews was to elicit expert opinions on how climate change may interact with food and then to scope out the main research projects, key papers and important research networks dealing with these issues. Experts were asked to provide a brief summary of published research in their area of expertise, along with key publications and a summary of ongoing research. The experts covered complementary knowledge areas, their broad topic areas are presented in Table 3-1.

Table 3-1 Topic areas and the expert panel

Topics	Bentham	Boxall	Draper	Fairweather - Tait	Hooper	Hulme	Hunter	Lake	Nichols	Waldron
Changes in microbiological, chemical and pesticide hazards at various stages of the food chain	■	■				■	■	■	■	
Changes in the foods that people choose to consume	■		■	■	■	■	■			
Shifts in the geographical areas from which our food is sourced	■			■	■	■				
The contribution of food choices and food waste to climate change, and how altering food choice to minimise climate change may impact on human nutrition and food safety				■	■	■		■		■

3.1.3 The interviews were carried out in parallel with a broad based literature review of the issues using Google and a variety of additional databases (including ISI Web of Knowledge, Geobase, SCOPUS, Embase and Medline) to track down key references on specific topics. This literature review was not a formal systematic review as the remit of the commissioned review is extremely broad. Initially we addressed the four topics set out in Table 3-1. These were addressed through summary of formally and informally published reviews in the relevant areas and through running specific searches for additional relevant primary and secondary research. We aimed to uncover relevant information of high quality to address the issues, but the searches were not complete and it is likely that some important points may have been missed (although there was evidence that we were reaching saturation in terms of issues raised in published reviews). Many issues within the review are extremely complex and we have tried to introduce the issues and the way that events may transpire, but with many complex climatic, social, cultural, scientific, legal and policy interactions there are more uncertainties than answers. Research included in the review has been summarised narratively, highlighting both established answers and remaining questions. The review was used as the basis for compiling the data and references provided by the interviews.

3.1.4 The first draft of the review, including experts' input, was sent out to all the experts with a request that they identify further priorities for development of the review, comment on the issues developed and evidence employed, as well as filling in gaps in the review to date with their expert knowledge and key references. These comments were incorporated into the review with further searching as necessary to fill in the gaps indicated.

3.1.5 A dissemination event was held at the FSA and used to map the major research themes onto the FSA strategic plan for 2010-2015. The draft report was circulated within the FSA before and after this dissemination event, and comments from FSA experts and departments were incorporated into the review.

3.1.6 This final report was then submitted to the FSA summarising the information collected in all phases.

3.2 EXPERT GROUP

Professor Graham Bentham (School of Environmental Sciences, University of East Anglia) – provided expertise in environmental science, food borne disease under climate change and the health impacts of food composition changes. His research is concerned with the effects of environmental conditions on health and includes work on the effects of climate change on the risks of heat-wave deaths, the incidence of food poisoning and the impact on water-borne enteric infections such as cryptosporidiosis. He has also recently worked extensively on anti-oxidant status and age related macular degeneration. He was Co-Chair of the MRC-NERC Cooperative Group on Climate Change, Ozone Depletion and Health and a member of the Department of Health Expert Group on the Health

Effects of Climate Change in the UK. Within this group he wrote the chapter on foodborne disease and climate change.

Dr Alistair Boxall (EcoChemistry Research Group, University of York / FERA) - provided expertise on environmental exposure and food safety. Alistair currently leads the EcoChemistry Research group which is a joint initiative between the University of York and the Food Environment Research Agency. The group is a world leader in the area of environmental chemistry, ecotoxicology and environmental risk assessment and has recently worked on projects funded by DEFRA and NERC into the impacts of climate change on the risks of chemicals in agricultural systems. Alistair is an environmental chemist with an international reputation in the area of emerging contaminants in the environment. He has previously co-ordinated large projects (including the EU FPV project ERAVMIS) for the European Commission and the UK government. He was work package leader on two recent EU projects (ERAPHARM and KNAPPE). Dr Boxall sits on the UK government Veterinary Products Committee and is an ad hoc member of the EFSA working group on risk assessment of feed additives and a member of the UK Advisory Committee on Hazardous Substances. He is lead author of a recent multi-author paper on climate change and human health (Boxall et al., 2009).

Dr Alizon Draper (Centre for Public Health Nutrition, University of Westminster) - provided expertise in food choice. Alizon is a Reader in public health nutrition and her research focuses on the social and policy aspects of nutrition, including analysis of the social factors influencing food use and dietary intake. Recent projects include the social construction of risk in relation to food safety and the implications of this for health surveillance and policy development, the value of participatory approaches for consumer involvement in food policy and health promotion, and evaluation of the Well London projects that include healthy eating initiatives. Past work has included research on infant feeding practices, micronutrient deficiencies, health seeking behaviours, and vegetarianism. She is currently a member of the project management panel that is overseeing the research into front of pack nutritional labelling schemes for the FSA and has acted as an external appraiser for their Food Acceptability and choice research programme NO9 (summer 2006).

Professor Sue Fairweather-Tait (School of Medicine, Health Policy and Practice, University of East Anglia) – provided expertise in the nutritional impacts of changes in food growth and supply networks, and food choice. She is a member of the Diet & Health Group at the School of Medicine, Health Policy & Practice, UEA. Before joining UEA she was head of the Nutrition Division at the Institute of Food Research, Norwich. She leads a research programme on micronutrients, which is internationally recognized primarily in relation to the bioavailability, metabolism and homeostasis of dietary minerals, including iron, zinc, calcium, copper and selenium. Current research includes running work packages for EURRECA, a European Network of Excellence whose members are scientists, nutrition societies, consumer organisations, small & medium-sized enterprises and wider stakeholders funded by the European Commission (EC) who work together to address the problem of national variations in micronutrient recommendations. UEA is responsible for delivering systematic reviews to assess the impact of micronutrient intake and status on health outcomes, as well as assessing micronutrient biomarkers and bioavailability. She has been appointed to the EFSA NDA Panel, and is a member of the Working Groups on DRVs and Health Claims.

Professor Mike Hulme (School of Environmental Sciences, University of East Anglia) – provided expertise across all areas with specific emphasis upon adaptation and mitigation. His core research interest is an inter-disciplinary understanding of climate change, especially: representations of climate change in history, society and the media; interactions between climate change science and policy; and construction and application of climate change scenarios for impact, adaptation and integrated assessment. He was the Founding Director of the Tyndall Centre for Climate Change Research, UK, and has prepared climate scenarios and reports for the UK Government (including the UKCIP98 and UKCIP02 scenarios), the European Commission, UNEP, UNDP, WWF-International and the IPCC. He was co-ordinating Lead Author for the chapter on 'Climate scenario development' for the Third Assessment Report of the UN Intergovernmental Panel on Climate Change (Mearns et al., 2001) , as well as a contributing author for several other chapters. He is also leading the EU Integrated Project ADAM (Adaptation and Mitigation Strategies), which comprises a 26-member European research consortium contributing research to the development of EU climate policy.

Professor Paul Hunter (School of Medicine, Health Policy and Practice, University of East Anglia) – provided expertise in food and waterborne disease risks. His research interests are concerned with emerging infections and those related to food and water. He has been involved in the investigation of many food and waterborne outbreaks. He was a Consultant in Medical Microbiology and Consultant in Communicable Disease Control at the Cheshire Public Health Laboratory prior to moving to a professorship at UEA. He sits on several national and international committees. For example, in 1999 he was Chair of the OECD/WHO expert group on "Approaches to establishing links between drinking water and infectious disease" and in 2002 and 2003 he was a member of the OECD Expert group on "Emerging Risks to Global Water Supplies". He is also a member of the FSA Advisory Committee on the Microbiological Safety of Food.

Dr Gordon Nichols (Centre for Infections, Health Protection Agency) – provided expertise in food borne disease risks. He is a Consultant Epidemiologist working within the Gastrointestinal, Emerging and Zoonotic Infections Department of the Health Protection Agency's Centre for Infections. He has 38 years of Microbiology and Epidemiology experience. He has participated in two NERC projects on Climate Change and on a Wellcome funded project on the impact of geography and weather on cryptosporidiosis. He has also been involved with a number of other research projects funded by DEFRA, UKWIR, Scottish Executive, FSA and the European Union (DG Sanco). He is an HPA representative on the FSA Microbiological Safety of Food Funder's Group. He is also a member of the Department of Health Expert Group on the Health Effects of Climate Change in the UK. In this group he wrote the chapter on water and disease and climate change.

Professor Keith Waldron (Institute of Food Research) – provided expertise in changes to the food chain as a response to climate change. He is head of Sustainability in the Food Chain Exploitation Platform at the Institute for Food Research. He is a Senior Scientist, a Fellow of the Institute of Biology, and a Fellow of the Royal Society of Chemistry. In 1999 he was a Royal Institution Scientist for the New Century. He has published widely on the topic of plant cell walls (research papers and university texts) and his research interests have focused on interpolymeric cross-links and texture of plant-based foods. Since graduating with an MBA in 2001 for which he received the Open University Ray Nelson Prize, he has devoted time and effort to understanding the potential for innovation in relation to environmental and economic sustainability. This has involved the development of the Food Chain Sustainability Special Interest Group which he chairs. He has coordinated a number of national and international (EC) projects and PhD studentships, and lectures widely. He recently coordinated the EC STREP "REPRO" and leads several projects on co-product exploitation funded by the UK BIS and DEFRA.

4 Climate change projections for the World, Europe and UK

4.1 Climate change background

4.1.1 There is widespread, but not unanimous, agreement that the process of climate change is clear and that climate change has, and will continue to have, an impact upon the world's environment (Stern, 2005b). For full discussion of the science and uncertainties the reader is directed to other sources (e.g. IPCC, 2007). There is greater uncertainty concerning the specific effects of climate change. This is due to large confidence intervals in predictions of future GHG emissions and scientific differences between the Global Circulation Models which are used to estimate future climate. These indicate a warming of global temperatures of 1.8 - 4.0 °C by 2100 (IPCC, 2007). Climate has a huge and wide ranging impact upon society, so many authors have highlighted changes to food production and supply as possible consequences of climate change (Confalonieri, Menne et al. 2007; Department of Health and Health Protection Agency 2008; Hutton 2008; Strategy Unit 2008). Section 2 has indicated that the food consumed in the UK comes from a variety of geographical locations and so this report will start by presenting the global climate change predictions followed by more specific assessments of the implications for Europe and the UK.

4.2 Effects on climate: global

4.2.1 The global average increases in temperature presented in Section 4.1 will not be constant across the planet and Figure 4-1 presents the likely spatial distribution of these temperature rises for high, medium and low emissions scenarios (SRES A2, A1B & B1)(IPCC, 2007). This indicates that nearly all parts of the globe will warm but that the impact will be greater towards the poles and in continental interiors (IPCC, 2007).

4.2.2 Precipitation also plays a significant role in food production and Figure 4-2 presents the projected percentage change in precipitation for the period 2090-2099, relative to 1980-1999. The values presented are the averages from a number of climate models and based upon a medium emissions scenarios (SRES A1B) (IPCC, 2007). Scientists, are most confident about the projected changes in the stippled areas, where more than 90% of the climate models agree in the sign of the change. White areas are where less than 66% of the models agree on the direction of the change. The models show that significant changes in precipitation are likely with increased summer and winter precipitation towards the poles. In the winter, mid-latitude regions in the northern hemisphere exhibit strong decreases in precipitation although the effects are less apparent in Asia. In the summer a similar pattern is seen except that there is a northward drift in the areas experiencing reduced precipitation. In mid-latitudes of the southern hemisphere there are likely to be few changes in rainfall during the winter, but decreases for Southern Africa, Brazil and SW Australia in summer. In equatorial regions increased winter rainfall in East Africa is the only obvious change (IPCC, 2007)

Figure 4-1 Projected surface temperature changes for 2020-2029 and 2090-2099 relative to the period 1980-1999 for high, medium and low emissions scenarios (Figure 3.2 from IPCC, 2007).

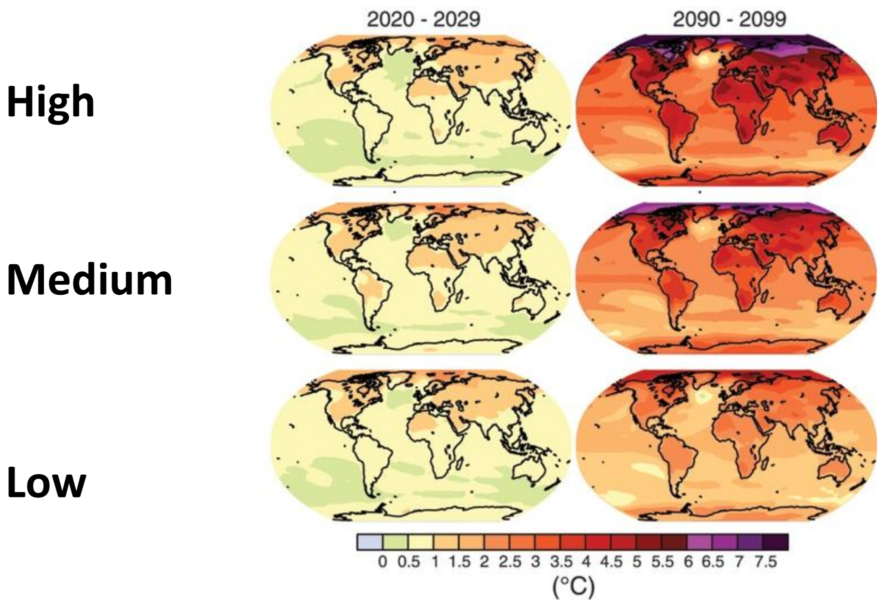
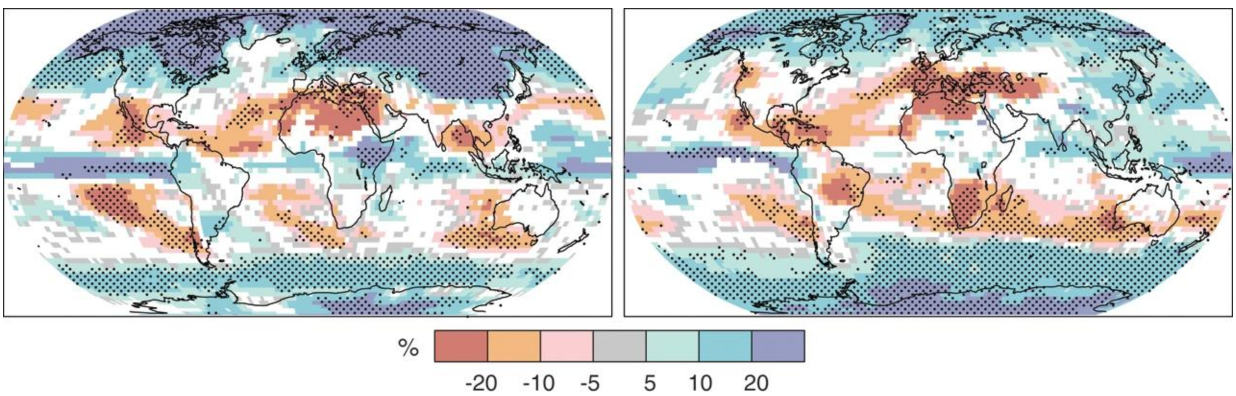
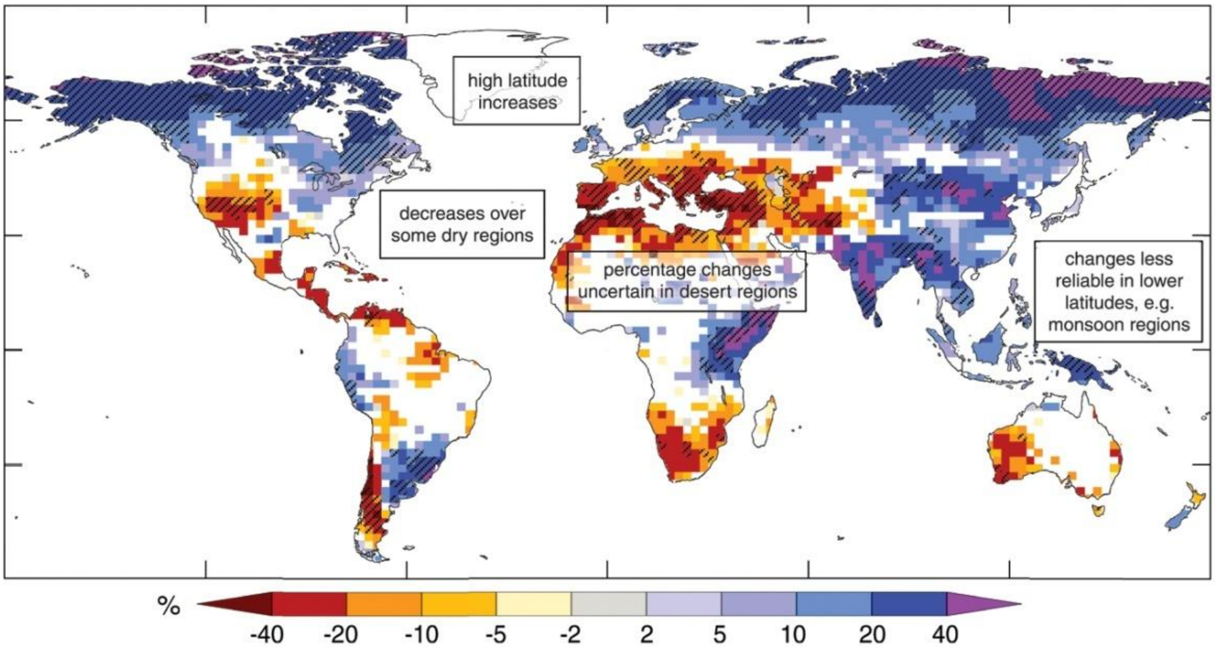


Figure 4-2 Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999 for the medium emissions scenario for December to February (left) and June to August (right) (Figure 3.3 from IPCC, 2007)



4.2.3 Of interest to agriculture is how changes in rainfall and temperature affect water availability and estimates are presented in Figure 4-3. In this Figure values represent the median of 12 climate models. White areas are where less than 66% of the models agree on the sign of change and hatched areas are where more than 90% of models agree. This Figure indicates major declines in water availability in semi-arid zones, but increases in higher latitudes. Some decreases are apparent in the tropics (e.g. Northern Brazil).

Figure 4-3 Change in annual runoff 2090-2099, relative to 1980-1999 (Figure 3.5 from IPCC, 2007)



4.2.4 In addition to changes in mean conditions there is consistent evidence that extreme events will increase. This is important because the most intensive impacts of climate change are experienced through extreme events as opposed to gradual changes in levels (IPCC, 2007). Even areas that benefit from a change in climate are highly likely to suffer from more extreme events. These extreme events can have serious adverse effects on food production systems. For example over most land areas it is virtually certain that there will be a warming of the most extreme days and nights each year. In addition it is very likely that the frequency of warm spells / heat waves and heavy precipitation events will increase in most areas. It is also likely that the area affected by drought will increase alongside an increase in intense tropical cyclone activity and of extreme high sea levels (IPCC, 2007).

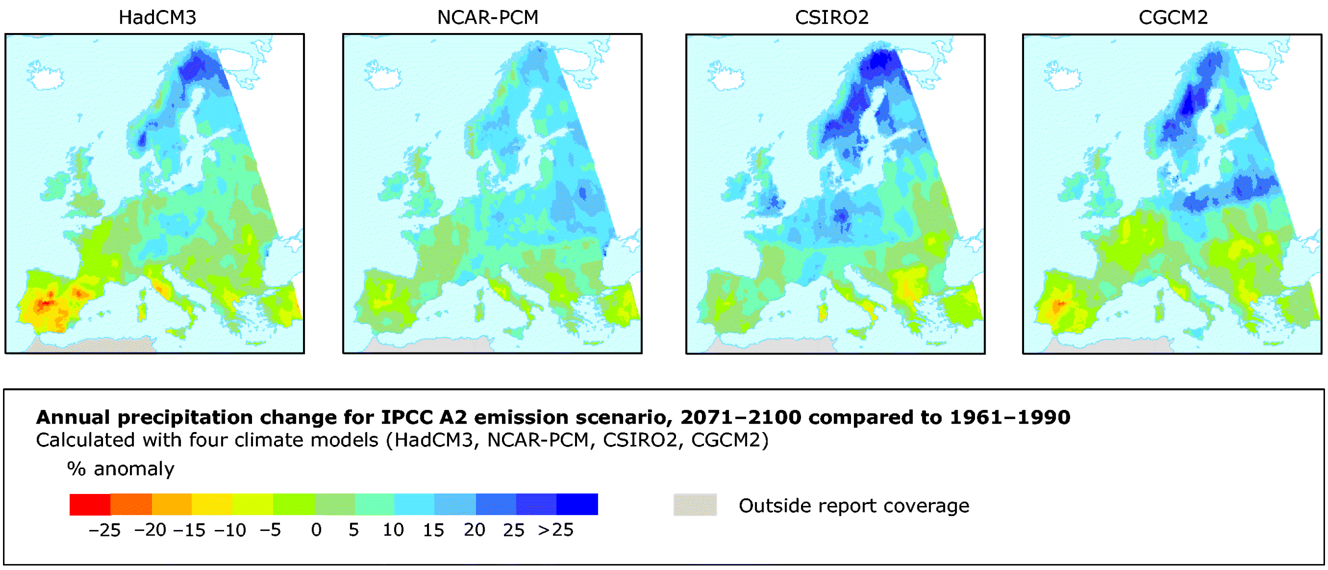
4.3 EFFECTS ON CLIMATE: EUROPEAN

4.3.1 The European Environment Agency has produced a comprehensive assessment of the impact of climate change upon Europe (EEA, 2007). This indicates a warming of 2.1–4.4 ° C by 2080 or possibly 2.0–6.3 ° C with the greatest increases occurring in Northern and Eastern Europe. In terms of seasonality, greater warming may occur in winter than in summer in Northern

Europe and by as much as 8–10 °C by 2080 in Arctic regions. In Southern and Central Europe warming is likely to be greatest in summer with increases of up to 6°C possible in some areas.

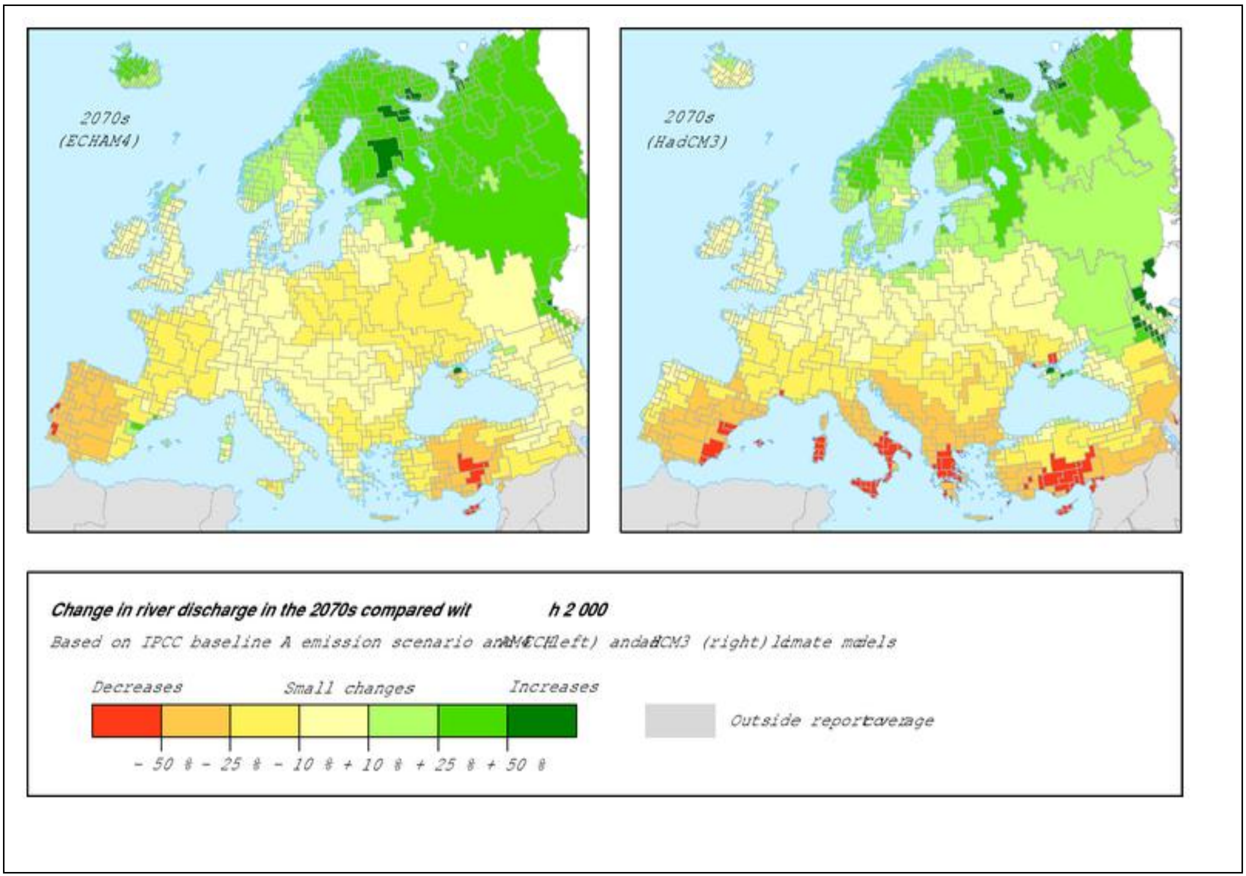
4.3.2 Figure 4-4 indicates the likely annual changes in precipitation across Europe by the end of the century. The models indicate broad agreement that the Northern and Eastern Europe will become wetter while the Mediterranean is likely to become drier. In terms of seasonality Europe may experience more precipitation in winter except for the Mediterranean region. Most models project lower summer precipitation across Europe.

Figure 4-4 Changes in annual precipitation for the IPCC A2 scenario (2071–2100 compared with 1961–1990) for four different climate models (EEA, 2007). Copyright EEA, Copenhagen, 2007



4.3.3 Combining temperature and precipitation information, Figure 4-5 demonstrates likely changes to river flows across Europe for 2070. This is important for food because lower river levels indicate less water for agriculture. The maps suggest increased flows across Northern and Eastern Europe and decreased flows in the Mediterranean (EEA, 2007).

Figure 4-5 Projected changes in annual river discharge in Europe for 2070 using different climate models(Lehner et al., 2005) (From Lehner, B., Czisch, G., Vassolo, S. (2005) The impact of global change on the hydropower potential of Europe: A model-based analysis. Energy Policy 33: 839-855.)

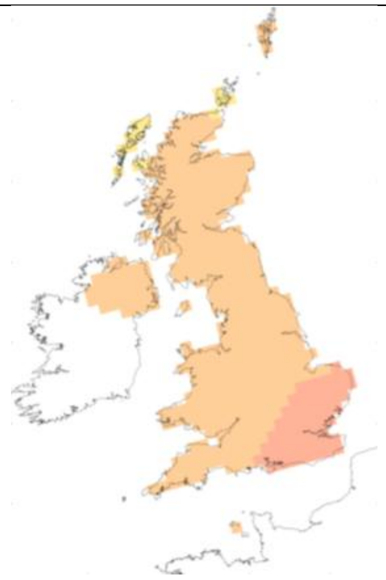


4.3.4 In terms of extreme events, projections are highly uncertain. However, warm events such as heat waves, are expected to be more intense, more frequent and longer-lasting. These may occur especially in the Mediterranean and Eastern Europe. Extreme precipitation events are projected to increase in Northern and Western Europe, while many parts of the Mediterranean may experience further reduced rainfall and longer periods of drought (EEA, 2007).

4.4 EFFECTS ON CLIMATE: UK

4.4.1 The most comprehensive source of information on likely changes in UK climate are produced by UKCIP09 (UKCIP, 2009) through funding from DEFRA and other government bodies. These data provide extensive projections on the probability density functions for future climate but only the central estimates are provided here. The temperature projections for summer and winter in the 2080's are presented in Figure 4-6 for a medium emissions scenario. The Figure indicates that under climate change all areas warm, and this is greater in summer than winter. The exact warming depends upon the season but averages around 3.5°C in summer with higher rises predicted in the West Country and lower rises in the far North. In the winter the rise is around 2.5°C with a higher rise projected for the South East and a lower rise in the North.

Figure 4-6 Change in mean temperature (°C) for the 2080s under a medium emissions scenario (50% probability level: central estimate)

Summer	Winter
	

4.4.2 The precipitation models presented in Figure 4-7 models suggest little change in the amount of precipitation that falls annually in the 2080's, but this obscures drier summers and wetter winters. In the summer 30-40% reductions in rainfall are projected for the South reducing to 10-20% in Scotland. In the winter the pattern is more varied with most places experiencing 10-20% more precipitation with higher amounts projected for Central Southern England and coastal areas. Upland areas tend to experience slightly lower increases in precipitation.

4.4.3 In terms of extreme events Figure 4-8 indicates that the amount of rainfall associated with an extreme weather event, such as a 1 in 30 rainfall event, is likely to increase by around 5-10 mm with greater increases occurring in more western areas. In terms of temperature the right hand panel indicates that, as an example, the warmest summer day in the 2080's is likely to be 2.5 – 3.5°C warmer in most areas but relatively hotter in the North and the Central South West.

Figure 4-7 Change in (%) mean precipitation for the 2080s under a medium emissions scenario (50% probability level: central estimate)

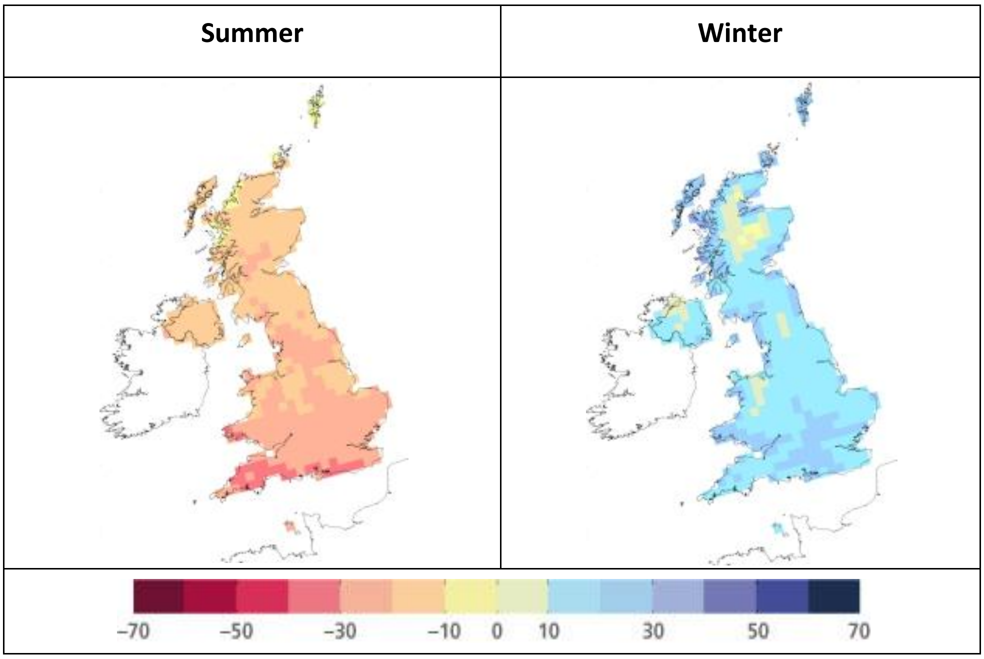
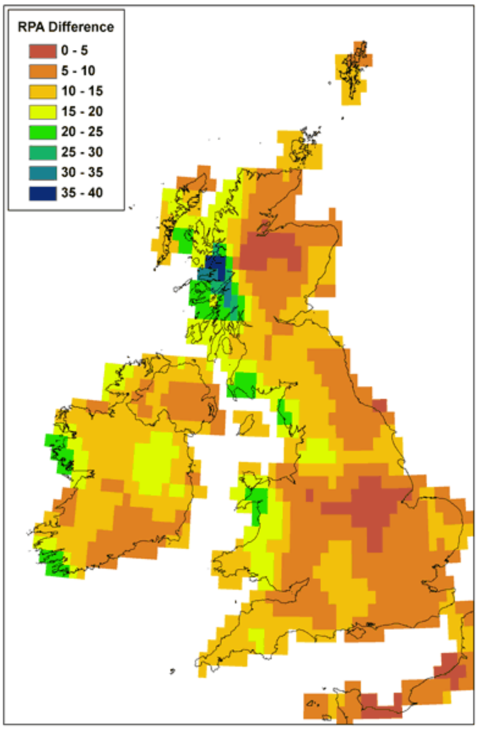
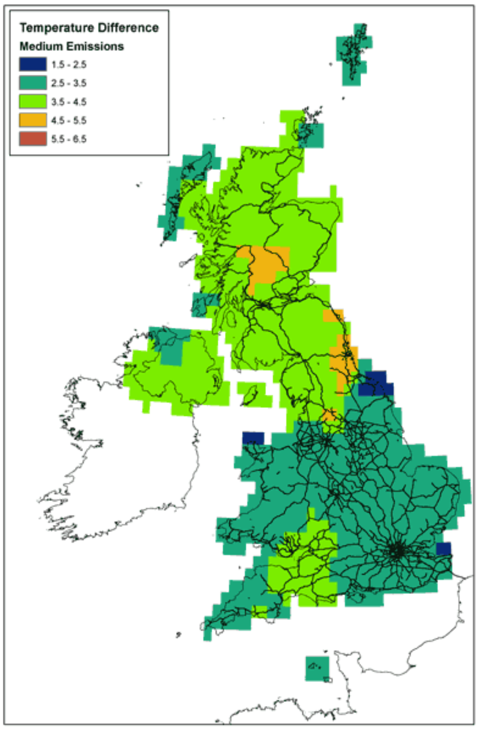


Figure 4-8 Changes in extreme events for the 2080s under a medium emissions scenario

Precipitation (mm) that falls for a 1 in 30 event	Temperature difference for warmest summer day





5 The impact of food production, consumption and waste upon climate change

5.1 Introduction

5.1.1 Food production, consumption and disposal have a significant role in causing climate change. Estimates of the degree to which world food production, processing, transport, storage, preparation, purchase and consumption contributes to Greenhouse gas (GHG) emissions vary depending on the analytic approach used from 15% to over 30% of total emissions (Garnett, 2008, Tukker et al., 2006).

5.1.2 It is crucial to understand how the GHG emissions of foods are estimated and to set down guidelines for such estimation in future, as different estimates produced by different means can provide very different answers. If we are to be able to compare the effects on the environment of different foods then estimates must be trustworthy, and the models used must be comparable. Section 5.2 starts by discussing how the GHG emissions of foods are audited using lifecycle analysis or assessment (LCA). It then examines food production and consumption and considers how these affect GHG emissions. The next section does the same for food waste. The section ends with a discussion of the various initiatives aiming to reduce GHG emissions from the food and agriculture sector.

5.2 CALCULATING GREENHOUSE GAS EMISSIONS FROM FOODS

5.2.1 Assessing the GHG emissions from food is complex and usually performed using an audit tool known as LCA. This is a process to identify and assess every environmental impact associated with the lifecycle of a particular product (ISO, 2006). LCA has the potential to examine all impacts associated with food (e.g. eutrophication potential, acidification etc.) but in this report we will focus upon assessing GHG emissions. LCA uses a cradle to grave approach, and so includes all emissions associated with producing, consuming and disposing of food. The form of LCA focussed upon emissions related to climate change (e.g. methane and carbon dioxide) is often known as carbon footprinting.

1. The first stage of an LCA is goal definition and scoping where the purpose of the LCA is decided and the scope of the analysis set. Setting the scope is crucial, and the most important decision is where to set the analytic boundaries. For example if we perform an LCA on soya grown by converting rainforest to cropland, decisions would need to be made about the emissions to include. Should the GHG emitted by cutting down the rainforest be included? What about emissions from the energy used to cut the forest? Similarly what about GHG emissions associated with storage and display of foods in a supermarket or the final disposal of food waste by the consumer? If major sources of emissions are excluded by scoping then the LCA produces misleading results. Understanding where the boundaries have been set is crucial to understand the results from LCA studies.

2. The next stage of the assessment creates an inventory of all the GHG emissions from cradle to grave. For many items on the inventory, (e.g. GHG emissions produced by a lorry per km driven) there are well defined numbers that can be used. However, these figures can be contentious and may lead to inconsistencies between studies.

3. The final stage is to convert all the GHG emissions data into a common unit. All emissions (e.g. NO_X, CH_4, CO_2) are converted into a common unit such as carbon dioxide equivalents. Different foods and methods of production can then be compared.

5.2.2 There are already international standards for LCA (ISO14040) and It is important to develop these international standards to make them applicable to food (Guinée, 2002). We need to be clear about what types of factors need to be included in LCA analysis for food and drink. For example, if considering tomato production, second level factors such as changes in land use, the GHG costs of materials used in building glass houses, the costs of heating, costs of refrigeration and transport all need to be included. Consistent decisions also have to be made about whether to include GHGs associated with home cooking as well as the processing already competed on the product. Additionally, GHG emissions need to be expressed in food portions, as expressing them by weight of food causes inconsistencies (for example between drinks sold concentrated or ready-to-drink).

5.2.3 DEFRA and the Carbon Trust have recently sponsored the British Standards Institute (BSI) to develop a Publicly Available Specification (PAS) for carbon footprinting (LCA studies focussed upon GHG emissions) to measure the embodied GHG emissions for a range of goods and services. This can be used for food and is known as PAS2050. This is one of the first attempts to provide integrated, consistent approaches to measure GHG emissions between products (Sinden, 2009). There has been extensive consultation on its design. Should it be widely adopted in the UK and internationally, will help ensure that studies can be compared across different foods.

5.2.4 GHG emissions associated with food are only one measure of environmental impact. Others (e.g. ecological footprint, pesticide hazard and water use) may not correlate well with GHG emissions. For example twice the amount of water is used in growing Spanish broccoli in comparison to UK grown broccoli, although the GHG emissions of each are similar (Edwards-Jones et al., 2008). LCA provides a snapshot in time and the emissions associated with a specific food will change if the method of production changes (e.g. changing from open to growing produce under glass). These factors are constantly changing and are likely to change more in response to climate change and attempts at mitigation. In the next section the GHG emissions associated with food will be considered by first focussing upon food production and consumption then food waste.

5.3 GREENHOUSE GAS EMISSIONS FROM FOOD PRODUCTION AND CONSUMPTION

5.3.1 This section begins by discussing the relative contribution of different stages in the food life cycle to GHG emissions, then examines the GHG emissions associated with different food groups.

5.3.2 A small number of studies have investigated where in the food cycle most GHG emissions occur. Two studies in the UK broadly agree that the major component of food production emissions, likely to be over 50%, are those associated with agriculture (Garnett, 2008). A US study (Weber and Matthews, 2008) found that 83% of food emissions were from food production, and only 11% were associated with food transport. However, these proportions will vary by food type and it has been suggested that whereas agricultural emissions dominate for meat and dairy consumption, for other produce, such as fresh fruit and vegetables, emissions are likely to be more widely spread across sectors. A set of examples include coffee, butter and frozen spinach. The GHG emissions related to drinking a cup of coffee relate primarily to the heat needed to heat water, the growing and production of the coffee (which is similar for instant and ground coffee), and any milk added to the final drink - the costs of transport and packaging are relatively minor. Frozen spinach GHG emissions were due primarily to household storage, followed by production then distribution and selling costs, with smaller cooking, transport and packaging costs. For butter the vast majority of GHG emissions are due to butter production, with small contributions only related to storage, transport, distribution and packaging (Büsser et al., 2008).

5.3.3 Looking at agricultural emissions in more detail, Stern (Stern, 2005a) found that fertiliser production accounted for the largest single source of agricultural GHG emissions worldwide (38%). Livestock was the next largest (31%), mainly due to enteric fermentation by ruminants. Wetland rice cultivation produced 11% of emissions followed by management of manure at 7% (Stern, 2005a). However, this analysis may underestimate the contribution of livestock to climate change and an FAO report suggested that livestock might be responsible for as much as 18% of all GHG emissions worldwide once land-change uses (e.g. deforestation for grazing) and raising of animal feeds were accounted for (Steinfeld et al., 2006). Another significant source of emissions that cuts across all the stages of the food cycle (e.g. agriculture, transport, storage, retail and home) is refrigeration. Refrigeration has important benefits for food safety, and has played an important role in providing a cheap supply of varied food year round. However, it is probably responsible for around 3 - 3.5%

(although there is significant uncertainty associated with this estimate) of the UK's GHG emissions, or 15% of food-related GHG emissions (Garnett, 2008).

5.3.4 Several European studies have assessed the GHG emissions of food groups within whole diets, and come to surprisingly similar conclusions (see Table 5-1). Data from the UK (Barrett et al., 2002), Netherlands (Kramer et al., 1999) and Sweden (Wallén et al., 2004) all agree with an analysis of European food consumption (Tukker et al., 2006). They highlight that dairy and meat products account for over 50% of the GHG emissions associated with food in each country. In the UK drinks and sugary foods contribute around 20% of emissions. The other dietary components vary by country but bread, pastry and flour account for around 10% of emissions as do potatoes, fruit and vegetables.

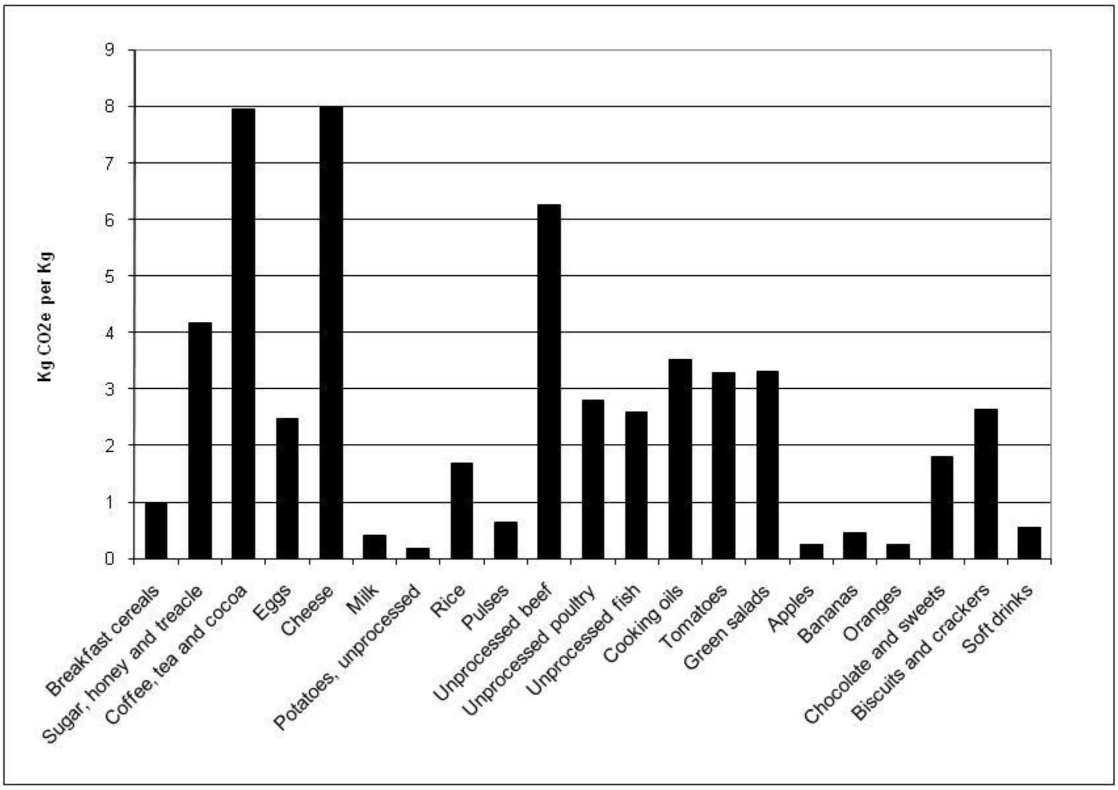
Table 5-1 Contributions of different food categories to food related greenhouse gas emissions, as percentage of total food-related emissions

Food types	Percentage of total greenhouse gas emissions		
	Netherlands	**Sweden**	**York, UK**
Bread, pastry & flour	13%	10%	5%
Potatoes, fruit & vegetables	15%	19%	6%
Drinks & sugary foods	15%	Included in 'other foods'	20%
Oils & fats	3%	4%	10%
Meat, meat products & fish	28%	35%	38%
Dairy products	23%	15%	15%
Other foods	3%	17%	3%

Data from the Netherlands from (Kramer et al., 1999), Sweden from (Wallén et al., 2004), York from (Barrett et al., 2002) , differences are due to differences in analysis, dietary patterns and slightly different classifications of specific foods.

5.3.5 A review of analyses of the GHG emissions across a range of individual foods has been published (Wallén et al., 2004), and the results of this Swedish study are summarised in Figure 5-1. However it is unclear how comparable the analyses are as some include first and second order effects (or direct and indirect effects) and others only first order effects. Also, in most cases consumer-level costs have been omitted, so that foods sold raw will be favoured over foods more highly processed at purchase. It indicates that the highest GHG emissions are associated with beef, cheese, coffee, tea and cocoa consumption (expressed per kg of product sold, Figure 5.1). This concords with other estimates that meat and dairy products have GHG emissions 3 to 13 times greater than plant based foods (Barrett et al., 2002). Moderate to high GHG emissions are associated with salads and Mediterranean type vegetables (e.g. tomatoes and cucumber and other vegetables), sugar (from beet) and related products and vegetable oils. One reason for the level of emissions associated with Mediterranean type vegetables is that they are home-grown in heated greenhouses, trucked in from other countries in refrigerated lorries or both (Garnett, 2006). Moderate GHG emissions are associated with poultry, eggs, fish, biscuits and crackers. Finally staple fruits (e.g. apples, bananas and oranges) have similarly low GHG emissions even though oranges and bananas are imported.

Figure 5-1 Emissions of CO2 equivalents per kg of food (Wallén, Brandt et al. 2004)



5.3.6 Many of the differences in GHG emissions between similar foods are due to the minutiae of production. An assessment of methods of strawberry production within the UK found that levels of GHG emissions could vary by a factor of 3 according to the production system, including use (or not) of soil fumigation, polytunnels, soil as a growth medium and organic type production methods (Warner, 2008). Therefore, it is misleading to work out the GHG emissions of an average UK strawberry, but different strawberry varieties, grown under specific conditions, and transported in different ways, should be analysed separately. This highlights the need for full LCA to be carried out on outwardly similar products before conclusions can be made on the GHG emissions associated with these (Edwards-Jones et al., 2008, Smith et al., 2005). Analyses will need to be updated regularly as agricultural, processing, transport, packaging, and cooking methods alter. One of the most extreme examples comes from rice production. Irrigated rice from the USA uses 15-25 times more energy that low-input rice from Bangladesh, China, and Latin America (Pretty and Ball, 2001).

5.3.7 To explore this issue in more detail other studies have compared identical foods produced in different geographical locations. The results from a series of studies comparing local production with importation from other countries are presented in Table 5-2, and indicate that in some cases importing foods and other commodities resulted in lower GHG emissions, and in other cases locally produced foods were lower GHG emitters. A common theme is that fruit and vegetables that can be produced in season (generally without protection from glass or plastic) in the UK are lower in GHG emissions than foods produced elsewhere and imported. Out of the UK season the equation is much more complex and importing fruit and vegetables from warmer climates, where it is in season, may cause lower, higher or similar GHG emissions to out-of-season UK produce preserved in cold storage under gas. However, all these studies address fresh fruit and vegetables and alternatives for UK production would be seasonal production followed by conversion to frozen, dried, juiced, tinned and preserved products. The GHG implications of these are unknown but could enable consumers to achieve healthy fruit and vegetable intakes from UK produce year round.

5.3.8 An issue highlighted in this table, is that importing green beans from East Africa consistently produces more GHG emissions than more local production. This is caused by the air freighting of African beans to the UK. Although currently only 1.5% of fruit and vegetables are air freighted this small proportion accounts for 40% of fruit and vegetable transport CO_2. This amount is increasing at 6% per annum (Garnett, 2006). On the other hand many people in low-income countries who depend on food exports for their livelihood may be impoverished if UK consumers limit our consumption of foreign foods (Brenton et al., 2008). However, some comparisons presented in this table may be criticised because the LCA analyses have used poorer or less comprehensive methodologies (See Section 5.2) (Garnett, 2006) . Hospido et al point out that there are bigger differences in the GHG emissions of lettuces grown on adjacent farms (either in Spain or the UK), than between UK and Spanish production differences (Hospido et al., 2009).

5.3.9 Another issue with LCA analyses considering the advantages of consuming local seasonal fruit and vegetables compared with importing from further afield is that the concept of “local” is not clearly defined. There is some evidence from an LCA analysis of apples, watercress and runner beans from a variety of sources that eating these from the UK within their natural seasons was beneficial in terms of GHG emissions. For produce outside its usual UK season the relationship is less clear (Sim et al., 2007).

Table 5-2 Summary of studies comparing foreign grown and imported foods with locally grown equivalents

Commodity	Comparison	Effect size	Reference
Green beans	Importing from Kenya vs. UK grown	12 x energy use	(Jones, 2006)
Green beans	Importing from Guatemala vs. UK grown	20-26 x greater global warming potential	(Sim et al., 2007)
Green beans	Importing from Kenya, Uganda or UK grown fresh and frozen	Global warming potential of Kenyan and Ugandan beans ~11 $kgCO_2$ eq/kg beans, ~2 for frozen UK and ~1.5 $kgCO_2$ eq/kg for fresh UK beans	(Edwards-Jones et al., 2008)
Broccoli	Growing in America and importing frozen to Sweden vs. growing in Sweden	Little difference in greenhouse emissions (adjusting for nutritional differences between fresh and frozen)	(Fogelberg and Carlsson-Kanyama, 2006)
Broccoli	Growing in Spain or the UK	In some systems the Spanish broccoli , in others the UK broccoli produces lower Global Warming Potential	(Edwards-Jones et al., 2008)
Chicken	Growing in America and importing frozen to Sweden vs. growing in Sweden	Little difference in greenhouse emissions (using feed imported from south America)	(Fogelberg and Carlsson-Kanyama, 2006)
Apples	Storing European grown apples into the spring/ summer or importing them from the southern hemisphere where in season	little difference in energy use	(Blanke and Burdick, 2005, Mila i Canals et al., 2007a)
Lettuce	Spanish lettuce production with refrigerated road transport vs. growing lettuce in the UK winter	Spanish production causes high emissions, but lower than winter grown UK lettuce	(Hospido et al., 2009, Mila i Canals et al., 2007b)
Lettuce	Comparison between Spanish, Ugandan and UK grown lettuce production (for consumption in the UK)	Global warming potential was <1 kg CO_2 eq/kg lettuce on plate) except for Ugandan grown and winter-grown UK lettuce (~10 and ~5 kg CO_2 eq/kg lettuce respectively)	(Edwards-Jones et al., 2008)
Lamb	New Zealand produced lamb shipped to Europe vs. UK or German locally produced lamb	NZ production with transport more efficient	(Saunders et al., 2006, Schlich and Fleissner, 2005)
Tomatoes	Spanish tomatoes (grown without additional heating) imported to UK vs. tomatoes grown in heated UK greenhouses	British grown tomatoes generated over three times as much CO_2 than those grown in Spain and imported	(Smith et al., 2005)
Salmon	Salmon farmed in Norway (generally fed with plant-based feeds) or the UK (generally fed with animal-based feeds)	Norwegian farmed salmon was responsible for lower environmental impact than UK-farmed salmon	(Pelletier et al., 2009)

5.3.10 Few full LCA have been carried out for alcoholic drinks, and the existing data are difficult to interpret (Garnett, 2007a). Garnett estimates that alcohol intake (including imports and excluding exports) accounts for 1.5% of the UK's GHG emissions, but states this is likely to be an underestimate. For beer consumption emissions related to the place of sale, pubs and restaurants, dominate. For wine emissions associated with transport dominate, followed by refrigeration (for white wine). For spirits GHG emissions are distributed across the whole lifecycle. It is difficult given current data to choose the type of alcohol with lowest GHG emissions, and these are likely to vary by brand.

5.3.11 A few LCA studies have addressed other questions including how large-scale centralised production with transport compares to smaller scale more local production of foods. For fruit juices and lamb one study found that centralised production was more energy efficient than smaller local-scale production (Schlich and Fleissner, 2005). A comparison of purchasing raw foods and cooking them at home, or purchasing a ready meal, or semi-prepared foods found that the differences in GHG emissions were small, and depended mainly on the agricultural inputs, and wastage of foods in specific settings (Sonesson et al., 2005). One large study found that the GHG emissions of organic production was 2-7% lower than conventional production (Williams et al., 2006). The strawberry analysis mentioned above suggests that organic production may compare favourably with conventional agriculture, but only where production levels are maintained (Warner, 2008). A Swiss study suggests that improved sustainability of apple growing is not associated with reduced profit, but rather profit and sustainability both rely on training and cognitive skills in farm management (Mouron et al., 2006).

5.3.12 Few LCA studies consider GHG emissions associated with food once it has been purchased but these may be significant. The energy costs of getting fruit and vegetables home from the shop or market, storage, preparation and cooking are also significant. For those fruits and vegetables that are cooked, the energy needed for cooking can dominate the energy inputs (meaning that methods of cooking may be a key to reducing GHG). Data suggest that for broccoli and carrots cooking may be the most significant contributor to GHG emissions, and even for potatoes cooking may be responsible for 30% of all GHG emissions (Garnett, 2008). For frozen spinach the biggest contributor to GHG emissions is household storage, while for butter the major cost is production, and the cost of storage is minimal (Büsser et al., 2008). How food is prepared can also be significant and an appraisal of the PAS2050 methodology has indicated that heating a cottage pie in an electric fan oven uses 5 times more energy than if this occurs in a microwave (ADAS, 2008).

5.3.13 The characteristics of low GHG diets are discussed in Section 6.7

5.4 GREENHOUSE GAS EMISSIONS FROM FOOD WASTE

5.4.1 A significant contributor to GHG emissions which is rarely discussed in the figures is waste biomass generated throughout the food supply chain. It is estimated that 30% of food grown ends up as waste and this figure in some cases can be as high as 75% (Awarenet, 2004, RSC, 2009, Waldron, 2007, Waldron, 2010). Historically, the agri-food chain has been honed for the production of high quality food across a number of parameters. Many foods (fresh fruit and vegetables) are discarded on the basis of appearance and physical characteristics rather than nutritional quality. Some major commodities create very large amounts of waste co-products (e.g. 600,000 tonnes of brewers' spent grain in the UK annually). These are usually disposed of locally as animal feed, composted or added to landfill.

5.4.2 Probably the most significant impact of food on GHG emissions post purchase is wastage in households and the commercial sector. This is rarely considered in LCA of foods as it is difficult to monitor and quantify. In terms of public opinion food waste was spontaneously mentioned as a cause for concern by 5% of those surveyed recently by the FSA, and on prompting by 36% (FSA, 2009d). Most food waste is collected by local authorities (88%) and the remainder is composted, fed to animals or tipped down the sink (WRAP, 2008).

5.4.3 The weight of household food wasted is 6.7 million tonnes annually (WRAP, 2008). This is composed of 1.3 million tonnes (19%) of unavoidable waste (e.g. vegetable peelings, meat carcasses etc.), 20% is possibly avoidable (e.g. bread crusts and potato peelings that are eaten by some people or in some dishes, and not by others) while the remainder (61%) could have been eaten if managed more appropriately. One important element of this is the confusion amongst consumers between "Use by", "Best before" and "Display until\sell by" and it likely that some food waste is generated due to this confusion (WRAP, 2008).

5.4.4 Once food has been thrown away GHG emissions are produced in transporting this food to a processing facility in the UK. A large proportion will end up in landfill sites, where it will produce methane which is 23 times more potent a GHG than CO_2. A fraction of this will be recovered and burnt through methane recovery systems. A proportion of food waste is now treated through other processes such as composting, anaerobic digestion and incineration. In addition very significant emissions occur from the production of wasted food which is then discarded to no useful end (Garnett, 2008). The weightiest foods wasted include potatoes, slices of bread, apples, meat, and fish dishes. As a proportion of the weight purchased the most wasted foods are salads (45% by weight and 60% by cost of all salad purchased is thrown away). In addition 31% of bakery items and 26% of fruit purchased is thrown away. At least 8% of all avoidable food waste is thrown away within the 'use by' date. The full cost of this waste is £10.2 billion each year in the UK, or £420 for an average household annually (WRAP, 2008).

5.4.5 Commercial food waste probably follows a similar disposal route but data are difficult to acquire. Until recently large amounts of commercial food waste (especially from institutions such as hospitals) were used as animal feedstuffs. However, the Animal By-Products Regulation (EC) No. 1774/2002 prohibits catering waste from being fed to farmed animals due to concerns about diseases such as BSE and Foot and Mouth. This applies in all EU member states and applied from 1 May 2003.

5.4.6 A further source of GHG emissions associated with food are those associated with food packaging. There is some evidence that the costs here are small compared with other costs, and packaging may help to protect food and prevent food waste, some reductions in packaging quantities and/or changes in materials to ensure that they are re-usable or recyclable may be beneficial (Büsser et al., 2008).

5.5 MONITORING AND REGULATION

5.5.1 The Climate Change Act 2008 commits the UK to reduce GHG emissions by at least 80% by 2050, and by at least 34% by 2020. These are all relative to a 1990 baseline (DECC, 2008). To achieve these cuts the UK has developed a Low Carbon Transition Plan which sets out how we will meet the 34 percent cut in emissions on 1990 levels due by 2020 (DECC, 2009b). The goals for 2020 include the creation of green jobs, house makeovers and a variety of initiatives to produce low carbon energy and improvements in energy efficiency. To advise the government on how such cuts can be achieved and to monitor progress towards achieving these goals an independent body, the Committee on Climate Change, has been established. Its first annual report to parliament states that a step-change is required in government planning if we are to reach our goals: "The Committee now calls on the Government to build on its Low Carbon Transition Plan, moving from a high level vision to developing and putting in place a framework for delivery to which people and businesses can respond." (Committee on Climate Change, 2009).

5.5.2 Section 4 presented information that food and drink make up 15-30% of our total GHG emissions. It will therefore be very difficult to meet these stringent targets, especially 80% cuts by 2050, without addressing GHGs from the food and drink sector. Other countries have similar targets which is important if these countries are part of the chain supplying food to the UK.

5.5.3 There appear to be few all-encompassing initiatives to reduce the GHG emissions associated with food, which is unsurprising as food is a global industry comprising many various and diverse sectors, and we are still unclear of the true GHG emissions of individual foods. However, there are many measures in place to control emissions at various parts of the food chain.

5.5.4 There are a number of initiatives aimed at reducing GHG emissions from agriculture and a review of the options has recently been conducted for DEFRA (ADAS, 2009) . This includes improved timings of manure applications, breeding crops with improved N efficiency and using composts / straw based manures in preference to slurry.

5.5.5 In addition there are initiatives to reduce the GHG emissions of inputs to agricultural systems. The production of fertilisers is one of the most of significant contributors to GHG emissions. Under the EU Emissions Trading Scheme large industries, including chemical plants, are charged according to the amount of carbon they emit and so have a major incentive to reduce emissions. However, this only applies to fertilisers produced within the EU (and many of our fertilisers are imported from further afield). In addition there are a number of voluntary agreements between the UK government and specific industries to reduce emissions. The commercial cold storage businesses and UK government have an agreement to reduce energy use by 12% between 2005 and 2011 (DTI et al., 2003). The Climate Change Levy is charged on the industrial and commercial supply of energy and is aiming to improve energy efficiency by allowing businesses to receive up to an 80% discount from the Levy (Climate Change Agreements) in return for meeting energy efficiency or carbon-saving targets. Other initiatives include enhanced capital allowances which provide support for industry investment in energy saving technology.

5.5.6 The Carbon Reduction Commitment (CRC) Energy Efficiency Scheme (DECC, 2009a) due to commence in April 2010 will be the UK’s first mandatory carbon trading scheme, which will be compulsory for organisations that consumed over 6,000 MWh of energy in 2008. Many of these will be involved in the production of food. The aims of this scheme are to reduce the level of GHG emissions by 1.2 million tonnes of CO_2 per year by 2020.

5.5.7 There have also been a number of initiatives aimed at improving the environmental performance of priority products throughout their lifecycle. This is known as product roadmaps and in terms of food and drink a milk road map is already up and running and one element of this is a plan to reduce GHG emissions from the dairy industry through improved energy efficiency and improvements in packaging. A further roadmap on fish and shellfish is under development (DEFRA, 2009d).

5.5.8 Although the decarbonisation of agriculture is an important step to reducing GHG emissions it has been argued that altering the foods that consumers choose is an essential step for the control of GHG emissions (Friel et al., 2009). There are already a number of initiatives in this area, but this section has demonstrated that many, such as food miles, are of little consequence, despite widespread consumer interest. For example, in a recent FSA consumer attitude tracker 5% mentioned food miles spontaneously as a concern and 22% felt it was a concern when prompted (FSA, 2009d). Other initiatives vary from carbon labels on a range of products providing consumers with information on air freighting or on the GHG emissions associated with their production, transport and purchase. Examples include adding a symbol to indicate air freighting to labelling on country of origin (www.food.gov.uk/multimedia/pdfs/consultation/consultcountryoforiginscot.pdf), labelling on carbon footprint being developed by the Carbon Trust (www.carbon-label.com), or the plans to include sustainability advice on the eatwell website (www.eatwell.gov.uk). It has been recommended that the FSA become the source of integrated advice to consumers on food (Strategy Unit, 2008a).

5.5.9 The most effective measure to tackle food waste is to prevent it being produced in the first place, and through the Waste Resources Action Programme (WRAP) there are a number of campaigns to encourage consumers to reduce the amount of food wasted. The best publicised is the "Love Food Hate Waste" campaign (www.lovefoodhatewaste.com) which provides information to householders on how to reduce food waste. WRAP is also working with the FSA to clarify guidance on when food is no longer safe to eat. Finally through the Courtauld Commitment major UK Retail brands have agreed to work together to help reduce the amount of food the nation's householders throw away by 155,000 tonnes by 2010, against a 2008 baseline (www.wrap.org.uk/wrap_corporate/news/uk_grocery_sector.html). This agreement also includes initiatives to reduce packaging of food. In addition the EU thematic strategy on waste puts much emphasis on waste minimisation and the UK waste strategy specifically mentions aspirations to reduce the amount of waste produced. As food contributes such as large proportion of household waste there are likely to be more waste reduction initiatives in the future.

5.5.10 Where food is thrown away there are a number of initiatives to reduce its associated GHG emissions. These are of critical importance because when food degrades in a landfill site (the most common disposal method) it produces methane which is 23 times more potent a GHG than CO_2. The most significant piece of legislation is the EU Landfill Directive (DEFRA, 2009b) which requires a reduction in the biodegradable portion of municipal waste sent to landfill. Targets have been set for a 65% reduction on 1995 levels by 2020 and that existing landfill sites institute methane recovery systems. Up to this point much focus has been placed on non-food biodegradable sources of waste such as paper and textiles. However, as 2020 approaches increased processing of residual waste through techniques such as home and centralised composting (WRAP, 2008), mechanical biological treatment, anaerobic digestion and energy from waste will need to be developed (Bogner et al., 2008). In addition such techniques have the potential to generate electricity and heat which displace GHG from being produced in other sectors (e.g. electricity generation). The UK faces significant fines of up to £500,000 per day (from the EU) if it fails to meet these targets. One limitation of the Directive is that the targets do not apply to non-municipal sources of food waste such as commercial and industrial waste.

5.6 SUMMARY

5.6.1 The audit tool LCA is the only way to assess accurately GHG emissions associated with food. This potentially analyses all GHG emissions from food production through consumption and disposal, including secondary level effects (which include changes in land use etc). Simple proxies for GHG emissions such as food miles or local food often produce misleading results, especially as food transport is only responsible for a small percentage of GHG emissions. However, LCA has to be treated with caution as different studies can produce conflicting results due to varying assumptions between studies. PAS (2050) is an attempt to provide a common methodological framework for such studies.

5.6.2 Food production, consumption and disposal have a significant role in causing climate change, and it is estimated that the food cycle contributes 15% to 30% of total UK and EU emissions . The major component of food production emissions, likely to be over 50%, are those associated with agriculture although this proportion will vary greatly with food type. Other components such as food transport and processing account for a much smaller fraction. The importance of different components varies by food type.

5.6.3 Existing LCA studies provide some information on the GHG emissions of different diets. One consistent theme is that meat and dairy produce result in over 50% of the GHG emissions of food in a European diet. Meat and dairy foods, particularly beef, lamb, pork and cheese result in 3-13 times more GHG emissions than vegetables and pulses. Additionally meat is one of the food types most often wasted, which compounds the GHG costs. Other foods with large GHG emissions include sugary foods and drinks, tea, coffee, cocoa and air-freighted foods. Mediterranean style vegetables, eggs, poultry, fish, bagged salads, cooking oils, biscuits and crackers have moderate emissions and large quantities of salad vegetables are thrown away. There are potentially large differences in GHG emissions between foods produced using different agricultural methods, and transported in different ways. A systematic review of studies conducted using similar methodologies is urgently needed to assess accurately the GHG consequences of different diets.

5.6.4 As food is an important contributor to GHG emissions, there is much interest in reducing these. However, there are few comprehensive strategies to reduce the GHG emissions associated with food. Instead these occur through numerous initiatives to target emissions from various sections of the food chain from agriculture through to fertilizer manufacturing, refrigeration and waste disposal.

6 Climate change and food choice

6.1 INTRODUCTION

6.1.1 This section considers how climate change may alter the types of food that people eat. This includes an assessment of the constituents of a low GHG diet. Future sections of the report build upon this information to consider the nutrition and food safety implications for individuals, communities and populations.

6.1.2 Food choice is about why we eat the foods we do. At first glance this would appear to be a relatively simple matter, but human food choice is a complex phenomenon, hard to predict and manipulate, and consequently its analysis is not simple. The term *choice* itself is problematic with dictionary definitions including: the act of choosing, the power of choosing, that which is chosen, and an abundance of items from which to select (Murcott, 1998). Another complication is that food choice can be seen as a process of many phases comprising decisions all through the way through food chain from production, processing, purchasing and preparation, through to the final act of ingestion (Goode, 1989). For the purpose of this review and the prediction of likely changes in food choice because of climate change, food choice is defined as in Figure 6.1. That is as the selection of certain foods because they correspond to our tastes and preference, cultural norms and so forth, and that this choice or selection results in the consequent purchase of certain foods and not others. Figure 6.1 also demonstrates the huge range of factors that influence our food choices and consequent consumption. These include the availability of foods on the market, their price, the level of a household's or individual's income available to spend on food, policy interventions to shift our choices such as labelling information, through to social and cultural factors and advertising. These all operate on different aspects of this phenomenon of food choice and vary in terms of their relative strength and influence from person to person and context to context. This complexity makes it extremely difficult if not impossible to explain or predict patterns of food choice with any great precision. Also while there has been a great deal of research on human food choice, it is methodologically very diverse which means that we cannot just stack up the findings from disparate studies and disciplines to look for some lowest common denominator. Some of the data on expressed reasons for food choice are discussed in more detail in Section 6.4.1.

6.1.3 Following the recent Government Social Research Unit review on behavioural change (Darnton, 2008) different kinds of choice have also been differentiated. These can be categorised as non-volitional or reactive choice which occur when people are compelled to change their behaviour in response to environmental change, and directive or volitional choice which occurs when people change their behaviour willingly as a result of environmental change in some preceding variable (this could be a social or psychological variable, or a planned policy intervention such as food labelling). The former corresponds to consumer responses to the effects of climate change as realized through food availability and prices, the latter to attempts to mitigate the effects of climate change e.g. via consumption of a low GHG diet. Supporting engagement in sustainability and healthy diet is discussed in Section 9.

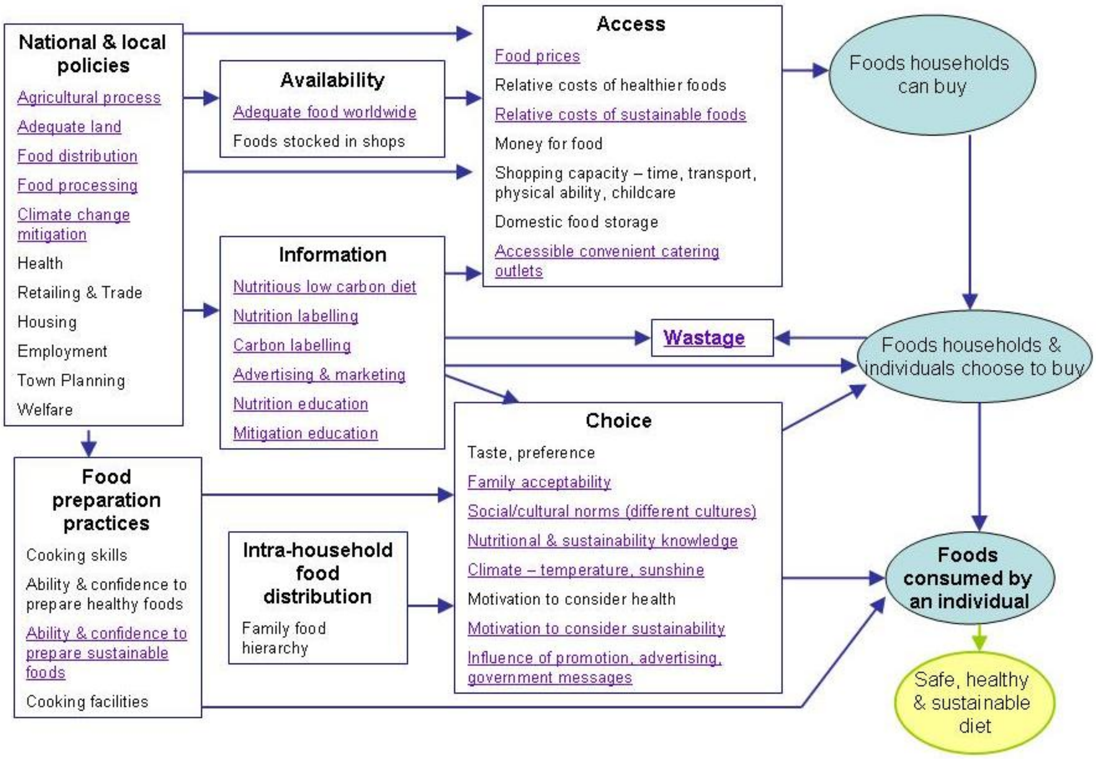
6.1.4 Despite these difficulties this section considers the evidence available to predict how climate change may alter patterns of food choice and consumption. We will be examining this through three main mechanisms:

1. Direct climatic effects on eating & food choice (Section 6.2)

2. Indirect effects on foods eaten, through changes in food prices and availability (Section 6.3)

3. Societal responses to climate change, including moves towards a low GHG diet (Section 6.6).

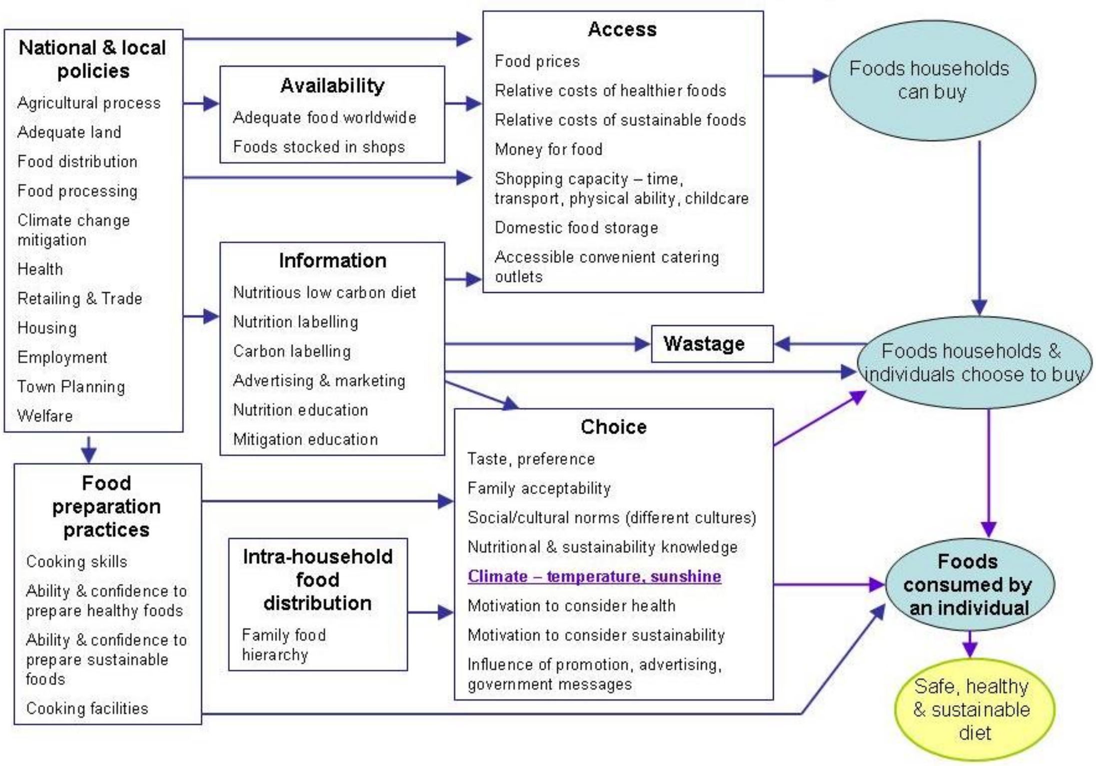
Figure 6-1 Framework of the determinants of food and nutrition security in the UK (Adapted from DoH, 1996). The factors highlighted in purple are those that may be affected by climate change



6.2 DIRECT CLIMATIC EFFECTS ON FOOD EATEN

6.2.1 The food that individuals consume is likely to be affected by weather and temperature, for example elevated consumption of fruit and salads occur during the summer (Cox et al., 2000) and barbecuing is also more common during this period (Lake et al., 2009, Mintel, 2004), Figure 6.2. The FSA's National Diet and Nutrition Survey indicates that types of food consumed vary seasonally (FSA, 2001b). Away from the UK a Spanish study suggested that men eat more calories and both men and women have higher nutrient intakes in the winter (Capita and Alonso-Calleja, 2005), and a Chinese study suggested higher winter intakes of meat, vegetables, fish and soy foods, but lower intakes of fruit (Fowke et al., 2004). If trends towards fruits and vegetables being available year round are reversed as part of moves to a low GHG diet (and we move back to local and seasonal produce), then seasonal eating may again become more pronounced.

Figure 6-2 Framework of the determinants of food and nutrition security in the UK – direct climatic effects on food eaten (Adapted from DoH, 1996). The factor highlighted in purple is the relationship considered here

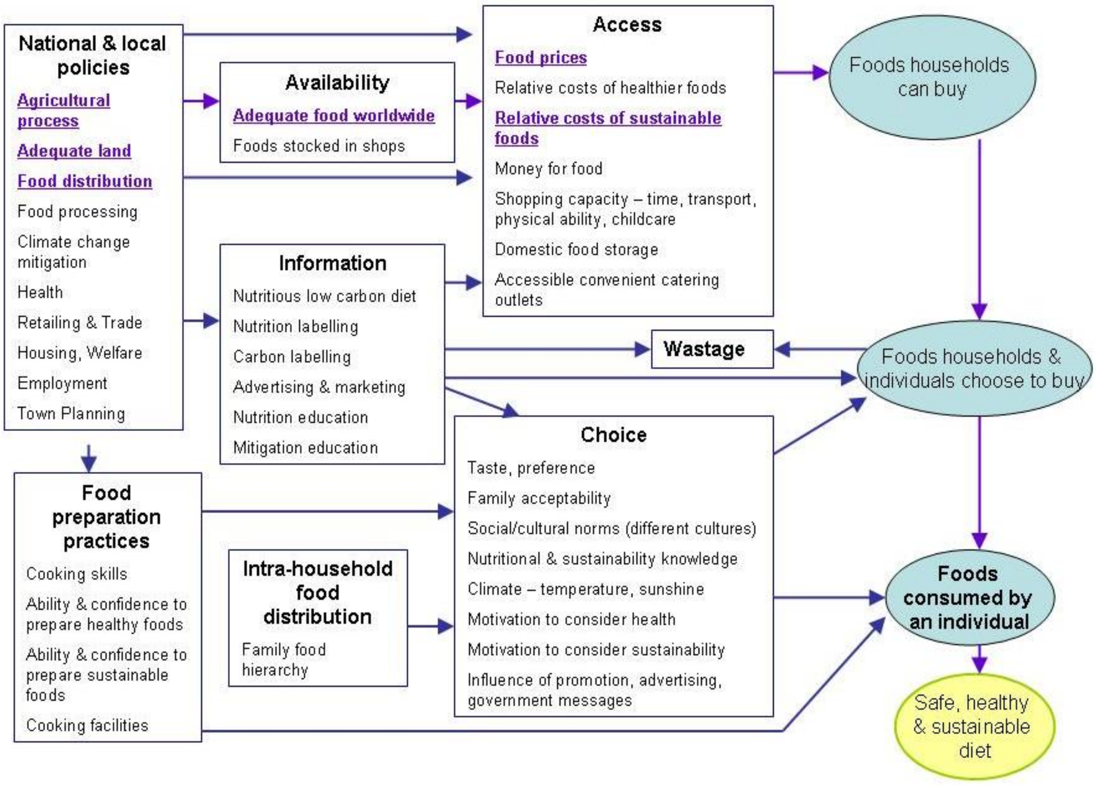


6.2.2 However, separating effects of weather and temperature from seasonal availability (for fruit and vegetables) and seasonal events like holidays (in the case of barbecues) is more difficult. Fruit consumption may increase in the summer but this does not necessarily imply that warmer summers will increase fruit consumption. The evidence for this would be that fruit consumption is elevated in warmer summers. Market data do suggest that salad and alcohol intakes increase in warmer compared with cooler summers (Mintel, 2003a, Mintel, 2003b, Mintel, 2004), although beer consumption peaks at Christmas. It is also likely that chilled and frozen drinks and snacks (such as ice cream) are eaten more in hot weather. However, it may be that there is a maximum number of barbecues that people will enjoy when the weather is warm, so that longer warm periods will not result in more barbecues. Similarly, increased alcohol intake may be a result of the novelty of warm weather, and longer warm periods may not result in greater alcohol intakes. Commercial data almost certainly exist to elucidate this issue, but the authors of this review do not have access to it. Under climate change the average annual temperature for the UK is expected to rise between 0.5 and 1 °C by 2040 (UKCIP, 2002), with increases in hotter days and durations of hot spells and summers are likely to become drier, so increases in overall consumption of alcohol, barbecued foods, salads, chilled foods and drinks might be expected to increase due to climate change if they are indeed temperature-linked (however this will depend on recent trends continuing).

6.3 INDIRECT EFFECTS ON FOOD CHOICE THROUGH FOOD PRICES

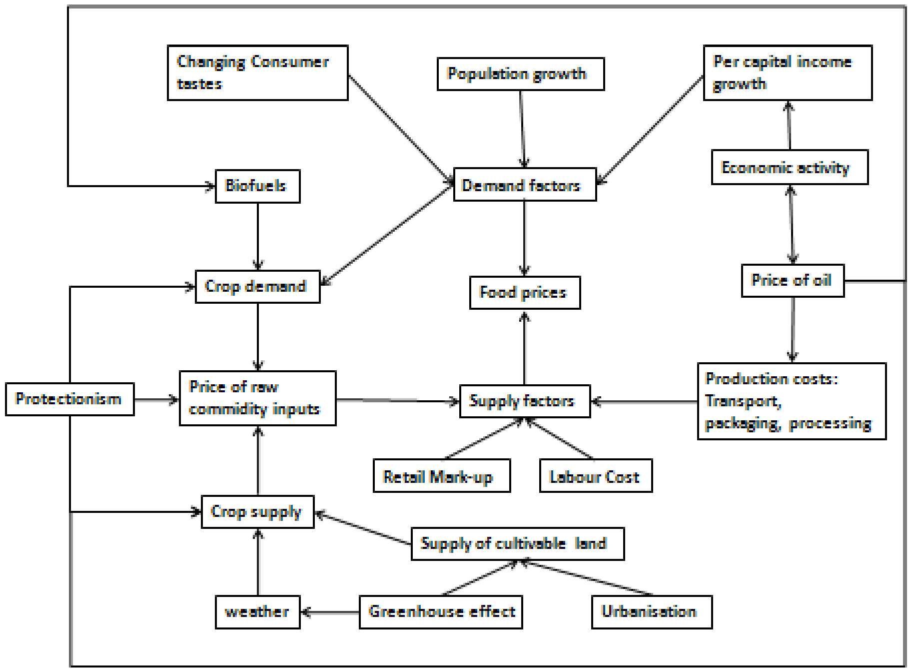
6.3.1 Climate change may have an effect on food prices and availability which in turn may affect the quantity or types of food individuals purchase and/or consume. However, as illustrated in Figure 6.1 food prices reflect interactions between many factors in the agricultural, production and distribution systems and in the world commodities markets as well as basic supply and demand factors. An example is the increases in food prices since 2003 which it has been argued are due to changing diets in rapidly growing economies (for example the increased demand for meat and dairy products and reduced demand for traditional plant-based staple foods in the very large developing economies of Brazil, Russia, China and India); changing agricultural focus (for example, reduction in land area used to produce food and increasing development of biofuels and export-oriented crops - via supply and demand forces and conditions attached to World Bank loans and agricultural support programmes); rising fuel prices increasing costs of farming, materials such as fertilisers, production and transport; and speculative investment in commodity futures markets (Lock et al., 2009).

Figure 6-3 Framework of the determinants of food and nutrition security in the UK, with a focus on the effects of climate change on food prices (Adapted from DoH, 1996). The factors highlighted in purple are those that may relate to food prices and climate change



6.3.2 In the UK and EU the Common Agricultural Policy (worth £3 billion per year to the UK) and environmental standards play major roles in affecting food prices (SACN, 2009b, Strategy Unit, 2008a). As we rely on more processed foods food prices have become more divorced from the prices of raw products - for example only around 10% of the price of a loaf of bread is due to the wheat component, so that the world wheat price could double and only make a small impact on the price of bread (Brown, 2004). In summary climate is only one factor in setting food prices.

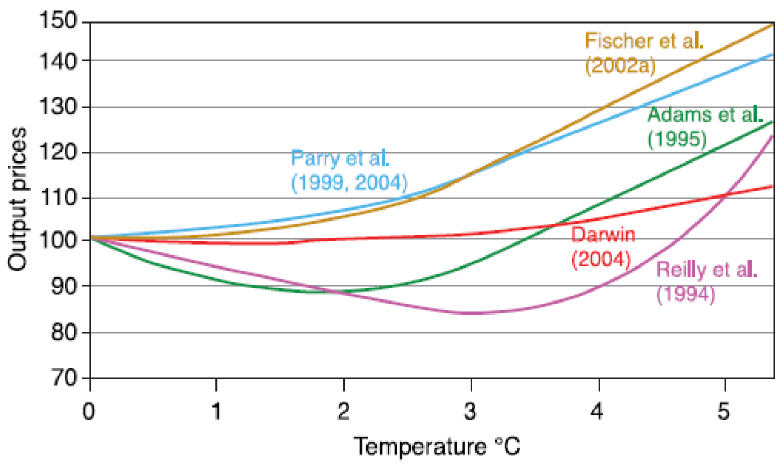
Figure 6-4 Influences upon food prices (Source DEFRA, 2008)



6.3.3 There is currently considerable uncertainty in the overall impact that climate change will have upon food prices, and the best review of evidence comes from the 4th assessment report of the Intergovernmental Panel on Climate Change (Easterling et al., 2007). An assessment was performed of the limited number of global cereal (wheat, rice, maize, soybean) crop models available. These models start by predicting changes in global food production based upon models of crop productivity which take into account the response of crops to elevated atmospheric CO_2 concentrations, increases in ground level ozone, as well as altered climates. The results of these models are then put into a food price model which incorporates factors such as adaptation strategies at the farm and regional levels and so include features such as changes in planting dates, application of additional fertilizer, and development of new cultivars and irrigation infrastructure. The results presented in Figure 6.3 indicate large discrepancies between models. In overall terms they indicate that, up to an increase in global temperature of around 3°C, prices of major rain fed cereals such as wheat, rice and maize are likely to remain constant or even fall. This overall trend masks a trend of increasing production in mid- to high-latitude regions but a lowering of productivity in seasonally dry and tropical regions (Easterling et al., 2007). In the UK prices are determined by availability, but also by the Common Agriculture Policy which leads to prices for sugar beet, beef and poultry at around 200% of world prices and provides farmers with £3 billion in subsidies each year (alongside ~£2.7 billion in sales of crops), and by supermarkets, which are able to charge very low prices on some products they regard as loss leaders due to their huge purchasing power (The Strategy Unit, 2008).

6.3.4 Insofar as prices are determined by availability, they are likely to rise substantially with increased warming due to reduced global yields over 3°C. One limitation with the crop price models presented above is that the modelling of extreme events is acknowledged to be poor. When changes in extreme events are taken into account crop prices are expected to be higher than the assessments presented in Figure 6.5 indicate (Easterling et al., 2007). An example of the impact of extreme weather events occurred in 2006 when ambient weather conditions led to a worldwide cereal production fall of 2.1% (FAO, 2008c) and a concurrent increase in price. Closer to the UK the 2003 heat wave is suggested to have reduced the French grain harvest by 30% and fruit harvest by 25% (Ciais et al., 2005). This lead to a 30-year low in wheat stocks, but while wheat prices rose the price of bread did not alter dramatically (Brown, 2004).

Figure 6-5 Cereal prices (percent of baseline) versus global mean temperature change for major modelling studies (Easterling et al., 2007)



6.3.5 The previous section assessed the impact of climate change upon cereal prices. Cereals are staple foods worldwide which suggests that they lack elasticity of demand. Large stores of cereals are held against emergencies worldwide, allowing some evening out of supplies and so costs from year to year. Stocks of other foods, including fruits, vegetables, legumes, dairy foods, fish and meat are also highly relevant to health and nutritional status and are much more reliant on the current year's harvest. For these foods demand is likely to be more elastic as one vegetable can be replaced by another if there are shortages. Transport of fresh fruit and vegetables, meat, fish, eggs, milk and dairy foods is more costly (both financially and in carbon emissions) than that of relatively non-perishable cereals, as refrigeration may be needed. The financial cost of international transport of food is currently relatively small (see Section 5.3.2) and so crop shortages in one area of the world can be compensated for by provision from other areas.

6.4 INDIRECT EFFECTS ON FOOD CHOICE THROUGH FOOD AVAILABILITY

6.4.1 A large proportion of UK food is purchased from the international market. Is where food is produced important to consumers? Recent evidence suggests that although there is widespread enthusiasm for local food, with local food being perceived as of better quality and fresher, the perceived barriers of price, inconvenience, and lack of availability do not currently make this an important factor in people's purchasing decisions (Chambers et al., 2007, Lobb et al., 2005, Lobb et al., 2006). This suggests that if food is sourced from further geographical areas then this is unlikely to have a major impact upon consumer preferences. Similarly, in a qualitative study carried out in Bristol, Hull and Liverpool the factor of major importance to consumers in choosing fruit and vegetables was price with respondents preferring lower priced produce. Other factors that were considered important, but much less so, were freshness and produce that was locally grown (Edwards-Jones et al., 2008). Currently, with fuel prices making up a relatively small part of the price we pay for food grown abroad, changes in areas where food is grown may not make a big difference to availability or prices. However, if fuel costs more accurately represent GHG emissions in future then the cost of transport may rise and potentially increase the costs of importation (and cold storage) from other parts of the world.

6.4.2 There are also questions as to how western countries will respond to specific food shortages in neighbouring countries? Will they allow market solutions (potentially causing shortages and price rises in their own country) or restrict sales of food to neighbours? Both have potential impacts on UK consumers. There is the potential for us to keep operating in a global market with reducing trade barriers. An alternative would be to move towards more localised economies, potentially with the re-emergence of trade barriers. This could be envisaged in a situation where the price of a basic commodity is at stake - a country faced with the prospect of its (adequate) crop being sold at high prices to other countries, thus raising the price of basic foods above levels that its own citizens can afford may well decide unilaterally to prevent export.

6.4.3 One of the most likely impacts of climate change is an alteration in the suitable areas for different types of agriculture (Easterling et al., 2007). For example in the UK the National Farmers Union suggest a range of agricultural impacts from climate change including increased grazing opportunities, heat benefits to crops such as onions, legumes, carrots and sweet corn and a lengthening of the growing season. However, on the negative side factors such as heat stress for animals, increased irrigation needs and reduced flowering season due to increased winter temperatures may reduce agricultural yields (NFU, 2005).

6.4.4 The geographical ranges of a large number of species may alter with implications for food crops. Certain plant crops may be vulnerable to changes caused by species extinction, in turn caused by climate change, for example crops needing insect pollinators or worm activity, altering food availability and areas of production (Stern, 2005b). Worm numbers may drop in SE England as soils dry out, potentially reducing soil productivity (Anderson, 1991, Hopp and Slater, 1948). Areas of endemic infectious diseases of crops and farm animals may alter (with infectious diseases surviving better over warmer winters). This has the potential to significantly alter the areas where certain foods are produced (e.g. blue tongue spreading north into British sheep, Alcamo et al., 2007, Easterling et al., 2007, Stern, 2005b).

6.4.5 Most world fish stocks are being depleted, and are generally in an unstable and unhealthy state (Brunner et al., 2009). On top of this, effects of climate change on fish and fishing may be dramatic, at least locally. Ocean acidification (due to absorption of CO_2 by the oceans) may alter fish species availability in different ways in different areas (Raven, 2005, Stern, 2005b). Increases in water temperature (which alter phytoplankton communities) on top of current overfishing are likely to cause varied effects in at least some areas, but are as yet not easily projected. Sea level rises may also affect spawning areas and nurseries. Shell fish may grow better, but there will be competition from invasive species, increased heat stress and greater numbers of pathogens (compounded by local aquaculture spreading disease into native fish populations; Alcamo et al., 2007). Local extinctions are expected at the edges of ranges, especially in freshwater fish and those that migrate between fresh and salt water, like salmon (Easterling et al., 2007).

6.4.6 However, no overall assessments exist considering the impacts of all these possible changes upon food prices. Such studies would need to adopt similar methodologies to the IPCC review and consider factors such as changes in geographical distributions and yields alongside other important elements such as the likely adaptation of farm and aquaculture systems (e.g. irrigation, new crop breeds, and changing farming practices) to a changing climate.

6.4.7 As well as changes in mean weather conditions across the globe extreme weather events, such as heat waves and flooding, are likely to become more frequent (Stern, 2005b). These will have important effects for food. In the UK and Europe heat waves are expected to increase in intensity and duration after 2030 (DoH and HPA, 2008). These will affect food production causing specific failures in particular crops in some years (Easterling et al., 2007, Stern, 2005b). This suggests that food availability and associated food prices are likely to become more unstable from year to year. For example the European heat wave of 2003 resulted in falls in French fruit and corn harvests of 25% (Holden, 2009). In the UK the increased tendency for drought in SE England may also alter crop production patterns (Stern, 2005b). Drought along the Atlantic coast (Ireland) may reduce forage crop growth so that animal stocking levels need to be decreased (Alcamo et al., 2007). Sugar beet, potatoes and vegetables may be sensitive to summer drought in the UK (talk by Pollock and Hopkins in DEFRA, 2005). Other extreme events may include flooding and salination of coastal areas (Cohen et al., 2008). The ability of food systems to adapt to these conditions will be crucial.

6.4.8 If farming and fishing systems are not able to adapt to weather extremes and changes in conditions then food availability (and price) of some foods in the UK may fluctuate more widely from year to year. The effect on foods grown in other areas may be more dramatic (as greater effects are expected on food production in other areas such as the Mediterranean) and may be exacerbated by migration and conflict. Migration and conflict may be caused by lack of food as well as other political factors, but they may exacerbate geographical changes and food insecurity (Cohen et al., 2008).

6.5 Effects of changes in food prices on food purchasing

6.5.1 In the UK food price increases are likely to lead to consumers altering their food choices (reactive food choice). There is good evidence from a large systematic review that price changes (through taxation or special offers) can alter alcohol consumption (Wagenaar et al., 2009), so it is likely that price changes in luxury or extra foods and drinks may also alter consumption. However, food is a necessity, and people may react differently to food price rises than to alcohol price rises.

6.5.2 There is reasonable evidence that price can alter type and quantities of food eaten (although most of the data come from the US). One US intervention study showed that higher price leads to reduced amounts of foods bought, as well as altering the likelihood of purchasing high- or low-energy dense foods (Epstein et al., 2007). Energy dense foods are those with a high number of calories per gram of food (for example, pure fat is the most energy dense food at 9kcal/g) while foods with low energy density have less energy per gram, and tend to have more nutrients per kcal (for example, fruit and vegetables). Cost was inversely related to availability of fruit and vegetables in the homes of US children, with lowest availability of the highest cost foods (Ard et al., 2007). An intervention study of low-fat snacks in school vending machines found that price reductions were significantly associated with increases in uptake, such that a price reduction of 25% compared with the usual fat item was associated with a 39% increase in uptake, and a 50% price reduction with a 93% increase in uptake (French et al., 2001). Evidence from a large US based randomised controlled trial found that the costliness of a low-fat diet (in both time and money) adversely influenced a woman's likelihood of sticking to an advised and taught low fat diet (Urban et al., 1992). However, while higher fast food prices correlated with a higher quality diet (higher fibre intake and lower saturated fat intake) in a large US survey, higher fruit and vegetable prices also resulted in higher dietary quality and lower levels of obesity (Beydoun et al., 2008). UK consumers stated that price was an important factor in their choice of fresh produce, and a much greater factor in their choice than freshness or place of origin, however when questions were asked differently the order of preference changed (with freshness, colour and shelf-life becoming more important than price)(Edwards-Jones et al., 2008). However, cheap is not always best, and higher priced products can be given higher value in some circumstances - it is likely that this mechanism works best with luxury products such as alcohol and confectionary.

6.5.3 A recent analysis by the ESRC assessed historical evidence on the response of consumers to food price rises, suggesting that price rises are unlikely to affect consumer behaviour as much as might be expected as we have all become reliant on highly processed foods. During the 19th and first half of the 20th century rises in food prices lead to people cutting down on expensive foods like meat and other animal products, relying more on staples like bread and potatoes. However, when prices rose in the 1970s the pattern was different - people retained their intake patterns and cut back on quantities of food across the board, so that consumption of milk, potatoes, bread and sugar all fell while fruit, vegetables, fish, meat and fats all rose slightly (ESRC, 2008). Meat intake rose because although beef, lamb, pork and sausage intakes all fell, chicken intake rose dramatically (as its production was intensified and prices fell suggesting that consumption of meat is responsive to price). However, this is complicated by the fact that during this time energy intakes fell, alongside a decline in physical activity levels required in work and domestic life. Overall, fat, protein and carbohydrate intakes all declined. While calcium and iron intakes fell a little, vitamins A, C and D remained constant suggesting that nutrient density rose somewhat (ESRC, 2008).

6.5.4 Price rises may lead to consumers switching to lower cost food items, and there has been much discussion of supermarket customers switching to supermarket 'own brand' products during the current recession, and switching from organic to conventionally grown produce (slowing the recent trend in growth of organic, fair-trade and free range) (Edwards-Jones et al., 2008). How consumer purchasing has altered in response to price rises since 2003 may begin to be clarified when initial results from the first year of fieldwork in the current National Diet and Nutrition Survey programme are published early in 2010. How consumers change their eating behaviour in response to price rises may be of concern for public health. There is consistent evidence that in the UK healthier food baskets are more expensive than less healthy food baskets (Cade et al., 1999, Cummins and Macintyre, 2006, Mooney, 1990), although organic foods are probably no more nutritious than conventional foods (Dangour et al., 2009), and 'own brand' products may be nutritionally equivalent (or better, some are lower in salt than more 'premium' brands). A recent analysis in the US has shown that foods with a high energy density (or low nutrient density, usually more processed foods with high sugar and fat contents) are usually cheaper than their less energy dense counterparts (due to cheaper components). Less energy dense foods (higher nutrient density foods, mainly fruits and vegetables) are often recommended to help reduce weight gain and be incorporated as part of a healthy diet. In the same study the highest quintile of energy dense foods (3.4 to 9kcal/g) cost $1.76/1000kcal while foods in the lowest quintile (0.14 to 0.64kcal/g) cost over $18/1000kcal. This effect of consumers switching to less healthy food is likely to be exacerbated by the fact that energy dense foods are less affected by price rises as food price is a small component of their overall cost. For example over 2 years of food price rises, the price of the most energy dense foods fell (by 2%) while that of the least energy dense foods rose by almost 20%, so that the most energy dense, and least healthy foods, appear both cheapest and also most resistant to inflation - presenting 'good value' in terms of cost per kcal (Monsivais and Drewnowski, 2007).

6.5.5 Other possibilities are that consumers may respond to raised food prices by buying frozen rather than fresh foods (which has minimal nutritional implications and may reduce waste, but see Section 7.7), buying products on offer (for example, 2 for 1 offers, which can provide good value, or may increase waste and provide very poor value as a result), cooking from basic ingredients (which may reduce shopping costs but increase time and energy for cooking, and may increase dietary quality), and eating out less often (which can be an effective way of reducing food bills, and may increase nutritional quality).

6.5.6 The effects of price rises on food purchases differ across the population and price rises are likely to have greatest impact upon the poorest members of society. In the UK the poorest 10% of households spent 15% of their income on food in 2006, while the richest 10% spent just 7% on food (Strategy Unit, 2008a). Poorer people use food as a flexible part of their expenditure; if their income falls a little it is difficult to cut the gas bill or pay less rent, but it is possible to spend a little less on food (Dowler, 2008). Also, as lower income households spent most on staples, nutrient dense foods, like bread, eggs and milk, they are most susceptible to any future increases in food prices (Strategy Unit, 2008a). Further evidence of this greater effect upon poor families emerged from Save the Children research conducted in the UK in February 2009. This found that, in the face of rises in the cost of food of over 11% in the previous 12 months, 35% of parents had cut back on food expenditure. For the poorest group of parents, 48% cut back on the money they spent on food (Save the Children, 2009). What is less clear is the effect this had on the nutritional intake and status of this group, although this is unlikely to be very positive. The FSA's Low Income Diet and Nutrition Survey provides good data on the diet and nutritional status of low income households in 2004 (Nelson et al., 2007), so providing a good baseline for future assessments of the effects of changes, including climate change.

6.5.7 Over the past decade the number of children and pensioners living in poverty (households with an income of 60% or less of the UK median household income) has reduced, while the numbers of adults of working age has remained static (Nelson et al., 2007). However, 3.8 million children and 1.8 million pensioners, as well as a high proportion of single parents and disabled people, still live in poverty. There is some evidence of differences in the dietary intakes and nutritional status of those with lower incomes compared to the general population, and these differences are likely to be responsible for some of the health inequalities apparent across socioeconomic groups in the UK (Nelson et al., 2007).

6.5.8 Data from Glasgow between 1997 and 2007 assessed the cost of a 'modest but adequate' diet that included 100% of the recommended daily allowances of nutrients, met healthy eating guidelines and reflected how people eat. Prices rose by 120% for baking potatoes, 112% for tinned tomatoes, 92% for fish fingers, 87% for new potatoes and 76% for carrots (having adjusted for inflation) over this 10 years while they fell by 27% for sausages, 37% for beef, 40% for cheese and cod fillets and 50% for fresh chicken breasts. Over the 10 year period there was a modest overall fall in the basket price, and prices remained lower in the poorer areas of Glasgow than the richer areas (overall). Over this 10 year period some types of fruits and vegetables (like apples and bananas) had become cheaper, while others (like onions, pears, tinned tomatoes) had become more expensive (ESRC, 2008).

6.5.9 The activity of the UK in the world food market makes it highly subject to world food shortages, or at least to price rises for scarcer foods. If food scarcity becomes common then food choices may be altered in a variety of ways. The UK is fortunate in being economically strong so we are likely to be able to purchase foods that we desire on the international markets, but shortages in this market are likely to mean we pay more. Poorer UK consumers and consumers in developing countries are likely to be more seriously effected in becoming unable to purchase specific (or adequate) foodstuffs. How wealthier nations, including the UK and the EU respond to such shortages politically is yet to be determined, and while we currently operate in a global market the development of more localised food production with the re-introduction of trade barriers is not impossible.

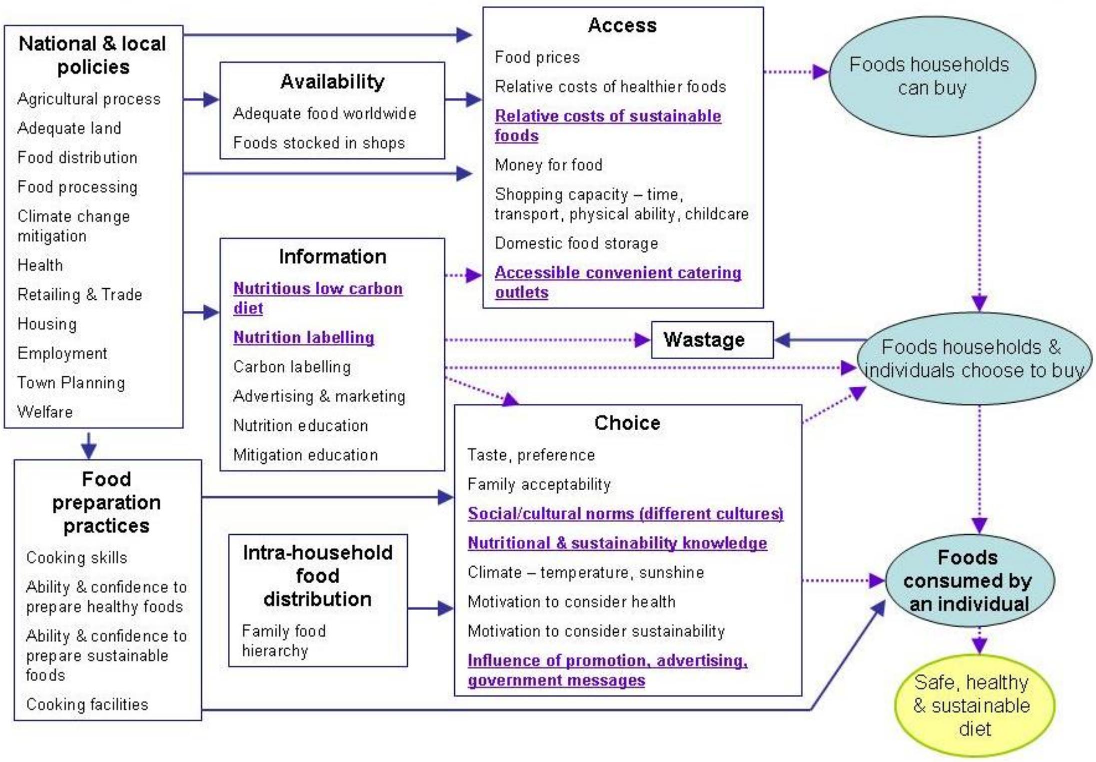
6.6 Societal responses to climate change; biofuels

6.6.1 It is clear that governmental policy changes, accompanied by financial incentives can alter some types of climate-related behaviour very rapidly. An example of this, and one of the most controversial societal responses to climate change, is the growth in biofuels as an alternative energy source. By potentially displacing food production it is argued that biofuels have the potential to raise food prices and cause food shortages in vulnerable populations. An analysis by the World Bank, has suggested that 75% of the doubling of the prices of staple crops, such as grains and oilseeds, since 2002 was due to increases in biofuel production, resulting in reduced food production (Mitchell D, 2008). However, biofuels grown using marginal land or based on waste products may be much more positive in their effects.

6.7 Societal responses to climate change; low GHG diets

6.7.1 The prerequisites for people to be able to choose a low GHG diet are that further research is carried out to understand the composition of such a diet to optimise both nutritional quality and sustainability, and then information is provided so that people can actively choose such a diet if they wish to. Such a diet needs to be socially and culturally acceptable, supported by sufficient information and encouragement and well-priced (so that it is available to all), and available from a range of accessible catering outlets (schools, hospitals, works canteens and fast-food outlets), see Figure 6-6. Even where all these criteria are met they may not be sufficient grounds for acceptance and uptake (see Section 9 on engagement and behaviour change).

Figure 6-6 Framework of the determinants of food and nutrition security in the UK, with a focus on low GHG diets and carbon labelling (Adapted from DoH, 1996)



6.7.2 One way to reduce the carbon footprint of the UK population would be to reduce production of meat and dairy foods, as well as reducing their consumption (so that we don't simply increase imports). In an analysis, where a Swedish meat and potatoes meal (pork chop, potatoes, tomatoes and bread) was replaced by a fully vegan Swedish meal of a pea-burger with potatoes, tomatoes and bread, the environmental impact was considerably reduced, from approximately 1150 g CO_2 equivalents /meal to 550 g CO_2 equivalents/meal (Davis and Sonesson, 2008). This method of comparing meals rather than finding alternatives for specific foods is likely to allow flexibility in reducing carbon footprint and also to ensure good nutritional intake. It reflects how people eat (in meals rather than in individual options; Carlsson-Kanyama, 1998).

6.7.3 Modelling of the climate effects of a transition to eating less meat suggests that it may have a very important role to play in our overall climate mitigation strategies. A scenario where ruminant meat (including beef, buffalo, sheep and goat) is no longer produced or eaten would reduce the total European mitigation costs to achieve a 450 ppm CO_2 eq stabilisation target by 2050 to 30% of the cost of mitigation required if we continue our current meat-eating status (Stehfest et al., 2009). Consumption of pork, chicken, milk and eggs were not altered in this scenario. Changing to a no animal products scenario (where no meat, milk, cheese or eggs were produced) cut the cost further to only 20% of that required in the reference (eating as normal) scenario. A compromise healthy eating model incorporating a healthy diet as advocated by Walter Willett (Willett, 2001) (with small amounts of beef and pork, and more moderate quantities of poultry, eggs and fish, aiming to reduce saturated fat in the diet while maintaining protein, iron and zinc intakes) would still reduce the overall total European cost of reaching the CO_2 stabilisation target by 2050 by 50%. In these models a large amount of grazing land is taken out of cultivation, and naturally regenerated vegetation would result in a large carbon uptake, while methane and nitrous oxide emissions are substantially reduced. This may or may not be considered appropriate for UK water meadows and upland grazing areas, but alternate uses of ex-grazing land were not considered in the model.

6.7.4 Garnett reviewed the issues around livestock farming and production of meat and dairy foods, suggesting that the system is complex, but inputs and outputs can be summarised as in Table 6-1. She suggests that our farmers, farmland and nutritional status would all suffer if we were to stop rearing and eating meat completely.

Table 6-1 Inputs and outputs to livestock farming with a focus on the UK (Table simplified from Garnett, 2007b).

Inputs	Outputs
○ Energy (relatively minor) ○ Feed (extensive, including most UK cereal production, plus imported feedstuffs such as soya and oilseed) ○ Land for grazing (competing with other land use in most cases)	Products including: ○ Meat and offal ○ Milk and dairy foods ○ Leather ○ Manure ○ Wool Environmental services including: ○ Soil quality ○ Species diversity ○ Landscape aesthetics

6.7.5 One of the main nutritional contributions of meat and dairy foods is protein. Carlsson-Kanyama discussed protein costs in kg of GHG emissions per gram of protein (Carlsson-Kanyama and Gonzalez, 2009). Whole wheat (domestic), herring (domestic) and soybeans (imported by boat) provided between 120 and 160g protein per kg of GHG emissions. In contrast, rice, carrots (domestic), green beans (imported) and beef (domestic) provided less than 20g protein per kg GHG emissions. Eggs, chicken (domestic) and Italian pasta (40-60g protein per kg GHG emissions) and potatoes, milk, pork, cheese and cod (all domestic, 20-40g protein per kg GHG emissions) were all intermediate protein sources. The review suggested that moving towards a more plant-based diet would be helpful in reducing GHG emissions, by extending meat in hamburgers and sausages with protein-rich plant-based foods (such as soy) and reducing the average meat consumption of 100g per person per day to 90g (Carlsson-Kanyama and Gonzalez, 2009, McMichael et al., 2007, Smil, 2002). This was illustrated by contrasting three Swedish meals with similar nutritional composition, one of carrots, whole wheat, soy and apples (0.42 kg CO_2 equivalents), one of green beans, potatoes, pork and an orange (1.3 kg CO_2 equivalents) and one of frozen vegetables, rice, beef and air-freighted tropical fruit (4.7 kg CO_2 equivalents) (Carlsson-Kanyama and Gonzalez, 2009).

6.7.6 However, all sources of protein are not equal - the amino acid composition of foods varies, and those that provide amino acid patterns that are closer to human needs for amino acids are considered to be high quality proteins (smaller amounts are needed to provide adequate protein intake). The available amino acid profile depends on amino acid composition, amino acid ratios, digestibility, source and effects of protein (Friedman, 1996). In developing countries cereals, though not high quality, are the major source of protein (59%), while in developed countries meat (26%) and dairy foods (17%) together provide more protein than cereals (29%). Assessing protein quality by Protein Efficiency Ratio (PER, the weight gain of test group/ total protein consumed) egg white (PER of 3.7) and minced beef (PER 3.4) are very high quality proteins, while pea flour and soy protein are intermediate (PER 1.6) and whole wheat flour fairly low (PER 1.0). Legumes are varied in their protein quality (soybean is quite high) but combinations of beans and grains often improve protein quality overall, so that whole wheat flour plus soy protein have a higher PER than either alone (PER 2.2). Traditional diets are often based on grain/legume combinations. Fortification of foods such as wheat and soy with specific amino acids can improve protein quality even more (soy protein with 0.1% added methionine raises the PER to 2.6) (Friedman, 1996).

6.7.7 There are arguments about the GHG emissions of soybeans - as nitrogen fixing legumes they tend to be low in inputs and are high protein outputs used for human food (soy beans, oils, tofu etc), animal feed and biofuels. However, there are questions about their growth in Brazil (63% of EU soy imports come from Brazil although it grows only 24% of the world supply), specifically in the Legal Amazonia region, where rainforest has been lost partially through pressure for grazing and soybean growing. These indirect costs of soy use have to be accounted for when we understand the GHG costs of eating soy, using it as livestock feed, or as a source of biofuel (Garnett, 2007b).

6.7.8 Another option is to reduce the GHG effects of eating ruminant meat and dairy foods. Mitigation options for ruminant farming include altering livestock farming by using nutritional supplements, preventing over grazing, using small more frequent feeding patterns and exploring different livestock breeds. Options for manure management include moving to aerobic decomposition or an anaerobic environment with production and use of biogas (methane) for other uses instead of more usual energy sources. Manure can also be used as a fertiliser, reducing the need for manufactured fertilisers (Stern, 2005a). However, as Garnett discusses in her review, and the Food Ethics Council reiterates, the system is highly complex, and for any paper recommending one strategy as environmentally positive there is likely to be another that reaches the opposite conclusion (Garnett, 2007b, MacMillan and Durrant, 2008). Garnett tackles the issues by discussing a range of scenarios for livestock farming in the UK, see Table 6-2. Stern's scenario (above) is equivalent to Garnett's 'maximising productivity' scenario, involving intensification of agriculture and extensive research to improve the nutritional value of foods produced - she argues that while this is likely to reduce GHG emissions in the UK the emissions due to feedstuffs grown in developing countries and imported to the UK is likely to outweigh the gains - this comes back to how we account for the costs of our lifestyle, but accounting for these second tier effects, and including them in the carbon-cost of our food, appears to be the most realistic option in allowing us to truly tackle GHG emissions and global warming worldwide (see Section 5.2). The favoured scenario from Garnett's analysis is the marginal livestock rearing approach where levels of dairy and meat consumption are limited by what is sustainably managed within the parameters of the amount of land unusable for other purposes, the amount of land that needs to be grazed (and at what density) to promote biodiversity and the volume of by-products required. Essentially, quantities of meat and dairy raised would be carefully balanced to exclude exports and optimise use of appropriate resources such as land and feed. Similarly the Food Ethics Council report encourages us to understand the complexity of meat and dairy production and the variety of possible ways to mitigate our carbon footprints while protecting farmers and the landscape from a livestock-free future (Food Ethics Council, 2009).

Table 6-2 Greenhouse gas implications of various livestock farming scenarios (Garnett, 2007b)

Livestock scenario	Implications for: Greenhouse gas mitigation	Human diet	Other issues
Letting current trends continue (increased productivity with decline in hill farming, intensification of lowland farming, plus growth in organic & extensive production)	Very minor reductions in livestock related emissions	Unchanged	Some loss of aesthetics if upland not used for grazing as intensification proceeds
Maximising productivity	Most consistent with current trends. Likely to reduce GHG emissions in UK, but effects on emissions in the developing world (providing feeds etc) unclear, possibly negative.	Nutritionally enhanced foods available	Negative implications for animal welfare
Switching to organic/extensive systems	GHG emissions unlikely to differ much from 'maximum productivity', but lower productivity and reduced impact on developing world (unless imports rise)	Minimal reduction in intakes	Possible gains for biodiversity and animal welfare
Combining intensive and extensive approaches (low stocking densities, high use of concentrates such as cereals, oilseeds & other feed inputs)	Likely to benefit GHG emissions, but differences from 'maximum productivity' would be minor, possibly negative effects on developing world	Unchanged	Possible gains for biodiversity and animal welfare
Livestock switching (increasing pig & poultry numbers at the expense of ruminants)	Unclear - life cycle analyses find pig and poultry products less GHG intensive than sheep, beef or dairy BUT second order impacts and possible losses in carbon sequestration potential in the developing world not considered	Chicken & pork intake to increase, beef, lamb & dairy intake to decrease	Negative impacts on cattle and sheep farmers, unclear for pig and poultry farmers.
Marginal livestock rearing approach (rearing only numbers that marginal land unsuited to other purposes can support)	Emissions per kg of meat or dairy might increase, but second order impacts on overseas farming systems would be eliminated. Would need to manage demand for meat and dairy so that additional demand not filled by imports.	Intakes of meat & dairy foods would decline substantially	Soil quality and biodiversity maintained. Would damage farm income if price for meat and dairy foods don't increase.

6.7.9 Some authors have tried to produce guidelines for low GHG diets. In addition to avoiding meat and dairy consumption, others have tried to summarize the characteristics of the most and least intensive GHG fruits and vegetables. One such summary of fruit and vegetables is presented in Table 6-3 and indicates that some characteristics of low GHG emitting fruits and vegetables may include local and seasonal produce. It is also argued that air freighted, unseasonal Mediterranean-style vegetables and pre-prepared salads and vegetables are GHG intensive (Garnett, 2006).

Table 6-3 greenhouse gas intensive and light fruits and vegetables

The most greenhouse gas intensive fruits and vegetables	The least greenhouse gas intensive fruits and vegetables
Air freighted fruit & vegetables (e.g. US berries, African green beans, pre-prepared salads produced outside Europe); **unseasonal Mediterranean style produce** (e.g. tomatoes, courgettes, aubergines, peppers and salads); **pre-prepared, trimmed or chopped produce** (e.g. salad bags, fruit salads); **highly perishable fruit & vegetables** (as are prone to being spoiling and being wasted)	**Seasonal field grown UK produce** cultivated without additional heating or protection, which are not fragile or easily spoiled; and **robust overseas grown produce**, cultivated without heating or protection and transported by sea or short distances by road

Data from Garnett for the Food Climate Research Network (Garnett, 2006)

6.7.10 The characteristics of a low GHG diet are likely to include (although this requires confirmation from further and more detailed LCA analyses):

1. Low intakes of beef and cheese, sugars, tea, coffee and cocoa, air-freighted foods and alcohol
2. Moderated intakes of eggs, poultry, fish, Mediterranean-style vegetables and salads, cooking oils, biscuits and crackers
3. Elevated intakes of other plant-based foods, pulses, and cereals
4. Reducing food waste, and composting what food waste we cannot avoid

6.8 MONITORING AND REGULATION

6.8.1 UK consumers are demonstrating increased interest in the quality and origin as well as convenience and taste of food (Strategy Unit, 2008a), suggesting that high quality labelling around food origins and carbon footprint may influence the behaviour of at least some consumers. Initiatives such as the carbon labelling of a wide range of products (including foods) being trialled by the Carbon Trust (www.carbon-label.com/), or the plans to enhance the eatwell website (www.eatwell.gov.uk) currently run by the FSA to include sustainability advice may help consumers to make more appropriate decisions on the impact of their food on climate change. Such integration of food information and/or labelling on nutrition, safety and environmental impact will be interpreted alongside other factors such as food prices, habitual purchases, image and food preferences. This type of labelling needs to be available both in shops and catering outlets, and could potentially be represented as one component of a Healthier Food Mark in public sector canteens and outlets. However, there is a significant debate about the usefulness of food labels in affecting consumer behaviour (Grunert et al., 2009).

6.8.2 More coordinated work is needed at the level of the European Union to discuss and develop policies to safeguard food stocks and help to maintain prices to support nutritionally rich diets should be considered and the FSA should be a major player in this process to ensure that its focus on nutritional intake and status is represented.

6.8.3 Policies such as carbon taxes (as advocated by Stern) applied to the UK food chain are likely to make eating red meat, cheeses, sugary foods, coffee, tea and cocoa more expensive (Strategy Unit, 2008a). This, in its own right, would be likely to reduce intake of red meats and cheese in the UK diet, except that it may provide such foods with higher status and cache.

6.8.4 For farmers, modification of the Common Agricultural Policy of the EU in 2003 has resulted in the introduction of the 'Single Payment Scheme' in the UK, as well as the voluntary 'Environmental Stewardship' scheme which repays those who maintain higher environmental standards. Further reform will occur in 2013 and 2020.

6.8.5 Public food outlets, such as those in schools, hospitals, works canteens, universities, councils etc should be at the front line in introducing low GHG, healthy and affordable food choice (although this will be a leap - many are not yet experienced in either providing healthy food or in labelling to help customers choose healthier options) .

6.9 SUMMARY- CLIMATE CHANGE AND FOOD CHOICE

6.9.1 This section has examined how people choose to eat the food they do and how this might change actively or reactively because of climate change. Individual food choice is affected and controlled by many variables on different levels. Consequently, predicting, manipulating or analysing it is a not simple.

6.9.2 There is some evidence that food and drink are affected by temperature and weather but from available data it is not possible to separate weather effects from seasonal availability and seasonal events.

6.9.3 Climate change may, as well as having direct effects on food choice, have indirect effects through prices and availability which in turn may affect the types and quantities of food eaten. However, although food prices are likely to rise overall, there is great uncertainty as to the impact that climate change will have on prices of individual foods. The impact of extreme weather events on availability and consequently price is also unclear.

6.9.4 The way we as a society, and as individuals, choose to mitigate climate change as regards food, will also alter the way we eat. These changes may occur actively as people become more aware of climate change or reactively because of policy changes aimed at climate change mitigation. Our current understanding of the GHG emissions associated with specific foods is minimal, but growing fast. Available data do suggest that the following broad strategies may be helpful in reducing GHG emissions due to food:

- Low intakes of beef and cheese, sugars, tea, coffee and cocoa, air-freighted foods
- Moderated intakes of eggs, poultry, fish, Mediterranean-style vegetables and salads, cooking oils, biscuits and crackers
- High intakes of other plant-based foods, pulses, milk and cereals
- reducing food waste, and composting what food waste we cannot avoid; and

6.9.5 Governmental policy changes can alter some types of climate-related behaviour very rapidly. Government responses and policy changes need to be carefully studied to ensure that they achieve their planned goals and not lead to higher prices, inequalities or nutritionally disadvantaging vulnerable groups.

7 Food choice, climate change and nutritional implications

7.1 Background

7.1.1 Current nutritional intake in the UK has been assessed in a number of ways and the National Diet and Nutrition Survey is currently being updated. The last set of data from 2000/1, published in 2002 (FSA, 2001a) found that adults were eating too much saturated fat, non-milk extrinsic sugars and salt, and too little fruit, vegetables and fibre. Alcohol intakes for large numbers of the population are unhealthy. Altering the way we eat to conform with national health goals: increasing fruit and vegetable intake to 5 portions daily; reducing salt intake to 6g/d; cutting saturated fat intake to 11% of food energy; and reducing added sugar to 11% of food energy would all help to reduce premature deaths and increase quality adjusted life years dramatically in the UK (Ofcom, 2006). Nutritional intakes have changed in the UK since the 1970s, the height of the cardiovascular epidemic in the UK. This can be viewed as part of epidemiologic and nutritional transition, the changes over the past 40 years that have included improvements in diet and lifestyle (along with improvements in treatment measures). These changes in lifestyle have reduced the risk in the population of cardiovascular disease, and led to huge reductions in deaths due to cardiovascular disease (from around 270 age standardised deaths per 100,000 in 1970 to 100 per 100,000 in 2003 in English people aged under 75) (Omran, 1983, Vital Statistics Outputs Branch, 2005). The theory of the transition is that different societies move through the stages of the transition at different times, with members of the highest socioeconomic groups moving through the stages before members of lower socioeconomic groups. In terms of nutrition the reduction in cardiovascular risk that has been demonstrated in the UK (with large reductions in smoking and saturated fat intakes and gradual improvements in fruit and fruit juice intakes) can be seen as changes that have been led by higher socioeconomic groups, and the changes have been taken up by lower socioeconomic groups a little later (Popkin, 1994). Increases in processed foods pioneered by higher socioeconomic groups have been taken up by all groups in society, but lower socioeconomic groups have taken up cheaper processed foods preferentially and these appear to have led to current increases in obesity (ESRC, 2008). It is yet to be seen whether the middle class trends towards more organic, fair-trade food, lower meat intakes, use of wholegrain cereals and an interest in dietary choices to mitigate climate change will become more widely accepted by all socioeconomic groups, but this would be suggested from previous trends. Populations at specific risk of undernutrition include the elderly, infants, immigrant populations and the poor.

7.2 DIRECT EFFECTS OF TEMPERATURE AND WEATHER CHANGES ON NUTRITION

7.2.1 Climate change may provide both risks and opportunities for provision of adequate dietary energy and a balanced diet (SACN, 2009b). A trend towards increased alcohol intake due to rising summer temperatures runs counter to a suggestion that diets designed to mitigate against climate change may lead to reduced alcohol intake. Reduced intake would be more beneficial to health, at least in those with high or binge intake habits. The health issues, risks and cost implications associated with high alcohol intake are well documented (DoH et al., 2007) but alcohol also plays a positive part in social interaction, and its enjoyment and existence in nearly every human culture suggests that while we may choose to try and stem its worst excesses we are unlikely to remove its presence or influence. Department of Health guidelines suggest a maximum of 2-3 units/day for women (maximum 14 units/ week) and 3-4 units/day for men (maximum 21 units/week) with 2 alcohol-free days after heavy drinking. They run a number of active campaigns to promote this message (DoH, 2009). Statistics on alcohol sales indicate that consumption per drinking adult is over 3 units per day (Garnett, 2007a).

7.2.2 Hotter weather may lead to larger intake of salads, which may be positive in terms of fruit and vegetable intake (although some salads are high in fat, through dressings, cheese, mayonnaise etc), tending to improve health. However, this trend is not clear, and may be insignificant in a world where fresh bagged salad is available throughout the year. Mitigation may tend to reduce the current trend for perishable bagged salads, replacing them with salads made of seasonal and robust (less perishable) fruit and vegetables - the effect of this on demand for salad in any weather is unclear.

7.2.3 Warmer temperatures may increase barbecuing across the UK (although this is far from definite), increasing the risk of food poisoning from under-barbecued meats (see Section 8). There is limited evidence suggesting that barbecued meats can increase the risk of stomach cancer (World Cancer Research Fund, 2007), and an increase in barbecued foods may increase saturated fat intake.

7.3 INDIRECT EFFECTS ON NUTRITION THROUGH FOOD PRICES AND AVAILABILITY

7.3.1 If general rises in food prices occur, then less-healthy energy dense foods may be bought preferentially, especially by those on lower incomes. These are likely to increase the risk of micronutrient deficiencies and obesity (Kral et al., 2009, Ledikwe et al., 2004, McMillen et al., 2009). This risk may be partially countered by pricing goods according to their GHG emissions (so that transport and manufacturing costs become more expensive and putting up the cost of energy dense foods) but is likely to be present to some extent. There are few data on how temperature and weather events influence micronutrient intake.

7.3.2 Fruit, vegetable, salad and nut availability may be limited by any initiatives to limit our intake to locally seasonal foods (currently the majority of our fruit is imported, and changes in geographical areas for growth of specific crops. Fruit intake is associated with reduced risk of mouth, oesophageal, lung and stomach cancers, as well as reduced risk of cardiovascular disease (World Cancer Research Fund, 2007).

7.3.3 Current difficulties with fish stocks suggest that our fish consumption may fall in future due to smaller catches and changing species, regardless of the effects of climate change. We are increasing the amounts of fish we eat in the UK, although we eat less than the suggested 2 portions of fish per week, one of which should be oily (Scientific Advisory Committee on Nutrition, 2004). The increasing trend may need to be reversed to protect fish stocks, altering fish consumption to sustainable sources (Strategy Unit, 2008a). Climate change appears likely to exacerbate this situation locally in some areas and may provide new opportunities in others, but the overall effect is unclear. Fish is a good source of protein, and is an excellent source of selenium, iodine, long chain omega 3 fatty acids, vitamin D and calcium. Fish provide 20% of the animal protein in the diets of 2.8 billion people, so changes to fisheries and local fish populations pose real threats to world nutrition (FAO, 2008a), and may impact on world food stocks and international levels of unrest and migration. In the UK the Low Income Diet and Nutrition Survey found that only 15% of adults generally, and 3% of adults on low incomes, reported eating oily fish during the four days of their 24-hour dietary recalls, so that consumption appears considerably lower than the recommendation of a portion/ week, and intakes of white fish were similarly low. However, for adults all groups except women aged 19-34 achieved intakes over 100% of the RNI for calcium and iodine. Girls and boys aged 11-18 did not achieve 100% of RNI for calcium and girls aged 11-18 were just short of the RNI for iodine on average. The major source of iodine and calcium for this group was dairy food, so reductions in dairy foods may be a more important issue than fish intake in terms of iodine and calcium (Nelson et al., 2007). A useful source of iodine in a low meat, dairy and fish diet would be edible seaweed (Lee et al., 1994) as traditionally consumed around the UK coast, notably Wales. Vitamin D status does appear to be a problem, however more sunshine or supplements will be needed to address this issue (as dietary vitamin D is generally a small component of our requirements). See Section 7.4 for discussion of selenium.

7.4 EFFECT OF CLIMATE CHANGE ON NUTRIENT COMPOSITION (MINERALS)

7.4.1 Climate change is likely to alter the suitable areas for different types of agriculture (Easterling et al., 2007), and one nutrient that may be affected by this is selenium. Daily UK selenium intake is below the recommended dietary intake, potentially resulting in deficiencies for vulnerable sectors of the population (Finley, 2007). Selenium appears to be protective of prostate cancer (World Cancer Research Fund, 2007). Over the 30 years from 1970 to 2000 there was a 50% reduction in UK dietary selenium intake (Adams et al., 2002) coinciding initially with a shift of grain importation from Canada to the relatively selenium-poor soils of the UK and Europe. UK selenium intake has been rising since 2000, from 0.032 to 0.034mg/d in 2000 to 0.048 to 0.058mg/d in 2006 (FSA, 2009e). This is probably partly due to increasing food imports (from foods grown in areas of the world with greater soil selenium levels) and partly due to an increase in the supplementation of cattle with selenium (added to improve the health of the cattle, but resulting in greater selenium in meat and particularly offal). Climate change may alter suitable areas for growing UK wheat, shifting them substantially northwards (Ewert et al., 2005, Rounsevell et al., 2005), so that the selenium content of wheat may rise as Scottish (3.1mg/kg of soil) and Welsh (3.3mg/kg) soils are on average much higher in selenium than English soils (1.3mg/kg soil) (Morgan et al., 2009) - if growing wheat in hilly upland country becomes a realistic possibility. Alternatively, increasing localisation of food supplies could cause reductions in selenium intake, or both effects may be minimal compared to other changes in farming practices (which could include soil supplementation with selenium as well as continuing livestock supplementation).

7.4.2 Plants have regulated uptake for most micronutrients, so only selenium is likely to be appreciably affected by geographical shifts resulting in changes in soil composition.

7.4.3 There are likely to be many further developments in climate adaptation and mitigation via selective breeding and genetic research (including developing strains of rice that produce less methane, ruminants that produce less methane via genetic selection or altered dietary regimens, and crops that grow better under heat stress or with little water, as well as accumulating good gene banks for future research and development) (Burke et al., 2009, Lobell et al., 2009). Methods of farming will also change to help crops and farmers to adapt to climate change. These developments are beyond the scope of this work in general and a huge amount of work has been done by DEFRA in this area, with new grant funded programmes being announced (DEFRA, 2009a). Public acceptability as well as scientific viability of such changes need to be addressed. However, in ensuring adaptation and mitigation it is important that nutritional quality is not compromised. Trace element intakes fell in the UK between 1940 and 1991 (Thomas, 2003). A study using data from a long-term wheat farming experiment at Rothamsted found that zinc, iron, copper and magnesium in wheat had all decreased over that period. Careful analysis of stored samples from plots fertilised in different ways since 1843 found that wheat mineral content remained stable between 1845 and the mid-1960s, but have since reduced significantly on all plots (receiving no fertilisers, inorganic fertilisers and organic manure) (Fan et al., 2008). Semi-dwarf high-yielding cultivars were introduced in the mid-1960s and were associated with increased yield. The study found no changes in mineral content of the soil over this period, and an increase in bioavailable zinc, copper and magnesium. Reductions in human dietary mineral intake were attributed to reduced dietary intake (associated with lower levels of physical activity), lower micronutrient density in the diet and lower mineral content in wheat due to the new semi-dwarf cultivars. This suggests that the outcomes of crop breeding should focus on maintenance of nutrient content and absorption as well as improved yield and countering climate change trends. FSA monitoring may be appropriate to ensure that nutrient intakes from newer crops as well as from changing food intakes remain adequate and become optimal.

7.4.4 Any move to more localised growing of food would exacerbate problems of localised mineral deficiencies due to soil conditions, and also increase the risk of toxicity from soils with high natural levels of minerals such as copper and lead or industrial residues.

7.5 Effect of climate change on food nutrient composition (vitamins, antioxidants and amino acids)

7.5.1 Changes in geographical sourcing of foods may alter further aspects of nutrient composition. Edwards-Jones has compared nutrient composition in home-grown and imported vegetables. He found that slightly higher vitamin B6 and vitamin C levels in beans from Kenya and slightly higher vitamin B3 and K3 levels in UK beans. Antioxidant levels were similar in Kenyan and UK beans, but levels of essential amino acids (arginine, histidine, lysine, methionine, phenylalanine and tryptophan) were much higher in UK beans (although Kenyan beans were higher in valine and leucine). Some phytosterols were also much more abundant in UK grown beans (Edwards-Jones et al., 2008). It was not clear whether these differences were due to varietal differences or conditions of growth and handling.

7.5.2 The same group examined nutritional changes in broccoli (over 20 days) and cabbage (over 6 months) due to commercial type storage, finding that the most storage sensitive nutrients were vitamin C, B3, B5, B6, flavonoids, phenolic acids and amino acids. On the other hand, freezing did not result in similar changes, and frozen beans and peas retained most of the nutrients that existed in the original produce. They found, rather intriguingly, that fresh produce supplied to supermarkets were different in their nutritional composition than fresh produce used for freezing - with reduced flavonoids, phenolic acids and phytosterols in the produce due to be frozen (Edwards-Jones et al., 2008). This is likely to be due to different varieties used for frozen produce. An up-to-date review of the effects of different types of food storage on nutrient content would be helpful.

7.6 COOKING METHODS- IMPLICATIONS FOR NUTRITION

7.6.1 With increasing energy prices (Fuel Poverty Advisory Group, 2008) there may be increased pressure to cook using as little energy as possible, making microwave cooking more common than cooking on a hob or grill, and these more common than using the oven (Rhee and Drew, 1977). Those in fuel poverty, especially pensioners and poor families, spend a large part of their income on fuel and this will impact on money for food, especially if food prices are also rising. A full review of the GHG costs of different cooking methods, alongside fuel costs, nutritional and food safety implications of the different cooking methods, would be helpful in driving policy. Some traditional tips for saving energy during cooking include using a pressure cooker (although this may impact on nutrition), using a saucepan lid, simmering rather than boiling, minimising water for boiling vegetables, only boiling as much water as is needed for hot drinks, and filling the oven rather than cooking single dishes, as well as microwaving in place of oven use.

7.6.2 Mitigation diets appear to require a rather more limited selection of foods, and are likely to require cooking skills - those with fewer skills or time may find it monotonous and miss luxuries. However, some of these skills may be provided in the form of readymade meals as the carbon footprint of ready meals appears similar to that of home-cooked foods (see Section 5.3.10). Although eating ready meals has been considered to be a sign of a poor diet and poor nutritional intake, following efforts in the food industry in the 1980s and 90s to keep prices down by reducing the nutritional content of ready foods and adding fats, sugar, salt and flavouring, there is no good reason why, in principle, ready (frozen or chilled) ready meals cannot be as healthy as home cooked meals (ESRC, 2008, Lindsay et al., 2008).

7.7 FOOD STORAGE - IMPLICATIONS FOR NUTRITION

7.7.1 Extreme weather events may lead to food shortages of specific items in certain years. Increased probability of such occurrences may lead to altered models of food storage and 'mountains' to help the UK through lean years (for example world stocks of stored wheat and rice vary in size from year to year). This needs to be carefully planned to ensure that food stocks are nutritionally adequate for specific problems. Stocks need to be appropriately stored as aflatoxins from mould in grains and legumes increase the risk of liver cancer (World Cancer Research Fund, 2007) and account taken of nutritional changes during storage (see Section 7.5). In choosing food to store it will be appropriate to ensure reduced bulk, and manage safety, maintenance and turn over. Individuals may also feel the need to hoard food, which may exacerbate shortages and lead to food spoilage and wastage.

7.8 NUTRITIONAL EFFECTS OF A LOW GHG DIET

7.8.1 Further research will be needed to understand the long term nutritional effects of altered dietary patterns. Some of the ways that we may choose to mitigate climate change through foods eaten appear below. Replacement of a proportion of high GHG items with nutritionally equivalent lower GHG, and lower cost, items, are likely to lead to reductions in consumption of beef, lamb and dairy foods, coffee, chocolate, alcohol and sugar and greater consumption of plant-based foods (see Section 6). A major issue is how such changes in diet may come about and this is discussed in Section 9 on engendering behaviour change.

7.8.2 One method to reduce GHG emissions is to reduce meat and dairy foods, or at least to partially replace beef, lamb and dairy foods with pork, chicken, eggs or pulses, as meat and dairy foods together are responsible for over 50% of the carbon footprint of the food we eat (section 5.3). Nutritionally for most of us in the UK reducing our meat intake would help to reduce our saturated fat intake (UK goals are to reduce saturated fat intake to less than 11% from the current level of 14% of food energy; Scientific Advisory Committee on Nutrition, 2004). A survey confirms these suggestions of the nutritional effects of cutting down on meats - self-selected UK vegetarians and fish eaters (both avoiding meat, but eating dairy foods) had lower saturated fat and higher fibre than meat-eating women (Cade et al., 2004, DEFRA, 2003). In an intervention study substituting a vegetarian soy-based protein source for a beef-based diet resulted in lower levels of low density lipoprotein (LDL) cholesterol, consistent with reductions in cardiovascular risk (Haub et al., 2005). With good knowledge (which not everyone has) and a wide variety of available foods there is little evidence that being vegetarian increases the risk of anaemia in adults, even though serum ferritin is often much lower on average (Ball and Bartlett, 1999, Craig., 1994, Helman and Darnton-Hill, 1987).

7.8.3 Absorption varies from individual to individual and according to factors including other dietary substances and nutrient status. For iron, for example, uptake is regulated by iron status, so that those with a low iron status have much greater levels of absorption than those with moderate or high status. Haem iron is more completely absorbed than non-haem iron, and dietary factors such as phytates and polyphenolics, zinc and soy protein, tea and coffee taken at the same meal reduce non-haem iron absorption while vitamin C and meat, poultry and fish enhance non-haem iron absorption (Craig., 1994). However, data from longer term studies suggest smaller effects of these factors (SACN, 2009a).

7.8.4 A review of the health effects of vegetarian diets found that most data have been gathered on well educated vegetarians living in western countries. Vegetarian diets tend to be high in carbohydrates, omega 6 fatty acids, carotenoids, folic acid, vitamin C and E and magnesium, as well as fibre, while being lower in protein, saturated fat, long chain omega-3 fatty acids, retinol, vitamin B12 and zinc. Vegan diets tend to be lower in vitamin B12 and calcium. The review confirms that vegans and vegetarians tend to have lower body mass index, lower LDL cholesterol and higher homocysteine than omnivores, and similar mortality rates to health-conscious omnivores (Key et al., 2006). Reduced intake of red and processed meats is associated with a reduced risk of colorectal cancer, while reductions in milk and perhaps cheese appear to increase the risk of colorectal cancer (World Cancer Research Fund, 2007).

7.8.5 Some groups, including infants, adolescents, and pregnant women, are more at risk of nutritional deficiencies than average. Iron deficiency is a serious problem in Asian vegetarian infants and pregnant women, especially where rice rather than wholemeal bread is the staple. Vegan children have lower vitamin B12 and calcium intakes than omnivores of the same age (Sanders and Reddy, 1994) although they also have higher intakes of most other nutrients including vitamin A, thiamin, biotin, vitamin C, vitamin D, folate and iron. However, the terms vegetarian and vegan cover several distinct groups, with different reasons for being vegetarian and very different diets. A study of adolescent girls in London found that prevalence of low haemoglobin was 25% in girls who dieted in the previous year, 23% in white vegetarians and 17% in Indian vegetarians, compared with 4% in white omnivores and 32% in Indian omnivores (Nelson et al., 1994). Overall, the effects on risk of anaemia does not appear to be very different in vegetarians and non-vegetarians (SACN, 2009a).

7.8.6 The Collins study assessed current diet and modelled changes, highlighting some potential nutritional deficits, but not finding any very consistent deficits and not outlining how far below RNI specific deficits fell (Collins and Fairchild, 2007). They addressed an ecological footprint (rather than using LCA) which assesses the amount of land needed to produce specific commodities. They note that a moderate model, scenario 3 where food items with an ecological footprint of at least 0.004gha/kg were replaced by lower footprint alternatives, gave the most positive nutritional effects (see Table 7.1), and was the only scenario with a salt intake as low as recommended (less than 6g/d)(FSA, 2005). It is worth noting that this model includes pork and eggs still, so is not vegetarian, but chooses lower impact protein sources, thus maintaining some of the advantages of our current UK diet (maintaining a haem iron intake for example), which is likely to be of benefit for groups at increased nutritional risk (including young children, women, older people, chronically ill, poorer people). This model results in a 23% reduction in ecological footprint, and reduces the cost of food bought, so may be appropriate for a wide variety of socioeconomic groups, although its acceptability as a diet has not been assessed. However, it must be noted that this methodology is not necessarily equivalent to LCA, and further modelling is needed.

Table 7-1 Modelling of the effects of specific dietary changes on total ecological footprint and nutritional effects, data from (Collins and Fairchild, 2007)

Scenario	% reduction from current	Nutritional issues
Current Cardiff consumption	-	Energy, CHO, fibre, vit B6 & polyunsaturated fats below RNI
1: consumption of organic food and drink in place of similar non-organic food and drink	23	Nutritional intake assumed to be as current Cardiff diet
2: replacing items with a very high ecological footprint (≥0.006 gha/kg) by lower footprint foods (e.g. beef replaced by pork, cheese by eggs)	18	Energy, CHO, fibre, folic acid & polyunsaturated fats below RNI, vit C reduced but above RNI (note energy, CHO, fibre better than current intake)
3: replacing items with a high ecological footprint (≥0.004 gha/kg) by lower footprint foods (as above, plus e.g. ice-cream replaced by yoghurt, spirits by beer)	23	Energy, total fats, polyunsaturated fats & fibre below RNI (fibre highest of all scenarios, only scenario with <6g/d salt)
4: replacing items with a moderate ecological footprint (≥0.002 gha/kg) by lower footprint foods	26	Energy, total , mono-& poly-unsaturated fats, fibre & salt below RNI
5: typical lacto-ovo vegetarian diet (does not eat any kind of animal flesh but does consume dairy and egg products)	6	Energy, total, saturated, mono- & poly-unsaturated fats, protein, fibre, vit B6 & salt below RNI (few nutritional benefits over current)

EF: ecological footprint, the amount of land needed to produce specific commodities

7.8.7 Reductions in dairy foods may be a greater problem nutritionally than reducing red meat or switching to lower carbon footprint meats. Calcium and iodine intakes are reliant on dairy food intakes, and tend to be poor in low income girls (see Section 7.3.3). Long term deficiencies in calcium may be important in blood pressure control and bone strength, and there is evidence that low iodine intakes may be related to thyroid cancer risk (World Cancer Research Fund, 2007).

7.9 NUTRITIONAL EFFECTS OF CHANGES TO SPECIFIC FOOD GROUPS

7.9.1 **Energy.** There are some suggestions that with increases in plant based foods, the nutrient density of foods may rise (and the energy density fall). This may in turn lead to a fall in total energy intakes, potentially leading to reduced levels of obesity. However, if highly processed foods high in fats and sugars remain cheap then energy density and energy intakes may remain high. This is unclear. If nutrient density rises, and energy density of foods falls, the risk of low energy intakes in children, older people and those with eating difficulties rises.

7.9.2 If food starts to become priced according to its GHG potential then, as well as an increase in food prices generally, greater rises may occur in the costs of meat and dairy foods. There are also likely to be price rises for luxury and processed foods such as alcohol, chocolate, coffee, tea and soft drinks, making these items less accessible. This may also result in reductions in energy intake and potentially in body mass index.

7.9.3 **Fruit and vegetables**. The most helpful change that would help to mitigate climate change around fruit and vegetables would be reduced use of air-freighting of foods unless they are highly 'ethical' in other ways (for example they may also be organic and fair-trade items). As only a small proportion of fruit and vegetables are currently air freighted, this change would reduce available variety only slightly, but the current trend is towards more air freighting, so reducing it now may be important for the future (section 5.3.8) (Garnett, 2006).

7.9.4 Greater consumption of robust and locally sourced seasonal fruits and vegetables may be a further step taken to mitigate climate change - although its effect will be less helpful in total than reducing meat and dairy food intake. Greater fruit and vegetable consumption is clearly associated with better health, reduced chronic disease and reduced mortality (although it is not totally clear that this relationship is causal, this is likely) (He et al., 2006, , 2007). If the trend is consumption of larger quantities of fruit and vegetables then this would be positive for health and nutritional status. However, limiting ourselves to seasonal fruit and vegetables in the UK is likely to lead to reduced intakes of vitamin C in the winter and spring, so low-carbon ways to enhance fruit (or fruit juice or fruit compote) intake in the winter and spring (especially April) will need to be developed. Cooking skills will be needed to make good use of seasonal vegetables and we will need to deal with the image issues around winter vegetables (Food Ethics Council, 2008). UK fruit and vegetable production will need to rise substantially, possibly utilising land currently used for meat and dairy production.

7.9.5 There will be a need to monitor seasonal nutritional status if the local seasonal sourcing of fruit and vegetables becomes common (especially in vulnerable populations such as the homeless and immigrant populations), so that gaps and dips can be moderated.

7.9.6 **Pulses**. If pulses are used more widely as a protein source in place of meat and dairy foods there may be nutritional benefits, such as those associated with vegetarian diets. There is evidence that soy protein may be beneficial in reducing prostate cancer risk and improving lipids (Taku et al., 2007, Yan and Spitznagel, 2009), but there are some worries that it could also lead to increased breast cancer risk in some groups (Hooper et al., 2009).

7.9.7 **Fish.** Fresh fish are widely air-freighted, and a change to consumption of frozen fish (transported by boat or road) from fresh air-freighted fish would result in reduced GHG emissions (section 5.3.9). Freezing is unlikely to affect nutritional intake from fish substantially and may improve it.

7.9.8 **Organic production methods**. Increased consumption of organically produced foods (produced in ways that do not reduce productivity), may or may not reduce our carbon footprints (see sections 5.3.6, 5.3.9 and 5.3.12), but would be unlikely to alter our nutritional intake substantially (Dangour et al., 2009).

7.10 SHOPPING

7.10.1 Reduction in use of the car for shopping trips, which would need to be supported with good public transport to supermarkets, more local shops and/or high quality delivery systems, would be helpful mitigation strategies. The nutritional implications of this are unclear, but some scenarios may result in increased physical activity. Increased physical activity tends to be associated with greater nutrient intake while reducing obesity, which would be positive for health .

7.11 INTEGRATION OF NUTRITION, SAFETY AND SUSTAINABILITY MESSAGES

7.11.1 The grocery industry has focussed on health and nutrition to drive policy for a number of years, and has recently published a report assessing how well sustainability issues can be integrated with a healthy eating agenda, especially with regards to fish, fruit and vegetables, reducing portion sizes and saturated fats (IGD Working Group Report, 2008). Respondents, who included 21 manufacturers, 5 retailers, 3 food service businesses, 3 NGOs, 3 academics, 1 industry body and 2 others discussed issues related to environmental impacts of nutritional goals on energy use, waste, water use, transportation, biodiversity and GHG emissions. Issues they felt were related to GHG emissions were limited to: sourcing fruit and vegetables from further afield would increase emissions (which is not necessarily true, as discussed previously); different GHG production by animals produced with a less fatty carcass; increased processing may be required to reduce saturated fat in foods, and this may increase GHG emissions; and that in replacing salt, fats and sugars in foods further raw ingredients may be required to compensate for flavour loss, increasing emissions.

7.11.2 When formulating foods to address nutritional objectives environmental impact is far down the list of concerns (9th of 9 for manufacturers), which is lead by organoleptic or sensory qualities of the food, ease of target customer acceptance and final nutrient composition. 45% of respondents indicated that they had measures of environmental impact or sustainability, and these included ongoing or planned lifecycle analysis (LCA), environmental policies, minimum standards, internal benchmarks and work with the Carbon Trust, Courtauld commitment, WRAP and Marine Stewardship Council.

7.11.3 When asked whether environmental sustainability impact was taken into consideration as part of achieving nutritional objectives 27% of respondents replied 'yes' although some then qualified this as 'no real environmental impact' or 'informally', while some reinforced it as 'core' or routine, or that it was performed for some specific products. The main resources used by respondents in providing information on the impact of nutrition on environmental sustainability (40 to 45% of respondents) were DEFRA, academia, FSA and research organisations. 5% felt that there is sufficient information available on the relationship between nutrition and environmental sustainability, while 76% said 'no'.

7.12 GROUPS AT RISK OF NUTRITIONAL PROBLEMS

7.12.1 As in other countries, the effects of climate change on food are likely to hit the most poorly resourced in the UK hardest (McMichael et al., 2008). The poorest groups in the UK already have a poorer diet than the UK average, and poorer health as a result, contributing to UK health inequalities. The Low Income Diet and Nutrition Survey (LIDNS) suggests that those on low incomes eat less wholemeal bread and vegetables, and more fat spreads, non-diet soft drinks, beef, veal, lamb and pork dishes, pizza, processed meats, whole milk and table sugar (Nelson et al., 2007). However, this may partly reflect changes in diet over time as the NDNS series used for comparison was carried out over the 1990s, finishing with a survey of adults in 2000/1 (the NDNS adults survey was carried out in 2000/1, the survey for children in the late 1990s and the survey for older people in 1994-5). It will be interesting to understand how the diets of those on low incomes have changed relative to those on average incomes when the results of the new wave of the National Diet and Nutrition Survey are further analysed - currently there is no mention of low income or poverty in the first report (www.food.gov.uk/science/dietarysurveys/ndnsdocuments/ndns0809year1).

7.12.2 Vegetable intake was about half a portion less than intake in the general population in both men and women, at just less than one portion daily for low income groups, while fruit intakes were similar, so that low income populations eat only half of the recommended 5 portions daily. Energy intakes were similar in low income groups to the general population, and while carbohydrate intakes were also similar the proportion of non-milk extrinsic sugars were higher in low income groups, well above the recommended levels for children especially (boys having around 17%, girls 16.5%, men 15% and women 13.5%, older men 13% and older women 12% compared to the goal of 11% of total energy). Saturated fat intakes were very similar to those in the general population, but all were higher than nationally recommended (boys and girls, older men and older women 14%, men and women 13%, compared to the recommended 11% of energy intake; Nelson et al., 2007).

7.12.3 Generally blood status assessments of micronutrients were adequate for low income groups, but iron status was problematic, with anaemia present in 8% of men and 12% of women. Low iron stores (indicated by low ferritin) were present in 16% of 11-18 year old girls, 21% of women aged 19-34 and 14% of women aged 35-49. Low red cell folate levels were found in 11% of men and 13% of women. For vitamin B12 10% of men over retirement age and 7% of women aged 19-34 years had low status, while other groups were generally of adequate status. 47% of men and 35% of women had low serum vitamin C concentrations. Plasma retinol and alpha-tocopherol concentrations were generally adequate (with less than 1% of men and women with low concentrations), but 20% of men and 17% of women had low 25-hydroxy vitamin D concentrations (which reflect sunlight exposure as well as dietary intakes). Low status levels were generally more prevalent in the low income group compared with the general population (Nelson et al., 2007).

7.12.4 Low income women had higher levels of obesity than the general population, and low income men and women had higher levels of central obesity, which increases risks of diabetes, cancers, cardiovascular disease, infertility and is associated lower quality of life (Nelson et al., 2007). It is related to both eating more energy dense, nutrient poor, foods and being less physically active (The Strategy Unit, 2008). There is evidence that people with limited food budgets are increasing consuming energy dense foods as these foods have been relatively protected from recent price rises and so represent good value calories, suggesting that recent price rises may exacerbate obesity (see sections 6.5.1). While there is potential to move to a cheaper, more nutritious, healthy and less obesogenic way of eating that will protect the environment, as part of the move to mitigate climate change, currently a healthy diet (equivalent to normal current eating patterns) is more expensive than less healthy diets (section 5.6.4). A healthy low GHG eating pattern, with reduced meat and dairy foods, and more whole grains and legumes, fruit and vegetables, is not yet usual fare or easily available - it is likely to require those with greater resources to lead the way to make it culturally acceptable (see nutritional transition, Section 7.1.1).

7.12.5 Those on low incomes appeared to have health deficits associated with their different diets. 42% of low income men and 35% of low income women had hypertension, and levels appeared somewhat higher than in recent surveys of the general population. Lower income participants were more likely to smoke and less likely to take high levels of physical activity, and appeared to drink less frequently. However, energy intake was lower in men and boys in the lowest income group (<£160/week) compared with the >£160/week group in the low income survey, and levels of nutrient intakes were lower in the most deprived (often urban) areas. 80% of the low income group shopped at large supermarkets rather than smaller local stores, and women using large supermarkets consumed more fruit and vegetables than other women. 53% of children received a free school meal. 29% of respondents reported food insecurity (lack of 'access to food sufficiently varied and culturally appropriate to sustain an active and healthy life') due to lack of money or resources such as storage or transport during the past year.

7.12.6 The LIDNS does not include data on the diets or nutritional status of the most deprived groups, those without homes, who may have very specific nutritional problems due to their circumstances, lack of facilities and chaotic lifestyles, and asylum seekers, who have distinct cultural needs and often problems with language and facilities (Dowler, 2008). Changes relating to extreme weather events, loss of the ability to grow crops and water shortages in other parts of the world may lead to instability and wars (Costello et al., 2009), leading to increases in migration, so that the UK may take in greater numbers of refugees and economic migrants in the future - the nutritional needs of these groups need to be assessed and supported.

7.12.7 In general older people eat a diet more closely aligned to healthy eating goals than other groups (Nelson et al, 2007). However, malnutrition affects around 14% of older people. Four out of ten people aged at least 65 admitted to hospital are already malnourished, and the prevalence of malnutrition in those aged over 80 is five times that of the under 50s (Bapen, 2005). In addition, 10% of free-living older people and 45% of those in institutions were anaemic, 15% men and 7% women in institutions (2% free-living), had low serum zinc (leading to loss of taste and reduced immune function), and intakes of dietary fibre were only half of dietary reference values (Finch S et al., 1998) Low serum vitamin D levels are especially worrying in many elderly, especially those who are housebound or living in institutions. These levels of anaemia and low zinc status suggest that for older people it may be important to ensure adequate intake of red meat, so that switching to a low meat and dairy food diet may have nutritional consequences that will need to be monitored.

7.12.8 While baseline nutritional status is poor in a large group of older people they are in many ways better equipped to deal with the changes imposed by climate change - they are more likely than average to have good cooking skills, to shop regularly, to hate wasting food and have experience of economising while producing healthy and tasty food. Older people are less likely now than in the past to live in poverty, although those that do are subject to the problems of low income described above.

7.12.9 Ethnic minorities have a high risk of obesity in the UK today, diabetes is 3 to 4 times more common in Bangladeshi and Pakistani men than the general population, stroke is twice as prevalent in black as white people, and chronic kidney failure is 3-5 times more common in South Asian and Afro-Caribbean than the white UK population (The Strategy Unit, 2008). Traditional ethnic diets vary, but many are higher in fruit and vegetables and lower in fat than the general UK diet, but may be higher in salt.

7.12.10 Recent immigrants to the UK are often financially disadvantaged, so that the issues relevant to poorer groups will be relevant to immigrant groups which make up part of our ethnic minorities.

7.13 RECENT AND CURRENT POLICY ON FOOD AND NUTRITION

7.13.1 While we have been making progress towards 5-a-day and saturated fat goals, that progress has been slow, and there has not been marked success in public health policy in reducing the obesity epidemic as it is in direct competition with the marketing of highly processed and flavoured foods (ESRC, 2008). Recent FSA work with manufacturers to reduce salt in processed foods appears to have been more successful, and working with retailers to encourage healthier eating has had some limited success (Buywell project, described in ESRC, 2008). Future policies to change our dietary patterns to mitigate climate change will face the same types of challenges as health promotion work. This contrasts with the dramatic changes that were engineered into the British diet during the Second World War, but the draconian legislation needed to bring in rationing (that resulted in such dramatic nutritional improvements for many, William and Frazer, 1943) would be politically suicidal if there was not a huge public will and cross-party commitment to such changes. Whether such a will could be attached to climate change mitigation is yet to be seen.

7.14 MONITORING AND REGULATION

7.14.1 For effective climate mitigation it is essential to be clear about what dietary changes will reduce our carbon footprints. Work on this has begun (section 6.7), and there are some clear messages around reducing meat and dairy intake, reducing food wastage and limiting air freighting of foods. Other clear messages with limited validity (for example, those around food miles) will need to be overcome for progress to be made.

7.14.2 However, there is a long way to go before we can account clearly and accurately for the GHG emissions from specific dishes and meals that we eat, and this is needed before much progress can be made. In order for this to occur we need a model of good practice for acceptable lifecycle analysis (LCA) that can be used to detail GHG emissions of foods (see Section 5.2). Many more minor issues, including whether the future expected cooking costs of raw or partly cooked foods are included in an assessment and method of travel home from the shops will also need to be addressed before we can attribute GHG emissions accurately.

7.14.3 Once LCA has been conducted on sufficient foods to properly model whole diets, research will be needed to model diets that are nutritionally optimal and low GHG. These are likely to be lower in meat and dairy foods and higher in some types of fruits and vegetables than current diets. Whether these diets are culturally acceptable is an unanswered question.

7.14.4 Monitoring, to ensure that vulnerable groups are not at increased nutritional risk from changes to food prices as well as mitigating policy changes affecting meat and dairy intake or waste reduction measures, and to put in force systems to rectify any issues that do arise, will be essential (Hutton, 2008). Such monitoring would include regular updates of the UK's highly successful and forward thinking Food and Nutrition Surveys (in children, in older people, in low income groups and in the adult population) with additional monitoring of hard-to-reach groups such as homeless people, mobile populations and recent immigrants.

These are organised by the FSA as part of their remit to "be responsible for monitoring and surveillance of the nutrient content of food and the nutrient content of the diet" (MAFF, 1998). Monitoring to assess nutritional status through the whole year (as in previous Food and Nutrition Surveys) may become more crucial if the potential trend to locally grown and robust seasonal produce is realised, so that nutritional status begins to fluctuate more seriously through the year (as vitamin D status does at present).

7.14.5 Further international mechanisms to monitor food and nutritional status include the following - these are monitoring resources that the UK can draw on where appropriate:

- WHO vitamin and mineral nutrition information system (VMNIS)
- WHO global data bank on infant young child feeding (IYCF)
- WHO global database on child growth and malnutrition
- WHO global database on body mass index
- USAID's Health Systems 20/20 (www.healthsystems2020.org).

These databases will all be brought together, with other databases from UNICEF, UN Statistics Division, UNDP, FAO, DHS, the World Bank, IFPRI (International food policy research network) and the International Labour Organization (ILO), into the Nutrition Landscape Tracking System, currently under development - this will allow nutrition monitoring with a new dimension (Siekmann et al., 2009) .

7.14.6 Assessment and monitoring of farming, agriculture and horticulture (including economics and environmental impact) are carried out by DEFRA, are important economically, and vital in assessing carbon footprint contributions for food and drink in the UK. DEFRA's Expenditure and Food Survey (DEFRA, 2003) is an annual assessment of household expenditure on food (which include wasted food).

7.14.7 Ongoing nutritional assessment and monitoring of staples such as grain, potatoes, major fruits and vegetables will be needed. These will change as conditions alter with incorporation of adaptations to higher temperatures, new varieties and cultivars, new geographical cultivation areas and new cultivation methods. While intake data (such as fruit and vegetable intake, or saturated fat intake) are important in assessing risk of long term chronic illnesses, nutritional status data are more critical in pinpointing low intake (such as selenium or iron status problems, where intake and status may not be closely related). Development of good biomarkers of nutritional status for more vitamins and minerals is needed for use in status surveys.

7.14.8 Recent trends towards reduced consumption and thrift in line with economic belt tightening that has occurred over the past few months, have been reflected in greater desire to grow our own food, buying smaller portion sizes, buying foods on offer, switching to different foods or brands to save money, freezing leftovers and cutting down on eating out and bottled water - frugality is becoming trendy (Wallop, 2008). How this trend will develop when the economy recovers is unclear, but work at RESOLVE suggests that the clash between consumerism and low GHG lifestyles may not be insoluble. They feel that social and cultural theories of consumerism suggest that the sociological functions of consumerism may begin to be provided by patterns of consumption less reliant on GHG production (Evans and Jackson, 2008). These trends will need to be monitored and the understandings developed used to support work to change behaviour.

7.14.9 Modelling has been performed on Joseph Rowntree Foundation data on the minimum income standards necessary for lifestyles with subsistence commodities and effective participation in society. This used consumption based GHG emission analysis, and the results suggest that this minimum income standard could result in a reduction in GHG emissions of around 38%. Interestingly this model resulted in a rise in emissions from food and non-alcoholic drinks, due to a rise in fruit and vegetable intake over and above that currently achieved (Druckman and Jackson, 2009). A sea-change in what is considered a socially acceptable diet through all social strata is needed for reductions in carbon footprint from food (behaviour change is discussed in more depth in Section 9).

7.14.10 Once LCA analysis of a wide range of foods and modelling of nutritionally optimal, culturally acceptable and low GHG diets are completed and adequate nutritional surveillance is in place the next level of work will be to include this information in the UK's planning for carbon reduction to develop appropriate policies. Changes in the way we eat as a nation have the power to substantially reduce the UK's carbon footprint - or to reduce the level and cost of changes needed elsewhere in the economy to achieve our carbon targets (Stehfest et al., 2009). Decisions will need to be made as to the methods of encouraging and supporting the UK population in making appropriate changes. Methods of engendering behaviour change and engagement in the issues of climate change, improving nutrition, reducing waste and supporting people to make appropriate changes are discussed in the main discussion of mitigation (Section 9).

7.15 SUMMARY - CLIMATE CHANGE AND NUTRITION

7.15.1 This Section has suggested a range of changes that may occur and has attempted to assess the nutritional impacts of these changes - for many these are unclear, and the message is that we need to monitor carefully for changes in nutritional intake and status in the UK population, especially in vulnerable groups (Table 7.2).

7.15.2 One major method to reduce the carbon footprint of our food is to reduce or modify our meat and cheese intake, as well as cutting down on sugary foods and drinks, which would be in line with nutritional goals to reduce saturated fat intake and extrinsic sugars (and possibly energy intake). However, this may have implications for iron, zinc and calcium status in vulnerable groups. Reducing food wastage is also import and is likely to have little effect on our nutritional intake (but may have implications for food safety and food management). The optimal composition of these diets for acceptability, price, nutrition and sustainability need to be developed, alongside GHG emissions labelling or advice, information on other aspects of the carbon footprint such as reducing energy costs of cooking while maximising nutritional intake, transport to shopping, labelling around air freighting of luxury goods, and ways to embed this in low GHG agriculture.

7.15.3 Ways to protect the most vulnerable from changes in food prices and availability resulting from climate change and food insecurity need to be considered now, and strategies to alleviate these problems developed.

8 Climate change and food safety

8.1 BACKGROUND

8.1.1 Three main factors affect the safety of food. The first is its microbiological content, the second the concentrations of chemical elements and finally the levels of radiation.

8.1.2 In terms of microbiology, risks occur due to the consumption of food containing a variety of microorganisms or their toxins. Examples include *Salmonella*, *Campylobacter*, *E. coli O157*, *Listeria monocytogenes* and *Clostridium p*erfringens. In terms of impact, the HPA estimates that there were 765,000 cases of foodborne illness in 2005 leading to 17,300 hospitalisations and 480 deaths in England and Wales. After several years of decline the number of cases of foodborne illness cases is starting to increase. The total cost to England and Wales associated with these illnesses was estimated to be £1.5 billion in 2006 (FSA, 2008).

8.1.3 In addition to microorganisms, chemicals in food, such as pesticide and veterinary medicine residues, natural, environmental and process chemical contaminants and migration from contact materials and articles may also have health consequences. Aflatoxins from fungi are included in this group. If the levels to which individuals are exposed through food are large, epidemiological studies often provide evidence on their health consequences. However, more frequently individuals are exposed to very low doses of these chemicals through food sometimes for extended periods. Low doses occur precisely because regulated levels in food are low. These may have health consequences, such as cancers in later life or damages to our reproductive ability. However, directly attributing this to food consumption is difficult. Estimates of health impacts may be produced using toxicology but estimating accurately the health consequences for a population being exposed to low doses of chemicals over long periods (e.g. many years) is difficult. When individuals are exposed to multiple chemicals, the combined effects produce further uncertainty. The final element of food safety is radiation levels. Radiation in food may occur from the breakdown of elements within food. These may be naturally occurring or enter the food chain from artificial sources.

8.1.4 There are several ways that climate change might affect food safety. These are:

1. Changes in the types of food that individuals consume;
2. Changes in chemical and pathogen inputs, fate and exposure;
3. Changes in the way that food is produced and processed from farm to fork.

Each of these will be considered in turn. If climate change has an impact upon food safety then the current mitigation measures in place and whether they are fit for purpose will determine the overall effect upon public health. Consequently the next section will also consider the current mitigation measures to ensure food safety

8.2 THE TYPES OF FOOD THAT INDIVIDUALS CONSUME

8.2.1 Different foods carry different risks and as an example Table 8-1 presents estimates of the risks from foodborne illness associated with consuming different food groups and types. For example consumption of poultry and shellfish, carry the highest disease risk and are associated with the highest hospitalisation rates. Conversely, consumption of cooked vegetables carries very low disease risks and hospitalisation rates. If individuals consume different types of food under climate change then the overall risk of foodborne illness will change. Section 6 indicated that there was little evidence of how food consumption patterns would alter under climate change, with the possible exception of increased fruit and vegetable consumption. This table suggests that an increase in fruit and vegetable consumption, if this occurred as the expense of meat, would have positive health consequences. The report has also presented stronger information on what might constitute a low GHG diet and it appears that a shift away from red meat towards vegetables and fruit would be positive from a food safety perspective. However, substituting red meat for poultry would appear to increase food borne disease risks.

Table 8-1 Microbiological risks associated with food groups and types, England and Wales Adapted from (Adak et al., 2005)

Food group / type	Disease Risk*	Hospitalisation Risk‡
Poultry	104	2063
Chicken	111	2518
Turkey	157	645
Eggs	49	262
Red Meat	24	102
Beef	41	153
Pork	20	93
Bacon/ham	8	39
Lamb	36	128
Seafood	41	293
Fish	8	41
Shellfish	646	1121
Milk	4	133
Other dairy produce	2	14
Vegetables / fruit	1	8
Salad vegetables	6	103
Cooked vegetables	0	0
Fruit	0	1
Rice	11	30
*Cases / 1 million servings ‡Hospitalisation / 1 billion servings		

8.2.2 Another impact of climate change is changes in the parts of the country and world from which food is sourced (Section 6) and this may affect food safety. As an example different countries have different approaches to the use of wastewater for irrigation (Drechsel et al., 2009) which may affect pathogen and chemical risks in fruit and vegetables. Data published by the Pesticides Resides Committee (www.pesticides.gov.uk) indicate that foods from different parts of the world contain different types and levels of pesticide residues. Mycotoxins are another significant food safety concern, are chemicals produced by certain moulds, and are considered to be carcinogens (FAO, 2008a). They are most common in foods from the tropics and sub-tropics. If climate change leads to the sourcing of foods from different regions then food risks will be altered accordingly. It is important to recognise that some of these changes could be positive for public health, others negative.

8.2.3 One mitigation response to climate change may be an increase in the quantity of food grown at home or on allotments (See Section 6.6). The impacts this may have upon food safety are unclear. In terms of chemical contaminants the generally urban nature of many allotments may lead to produce being grown on more contaminated soils (Papritz and Reichard, 2009) or being contaminated from atmospheric deposition of particular material (e.g. diesel particulars). However, a recent survey has not found high levels of heavy metals in home grown food (Weeks et al., 2007).

8.3 Chemical and Pathogen Inputs, Fate and Exposure

8.3.1 Through changing weather patterns, climate change may lead to the emergence or re-emergence of pathogens (FAO, 2008b, Patz et al., 1996) in food. Many of the new pathogens emerging over the past decades have been viruses of animal origin (e.g. HIV, SARS, Nipah virus and avian influenza). Although none of these have been transmitted by eating food, this suggests that viruses may be of special concern for food in the future, irrespective of climate change.

8.3.2 There is evidence that some bacteria (e.g. *E. coli* and *Salmonella*) have evolved stress tolerant mechanisms. When exposed to a difficult environmental condition (e.g. extreme heat) these enable the bacteria to survive even harsher conditions (FAO, 2008a, Rodriguez-Romo L et al., 2005). There is therefore the possibility that a more extreme climate could lead to bacteria more resistant to control. However, there is still uncertainty over whether the results from these laboratory experiments will be duplicated in the real world. Gene transfer between bacterial species is a common contributor to antibiotic resistance and is likely to be impacted by the environment. Therefore, a changing environment may have a significant effect upon the evolution of pathogens, their pathogenicity (FAO, 2008a) and on antibiotic resistance. There is nearly an endless list of different mechanisms through which climate change could affect pathogens and this makes risk prioritization problematic (FAO, 2008a). However, the pathogens that are likely to be of most concern are those that have low infective doses (e.g. enteric viruses, *Shigella* spp. Enterohemorrhagic *E. coli* strains and parasitic protozoa) and have a significant persistence in the environment (e.g. enteric viruses and parasitic protozoa) (FAO, 2008a). Pathogens with well shown stress tolerance responses to temperature and pH (e.g. enterohemorrhagic E. *coli* and *Salmonella*) may enhance their competitiveness under climate change (FAO, 2008a).

8.3.3 Freshwater and coastal environments are likely to be especially vulnerable to climate change because aquatic ecosystems are fragile (FAO, 2008a). A number of human illnesses are caused by consuming seafood (especially shellfish) containing natural toxins produced by algal blooms (FAO, 2008a). One suggested effect of climate change is a change in the distribution of algal blooms (IPCC WGII, 2007Ch 8) and it is suggested that algal blooms will become more common in the North Sea (Peperzak, 2003) and other parts of the world (FAO, 2008a). This implies that food safety may improve in seafoods from some regions but decline in others.

8.3.4 Mycotoxins are formed through complex interactions between the fungi and crop plants, both are affected by conditions of weather (temperature, humidity and precipitation) and soil. There is reasonable information on the weather conditions favourable to certain fungi but our understanding of how climate change may affect the distributions of mycotoxins is less certain (FAO, 2008b). A recent review has suggested that they may become an increasing problem in parts of temperate Europe and the United States. In other countries, such as Australia, elevated temperatures may mean that fungal growth and mycotoxin production could be reduced (Russell et al., 2010).

8.3.5 Climate change may affect the levels of pathogens and chemicals in food through agricultural adaptations. One major consequence of climate change for agriculture may be a large increase in the demand for irrigation water. It has been estimated that increases in crop irrigation requirements of between 5 and 8% may occur with greater increases in some areas (e.g. 15% in South East Asia) (Döll, 2002). In many cases this may be waste water which could lead to foodborne infections in consumers because of handling and consuming the irrigated produce (WHO, 2006, Islam et al., 2004). A decrease in the quality of surface waters is also predicted under climate change (Boxall et al., 2009) meaning that in the future, abstraction of surface waters for irrigation will be an important route for food contamination. Another farm adaptation may be agricultural intensification in some areas leading to greater use of pesticides and veterinary medicines. One concern regarding the latter (the increasing use of antibiotics) would be if this resulted in an increase in the prevalence of antibiotic-resistant pathogens (FAO, 2008a, FAO, 2008b). Conversely in other areas an altered climate may lead to reduced usage of veterinary medicines. Recent modelling work has examined changes in pesticide use that may be used in the future and suggested that climate change may increase the use of pesticides for certain crops such as potatoes and soybeans but decrease use for others such as wheat (Chen and McCarl, 2001). Although this is a US based study similar effects are likely to be observed in the UK.

8.3.6 Changes in transport pathways may also affect contaminant inputs to agricultural systems and food. Flooding is a well known mechanism to transport pathogens and chemicals, and the frequency of heavy rainfall events is likely to increase worldwide under climate change (Section 4.2.4). In terms of chemicals, transport of historical contamination from previously undisturbed sediments may occur (Boxall et al., 2009) and, for example, after hurricanes Katrina and Rita the USGS found evidence that some mobilised flood sediments were derived from the reworking of old, highly contaminated urban soils (Plumlee et al., 2007). Flooding downstream of industrial areas has also been demonstrated a mechanism to transfer contamination into food (Lake et al., 2005). However, the effects of increased flooding may produce very localised effects as only a small proportion of agricultural land is subject to flooding. In addition altered contaminant inputs to surface waters may have impacts upon aquatic species that are subsequently consumed.

8.3.7 Increases in the aerial inputs of volatile and dust-associated contamination may also occur. Changes in the bioavailability of chemicals are likely and it has been suggested (Booth and Zeller, 2005) that increases in temperature and a move of some soils from aerobic to anaerobic conditions could enhance the methylation rate of mercury and for each 1^{o}C rise in water temperature the methylation rate has been found to increase by 3-5%. This could increase the level of mercury in certain part of the food chain.

8.3.8 Once chemicals have been transported to soil, the physical and chemical properties of the contamination alongside the nature of the soil governs the uptake of these into plants. However, any such effects associated with climate change are likely to be small (Boxall et al., 2009). In terms of pathogens, changes in soil moisture, temperature and cloud cover (affecting UV levels) are likely to alter the survival of these organisms in the environment. However, there are few assessments of what the overall impacts might be.

8.3.9 One impact of climate change may be mitigation measures to reduce the carbon footprint of food at the farm level. A number of possible measures are being investigated in the UK and overseas (ADAS, 2009, DEFRA, 2009c, USDA, 2009). These include changes to fertilizer and pesticide applications as well as changes to manure spreading regimes. The impacts, positive or negative, that these may have upon food safety are unclear.

8.4 JOURNEY FROM FARM TO FORK

8.4.1 The next method through which climate change may affect chemicals and pathogens is changes in the journey from farm to fork. One recurrent theme in the literature is that the occurrence of some foodborne illnesses are correlated with temperature (e.g. salmonellosis D'Souza et al., 2004, Kovats et al., 2004, Lake et al., 2009), *Campylobacter* (Lake et al., 2009, Tam et al., 2006) and *Listeria* (Cairns and Payne, 2009). Elevated temperature is also likely to lead to increases in different types of mycotoxin from fungi. However, it does not necessarily follow that elevated temperature associated with climate change will lead to increases in these foodborne illnesses as it depends whether the impact of temperature upon the pathogen is direct or indirect. Direct effects occur in organisms that multiply at ambient temperature such as *Salmonella* where warmer temperatures associated with climate change may lead to increased bacterial reproduction and a greater chance of an individual receiving and infective dose. Indirect effects occur due to temperature affecting factors such as the way that people prepare food (e.g. more barbecuing in warm weather) or agricultural cycles that themselves affect pathogen risk. Therefore, it is not automatic that elevated temperature will lead to increased risk. Few food borne pathogens have been robustly examined to assess the likely impact of climate change. It is important to understand the drivers for seasonal changes in such infectious diseases so that the impact of climate changes can be estimated and the epidemiology better understood. Section 6.2.2 highlighted barbecuing as likely to increase under climate change and this method of cooking is widely known to be associated with food safety problems.

8.4.2 Transport, storage and processing of food affects food safety risks but there is little information on whether climate change will increase or reduce transport demands. Increases in transport might increase the probabilities of bacterial reproduction in food and the opportunities for fungal growth. It could also affect the migration of materials from packaging to food. Under climate change average temperatures will rise which will increase food borne risks unless enhanced refrigeration of foods occur during transport and food storage.

8.4.3 There are a number of societal responses to climate change that may affect the food journey from farm to fork. One response to climate change might be initiatives to enhance the efficiency of refrigeration systems and reduce the amount of packaging around food. It is important to ensure these do not have an adverse impact upon food safety especially as warmer temperatures are likely to increase the necessity of food refrigeration and appropriate packaging. Section 5.4 indicated that food waste is an important contributor to climate change and that improved management could reduce wastage at the consumer level. Again it is important to ensure this does not occur at the expense of public health.

8.5 MONITORING AND REGULATION

8.5.1 The safety of food is governed by a variety of different factors that impact upon the food chain from agriculture through to food consumption. Throughout this flow there are a variety of different organisations are involved in regulating food safety.

8.5.2 In terms of agricultural risks, DEFRA is the major government department with responsibilities for policy and regulations on the environment, food and rural affairs in the UK. It has the major responsibilities for animal health, takes a lead in agricultural policy and provides much advice to farmers on good practice. DEFRA has healthy food as one of its strategic objectives. In terms of regulating the specific chemical inputs to farming in the UK the Chemicals Regulation Directorate is a Directorate of the Health and Safety Executive with specific responsibilities to ensure the safe use of biocides, industrial chemicals, pesticides and detergents to protect the health of people and the environment. The Veterinary Medicines Directorate is also an executive agency of DEFRA and is responsible for the safe and effective use of veterinary medicinal products.

8.5.3 The legal levels of chemicals permitted in food (Maximum Residual Levels; MRLs) in the UK are mostly set on an international basis through the FAO/WHO Codex Alimentarius Commission (CAC) (FAO, 2006) which produce internationally agreed standards for levels of pesticides and veterinary medicine residues in food which apply in many countries. These levels are similar to EU standards which are based upon the results from food surveys and toxicological studies. The FSA represents the UK at the CAC and ensures that consumer interests are taken into account. The work of CAC falls into three general areas: commodity committees (covering a particular commodity; e.g. Beef and Beef Products); horizontal committees (addressing issues across a range of commodities e.g. labelling, food additives and contaminants); and regional committees. The outcome of these processes are international standards for pesticides and veterinary residues in food which have been worked into the national standards of many countries with whom the UK trades. This ensures that all the food consumed in the UK should comply with these standards.

8.5.4 As well as the FSA representing UK food safety interests at these wider international fora, the Agency is a leading player in the various bodies across the EU institutions that work to mitigate deleterious chemical and other contaminant effects to human health arising from their presence in the food we eat. It is present on EU risk assessment bodies and on bodies responsible for establishing analytical methodologies that identify the risks and those that set safety standards in agreement with producers and in law. Furthermore, the agency will take action to improve food safety even if specific regulations are not being broken. An example of such action is the voluntary agreements between food producers and the FSA against *Salmonella* which led to the re-introduction of Lion Brand eggs. This example shows policy interventions specifically targeted to reduce an increase in *Salmonella* noted in health surveillance data.

8.5.5 Some pathogen and chemical contamination is transferred from animals to humans through the food chain (e.g. heavy metals and Salmonella). Therefore, close monitoring of animal health is important. In England and Wales this is carried out through vets who inspect animals for illness and report these to the Veterinary Laboratories Agency who are an executive agency of DEFRA and operate national animal surveillance systems. This is essential as if new diseases emerge under climate change, then veterinary surveillance will be essential as it may detect these before infection in humans occurs. In addition, DEFRA's International Disease Surveillance team monitor the occurrence of major animal disease outbreaks worldwide and assess the risks these may pose to the UK. One limitation of this surveillance is that it is often focussed upon diseases of importance to livestock, not those that cause few signs of infection in animals but may be transferred to humans.

8.5.6 Once regulations are in place, monitoring of chemical and pathogen levels in food is essential to ensure that these regulations are adhered to. These provide information to the public, judge the effectiveness of regulation, monitor trends and assess risks. One advantage of these surveys is that they have the ability to examine all food consumed, including that produced outside the UK and EU (FSA, 2009c). In terms of monitoring the actual levels in UK and imported food much of this is undertaken by the FSA whose remit is to: "*protect public health from risks which may arise in connection with the consumption of food and otherwise protect the interests of consumers in relation to food*." (FSA, 2009a). Through regular food surveys the agency is able to monitor the levels of various chemicals in food and take action if required. One limitation of these surveys is that only a limited number of food stuffs can be tested due to logistical and budgetary constraints. Surveys are also undertaken by other organisations such as the Pesticides Residues Committee. An extreme example is the 2006 "Dioxins and Dioxin-like PCBs in Foods" survey (FSA, 2006) in which only eight samples of cow's milk were included. This is likely to be due to the high cost of processing each sample. Clearly if the concentrations of contaminants vary significantly across the UK and between countries from which UK food is sourced then these surveys have a low probability of detecting contamination. HPA labs also do much microbiological testing of food products. If the data were more readily accessible then the opportunities to look for trends over time would be possible. Another problem of food surveillance is the time it takes to detect pathogens. There are improved techniques available such as DNA hybridization, enzyme immunoassay and Polymerise chain reaction (PCR) techniques but all these still have time, sensitivity or volumetric limitations (FAO, 2008a).

8.5.7 In addition to monitoring MRL's in food it is important to ensure that food is processed in an appropriate manner. Again this area is well regulated and the EU Food Hygiene Regulations apply controls throughout the food chain, from primary production to sale or supply to improve food safety. Additionally there are less rigid interventions aimed at processes including the FSA's annual food safety week which encompasses a range of events to encourage better food safety. For the UK it is also important to engage with food safety issues in other EU countries from which much of our food is imported. Therefore, close cooperation with the European Food Safety Authority (EFSA) and the food safety authorities of other member states and countries outside the EU is essential to tackle the safety of imported produce. The UK has wide expertise in food safety so has much to offer other food safety organisations. It is also involved in the Technical Assistance and Information Exchange (TAIEX) unit of the EU Commission providing assistance to new Member States and other countries that may desire accession to the EU. In terms of food premises the responsibility for their hygiene falls under the remit of local authorities under their Environmental Health Departments.

8.5.8 Once food has been produced the final element in regulation is human disease surveillance and the monitoring of human health associated with the consumption of food is predominately the responsibility of the Health Protection Agency (HPA) who use human disease surveillance to detect the occurrence of outbreaks or epidemics so that immediate action can be taken to identify and control the source. In addition to these short term responses the HPA is also involved in monitoring long term trends in infections. This information is fed back into a number of organisations resulting in measures to reduce illness. In addition to this responsive surveillance, the HPA also has a Microbial Risk Assessment Group which has the specific remit of horizon scanning to identify and assess the threats posed by new or re-emerging infectious diseases. There is also Special Pathogens Reference Laboratory which has the remit of detecting new pathogens that emerge. These imply that if new pathogens emerge or existing pathogens increase in numbers then there are well developed structures in place to deal with these. In terms of chemical health surveillance, the Chemical Hazards and Poisons unit of the HPA collate details of chemical incidents some of which will be attributable to food consumption. However, because many chemical risks will be due to low level exposures over time and may emerge as disease (e.g. cancers) many years after exposure, attribution is difficult. The HPA has published estimates of the health impacts of environmental pollutants upon health, some of which may affect people through food. However, the results are not subdivided into food and non-food vehicles (HPA, 2005). Epidemiological studies of data on cancer registries which may indicate the effects of pesticides and veterinary medicine residues in food are carried out by other organisations such as university departments. The above sections have discussed the numerous mechanisms in place to control food quality and respond to problems which arise. It is important to re-enforce the point that human, animal and environmental health are inter-related and so good communication between these different groups is essential (FAO, 2008a).

8.5.9 The previous sections have presented much evidence on food regulation. However, the key question is whether these regulations are effectively protecting UK consumers from food safety risks. In terms of public perception, confidence in all organisations involved in protecting health with regards to food safety is currently 59% and over time this figure has shown a steady increase (FSA, 2009d). In terms of the chemical safety of food the effectiveness of regulations can be evidenced by the fact that the majority of food samples analysed were within regulatory standards. In terms of food borne illness there have been recent reductions in the numbers of cases, although the numbers do fluctuate from year to year (FSA, 2008). The response to specific food safety events can also be used as evidence of effective regulation as seen in the public enquiry (e.g. The Pennington reports on VTEC outbreaks; Pennington Group, 1997). Finally recent work on food borne illness has demonstrated that the impact of temperature upon food borne illness has reduced over time and argued that this is evidence of improved food safety practices (Lake et al., 2009).

8.6 SUMMARY: IMPACT OF CLIMATE CHANGE UPON FOOD SAFETY

8.6.1 One impact of climate change may be changes to the chemical and microbial contamination of food because of changing patterns of crop production, agricultural intensification and altered transport pathways. However, the overall consequences may be limited in the UK due to the many mitigation policies presented in Section 8.5. These are protecting current consumers and have an important role to play in mitigating against the effects of climate change. Although much of our food is produced outside the UK many food standards are common throughout the EU and the UK has influence on these through its work with the institutions of the EU. Furthermore, through the EU the UK has scope to influence standards outside the EU and several examples of this have been mentioned in the previous section. In addition third countries must be able to produce to EU standards to have access to our EU markets. Finally, food purchasers in the UK (e.g. supermarkets) can also exert influence over standards from third countries.

8.6.2 An additional check on these regulations occurs through food surveys (statutory and non-statutory) which should ensure that any changes to the microbial and chemical contamination of food remain within regulatory limits. These apply to all food sold in the UK. However, it is important to recognise that food surveys can only survey a limited number of chemicals and microbes. Additionally, they can only examine a small proportion of food in the UK which could be a problem as some of the impacts of climate change may be localised. This highlights the importance of audit and HACCP tools to identify where in the food chain elevated risks may occur due to climate change. Appropriate action can then be taken to minimise many of these risks without the need for large surveys. Additionally audit and HACCP tools could be used to target food from areas where climate change may increase these risks. Such areas could be locations where major agricultural intensification is occurring, where changing flood cycles are occurring or areas that are being brought into food production for the first time. Furthermore, audit and HACCP enable regulators to identify potential sources of concern at a very early stage.

8.6.3 One common theme for pathogens and chemicals under climate change appears to be increasing unpredictability and change. Therefore, horizon scanning bodies such as the HPA's Microbial Risk Assessment Group and DEFRA's International Disease Surveillance team will become increasingly important in identifying potential hazards before they occur. Additionally it will become increasingly important to develop rapid detection methods for pathogens and chemicals in food and in humans and to communicate these quickly to regulators so that appropriate action can be taken in a timely manner. These processes will be aided by improvements to our understanding of how climate and weather affects the safety of food. Finally, as climate changes effects become more apparent it seems prudent to learn from the mitigation and adaption strategies being carried out by other Governments.

8.6.4 In Section 6.6 one potential impact of climate change highlighted was a move towards agricultural decarbonisation. It is important for regulators to use appropriate risk assessment methodologies to ensure that this does not have adverse impacts on food safety. Additionally, the food safety consequences of individuals choosing or being encouraged to consume food from more limited geographical extent needs to be researched. The latter is especially important as climate change may lead to localised impacts upon food safety.

9 Engendering engagement and behaviour change

9.1 Introduction

9.1.1 Section 5.3 has demonstrated that food is an important contributor to climate change and in the UK one response to climate change may be initiatives to reduce these emissions. A certain amount of GHG emissions can be saved through agricultural decarbonisation and waste reduction but, especially if large carbon reductions are required, then there may be initiatives to affect the types of food that individuals consume because food choice has a large effect upon GHG emissions. Should such a move occur then it is important to consider the best methods to affect behaviour change.

9.2 The evidence

9.2.1 It is important to base attempts at behaviour change around nutritional and climate change goals on solid evidence both of what changes are needed, and of the mechanisms needed to engender the desired changes. It is clear that behaviour change is complex and difficult, and shouldn't be undertaken lightly. Behaviour change in this context may be to promote positive changes around prevention of climate change, food safety or improved nutrition, or to prevent changes for the worse in any of these fields.

9.2.2 A recent major review of how to motivate sustainable consumption sheds light on the main models of consumer behaviour and discusses policy options for behavioural change (Jackson, 2005). The review found that information campaigns are not effective ways to learn - we are more likely to base our behaviour on trial and error, observation of others and modelling our behaviour on how others behave - choosing others who are attractive to us, or influential, or who are similar to us. Effective persuasion includes understanding the target audience, and using this understanding to make an immediate and direct imaginative and emotional appeal. It tends to use individual commitment and buy-in, using techniques like loyalty schemes and retrieval cues (stimulus that helps us recall information in long-term memory) to catalyse new behaviours. A supportive social environment can help us to 'unfreeze' existing behaviours, examine them, and then choose new behaviours to be established into new habits.

9.2.3 Policy to support pro-environmental behaviour have tended to use actions from the rational choice model of behaviour and result in provision of information to modify attitudes and knowledge or to modify prices via taxes and incentives to support desired behaviours, but evidence suggests that such interventions, at least on their own, are not effective. What appears to be a more fruitful approach is to ensure that incentives and institutional rules all favour the desired behaviour(s), to enable access to choice, engage people in initiatives to help themselves, and to demonstrate the desired changes within the institution or government (so that its own practice is exemplary). Policy may include the following types of approaches to influence behaviour (Jackson, 2005):

- Incentive structures (including taxes, subsidies and penalties)
- Facilitating (providing information on and access to low GHG foods)
- Improving the institutional context (including rules, regulations and market structures supporting the provision of safe and nutritious lower carbon diets, this might include standards for the carbon cost of growing, transporting, storing and cooking of particular foods, and GHG emission assessment standards)
- Optimising the social and cultural context (governments send messages about national priorities and goals, what types of behaviours are rewarded and what types of attitudes valued, influencing social norms - and consistency within government is key here)
- Encouraging or legislating in good business practices (so that eating safe low GHG healthy foods at work, at school or in hospital will encourage individuals to eat safe low GHG healthy foods at home)
- Supporting communities to engender social change, and supporting community-based social marketing strategies
- Ensuring that the organisation’s own environmental and social performance is exemplary

9.2.4 NICE recently reviewed the evidence on behaviour change (NICE, 2007), and their findings were not dissimilar to those of the Sustainable Development Research Network report above (Jackson, 2005), they included the following:

- Careful planning, including assessment of the target group, and the behaviour which is to be changed
- Work together with the community (including other organisations) to decide on and develop initiatives
- Build on the skills and knowledge that already exist in the community, including encouraging support networks
- Consider specific barriers to change of the target group and help to solve them
- Base all interventions on evidence of what works

- Train staff to help people change their behaviour
- Evaluate all interventions
- Focus on individual, social, environmental, economic and legislative factors that affect people's ability to change their behaviour
- Mechanisms that may be effective in some circumstances include legislation and taxation, mass media campaigns, social marketing, community programmes, point of sale promotions.
- Population-level interventions have the greatest potential, if supported by government and implemented effectively (for example, legislation making it compulsory to wear seatbelts in the front seats of cars).

9.2.5 Examples employed by the FSA of the above types of strategies include the salt reduction strategy that has included negotiation to reduce the salt level of processed foods so that consumers can reduce their salt intake with little effort, as well as a mass media campaign and social marketing to encourage shoppers to purchase lower salt versions of foods. This appears to have had a small but positive effect, with average salt intakes of men aged 18 to 60 falling from 10.2 g/day (SD 3.98) in 2006 to 9.68 (SD 4.10) in 2008, and in women from 7.7 (SD 2.8) in 2006 to 7.66 (SD 4.77) in 2008 (www.food.gov.uk/multimedia/pdfs/englandsodiumreport.pdf and www.food.gov.uk/multimedia/pdfs/08sodiumreport.pdf). Plans are being developed for similar strategies to target saturated fat intake in the near future (www.food.gov.uk/consultations/ukwideconsults/2009/promolowfatprodssatfatreductions).

9.2.6 The complexity of behavioural change was confirmed in a review of the possibilities of using taxation to alter shopping or manufacturing behaviour. It concluded that taxation may be appropriate in helping to support behaviour change (Caraher and Cowburn, 2005), but that the effects of such taxes, especially on children and those with low incomes, should be carefully evaluated.

9.2.7 A recent review of the literature (Lorenzoni et al., 2007) found that while most members of the public have heard of climate change and are concerned about it, most do not take measures to reduce their energy consumption. Furthermore, those that do take action are motivated by financial and health reasons, rather than to mitigate climate change. Recycling appeared to be more common a behaviour than energy reduction, and there was resistance to changing travel habits. It also found that incentives and technological solutions have been more supported than taxation or higher energy bills in engendering behaviour change. This paper used mixed-methods to assess how people make sense of climate change and assess public engagement with it. Consistently with previous literature they found that people were widely aware of climate change but not engaged with it in terms of cognition, affect and behaviour. The barriers to this engagement that were identified (in studies in Norwich, the South of England and Rome) were both individual (including lack of knowledge, uncertainty and scepticism and distrust of information sources) and societal (including a belief that political actions should lead the way and/or will be ill targeted and ineffective and lack of business action) (Lorenzoni et al., 2007). Many of these barriers are seen as mechanisms of denial, to cope with the worry of the need to engage with climate change but a lack of actual engagement. They also found that more deprived groups experienced greater financial constraints and feelings of social alienation, suggesting that messages should be targeted to specific population groups. These issues are likely to be reflected in engagement with climate change as regards food and how we eat, and promotion of 'food miles' and its inadequacy are likely to promote individual uncertainty and scepticism.

9.2.8 Fear, while drawing attention to the issue of climate change, appears ineffective in encouraging genuine engagement in its mitigation. Non-threatening imagery that links everyday emotions and issues with mitigation appear most engaging.(O'Neill and Nicholson-Cole, 2009) Policy implications of this work are (Lorenzoni et al., 2007, Ockwell et al., 2009):

- Only a combination of individual (grass roots) and societal (top down) approaches will work, neither on its own has a chance of being effective.
- There is a need for basic information provision, sustained and from a trusted source - for those willing to mitigate climate change this will encourage them to make appropriate and positive progress. In terms of food issues, this might include carbon footprint labelling and information on diets that combine health and sustainability effects.
- Sustained messages from a trusted body, such as the FSA, would help to encourage acceptance.
- A social marketing approach encouraging awareness, acceptance and norms around action to combat climate change would be an appropriate approach to support the feeling that most people are making appropriate changes, encouraging individuals to join in.

- Providing these messages in a meaningful way, in the context of people's other concerns, for example in the context of a personal health, a healthy diet, saving money is likely to be most effective.
- Supportive infrastructure for individual change is also needed, designed to challenge habits and offer alternatives. An example of this might be labelling, reduced prices for lower carbon footprint foods, and/or taxation for higher carbon alternatives.
- Sustained support and positive reinforcement are needed to ensure continuance of new behaviours, and might include (as above) continuing financial benefits, local competitions with prizes, and free delivery of shopping or free buses.
- Long term structural change is also needed, and might be represented by allocation of personal carbon allowances, which would include food choices. Cross party work is likely to be needed to develop and support long term structural changes that would allow consistent solutions that bypass short term electoral issues.

9.2.9 In summary, behaviour change is complex and difficult and shouldn't be undertaken lightly. The strategies set out above provide some indications as to appropriate mechanisms to achieve change.

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