The University of Manchester
Sustainable Consumption Institute

INFORMING CHOICE
LEADING CHANGE

What's Cooking?

ADAPTATION & MITIGATION IN THE UK FOOD SYSTEM




Comments from some of our stakeholders on What's Cooking? Adaptation and Mitigation in the UK Food System

"This SCI report tackles head-on the key challenges of climate change and rising food demand. In particular we welcome its emphasis on the need to pay more attention to the emissions from agriculture in the future, the need to consider the embedded emissions in the food we import and consume as well as produce, and that simply providing information to consumers about their food choices is not enough without considering their wider cultural and social connotations with food."

Ann-Marie Brouder, Principal Sustainability Advisor, Forum for the Future

"The key message from this report is the diversity of potential scenarios. There is overwhelming evidence that the climate is changing; farmers are in the front line of this change. Nobody, however, can know the precise outcome. Hence, farmers and others in the food chain need to not only reduce their greenhouse gas emissions, but to develop systems, technologies and methodologies that allow them to adapt to the particular way in which climate disruption manifests itself in their region. Policy-makers need to put in place policies that are flexible enough to enable the food chain to respond to whichever scenario emerges over the coming decades."

Andrew Rigg, Farmer, Hill View Farm

"Thinking constructively about UK food's future, a highly complex non-linear system moving into an era of increasing uncertainty, is impossibly difficult. But we must try – it's so fundamental to our security. Scenario building is an important first step; a structured thought-process that breaks with linear thinking, it steers us beyond idle speculation and leads us to some uncomfortable places. It's far from simple in itself, but have you got a better idea? The authors have vigorously engaged with a wide range of people (it was intriguing to be one of them) as they strived to create some unnerving narratives. A dip into the report should start you thinking; the future won't be quite like any of the presented scenarios – so where are we going, what will it be like, and why?"

Peter Baker, Senior Scientist (Commodities and Climate Change), CABI

This report is impressive, as it has the potential to provoke a much needed wake up call to government, industry and consumers alike - all whilst remaining clear and accessible. There is much talk as to the serious challenges to be faced due to climate change but this report succinctly lays out the repercussions in real terms – along with potential ways in which to respond. Put simply - our consumption patterns need to become more sustainable. This is a challenge that the food industry can and should play a key leading role in. Regardless, the findings of the report are an essential insight for business.

Louise Neville, Sustainability Officer, Quorn Foods

What's Cooking?

ADAPTATION & MITIGATION IN THE UK FOOD SYSTEM

JULY 2012

A report prepared by the Sustainable Consumption Institute at The University of Manchester, UK.

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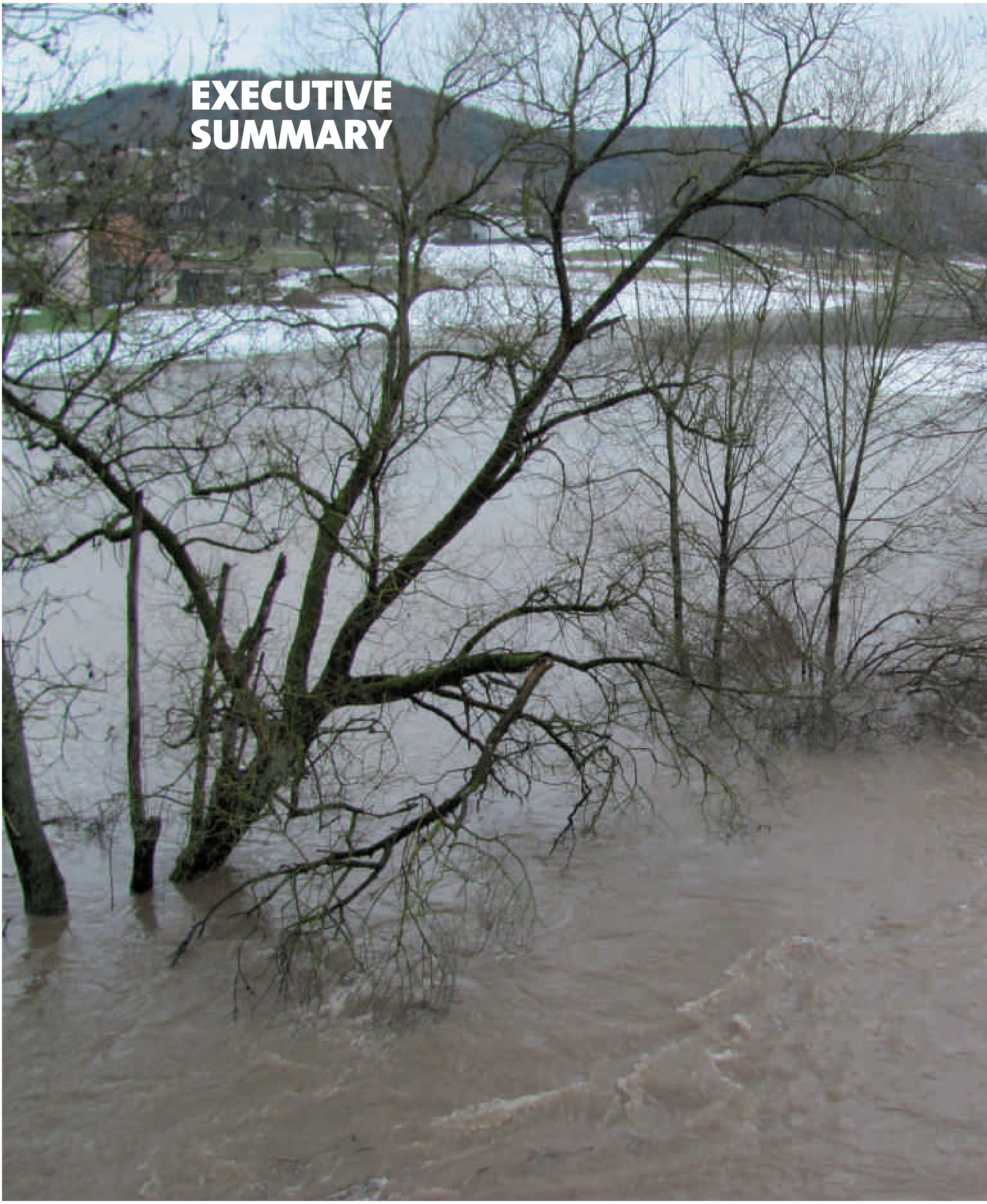

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Understanding climate change is pivotal to addressing the global demand for food. Although the extent to which climate change will exacerbate existing stresses or create new challenges for the food system is highly uncertain, finding ways to respond within this context is essential because:

1) A delayed response will lead to further accumulations of greenhouse gases and

2) The food system is inherently complex - eliminating uncertainty is not possible.

This report presents findings based on an interdisciplinary systems level scenario approach designed specifically to address complex societal problems. The project was funded by **the Sustainable Consumption Institute** to explore how the UK food system may develop and change in response to futures bounded by more or less extreme climate impacts and emission cuts.

Challenges facing food systems

The need to combine the challenges associated with a growing global demand for food, climate change mitigation and adaptation is more pronounced for the food system than for most other sectors. Many areas with a rapidly rising demand for food are also susceptible to early climate impacts, undermining growing conditions. In response, a greater use of agricultural inputs is required to maintain yields – further elevating greenhouse gas emissions. **Rising demand**, **adapting to climate impacts** and **reducing emissions** is a **triad of challenges** highlighting the need for a systemic approach that can consider the dynamic and complex nature of the food system.

UK food system scenarios

The UK is taken as a case study to explore suites of possible futures that address adaptation, mitigation and demand. To investigate how different scenarios may play out within the food system – from consumption to production – two contrasting climate futures are considered. One where mitigation and adaptation are commensurate with avoiding global temperatures breaching the 2°C threshold associated with 'dangerous interference with the climate system', and the other in a world aiming to avoid more than 4°C of warming. The analysis is framed by cumulative emissions, as opposed to long-term emission reduction targets, and takes a consumption-based approach to greenhouse gas emissions accounting. Five scenarios are developed, two in line with 2°C futures and three 4°C futures. Each is named after a typical meal: **Bubble & Squeak** & **Mash & Banger** (2°C), **Pasta & Pesto**, **Chicken Tikka Masala** & **Lab Chops** (4°C). The scenarios are developed through analysis of the coupled adaptation and mitigation strategies within agriculture, underpinning energy scenarios, in addition to a reallocation of patterns of consumer demand, all in order to mitigate emissions in line with the temperature targets. At each stage of development, stakeholder engagement formed a pivotal role, with experts from across the supply chain informing decisions and assumptions within the scenario development process. Moreover, consumer focus groups were invited to respond to some of the scenarios' core characteristics, to gauge acceptability and inform policy development. Although the scenarios are an outcome of the project, their most important role is as heuristics, providing key insights to the challenge throughout their development.

Key insights

A 'no climate change' future does not exist. The climate is changing because of our influence, and it will continue to do so. While this could be taken to be a hopeless message, instead it should be seen as an empowering one. It means that people, through personal choices, collective movements, technological inventions, organisations and positions of authority **have changed the past climate and will influence the extent of future change.**

Mitigation affects adaptation – adaptation affects mitigation... Cutting greenhouse gas emissions aims to reduce future climate impacts, but the converse is also important. Arguably more than other sectors, the food system will suffer climate impacts. With elevated temperatures and a shift in water resources, farmers will need to respond to more extreme weather events and different growing conditions. Areas that were once ideal for growing crops or rearing livestock may no longer be suitable. These impacts will influence levels of greenhouse gas emissions. The less suited an environment for a particular crop or animal, the more inputs will be required to maintain yields. Understanding the trade-offs and complementarity between mitigation and adaptation is essential to paint a realistic picture of future levels of emissions, and climate change impacts.

Rising food demand will elevate greenhouse gas emissions... The global demand for food will continue to rise in future decades. The more crops grown and livestock reared to meet this demand, the greater the amount of agricultural inputs and production effort required. Without efficiency or yield developments in low-input practices, careful land-use choices or radically new farming technologies, levels of greenhouse gas emissions will grow.

Solutions to mitigate non-CO_2 emissions associated with food are diverse. If these emissions must grow to support global food security, then nations with much higher per capita emissions need to find ways to reduce their contribution. At the production end, an efficient approach would be to maximise food production where inputs and emissions can be kept to a minimum. But an increase in demand for agricultural products at a national scale will be a driver for higher national greenhouse gas emissions under the current emission accounting framework.

It is important to see the full picture... The consumption-based accounting approach – which includes the emissions embedded in imports but excludes those from exports – is particularly appropriate for the food system because a high proportion of emissions are associated with the consumption of imported products[1] (29% compared with a national figure of 21% for the UK). Thus adhering to emissions targets that aim to reduce conventional production-based emissions will miss a very significant part of the problem. Complementing production-based accounting with a consumption-based one allows policymakers to consider the big picture, and increase their influence over global emissions and ensuing impacts.

Targets will be missed without integrating adaptation & mitigation... As much emphasis must be given to climate impacts and adaptation as is given to mitigation. This is particularly the case when considering the food system, to ensure the implications and risks associated with high temperature increases are not ignored in favour of assuming mitigation will successfully avoid 2°C of warming. Although UK arable farming may be favoured while temperatures elevate towards the 2°C threshold, above that, more severe impacts can reduce productivity. Reaping the benefits presented by climate change will also boost emission levels. Furthermore, the additional uncertain effects of extreme and disruptive weather events on the way towards the 2°C rise pose big challenges for the farmers.

Growth in consumption needs to be tackled to avoid 2°C... Taking the consumption-based approach to addressing mitigation means decarbonisation includes the emissions embedded within imports. As many countries will not have emissions targets or be signed up to reduce their emissions, this becomes more important the greater the level of mitigation sought. The UK currently maintains its commitment to the 2°C threshold. For futures aiming to avoid a 2°C temperature rise emissions intensities associated with imports must be reduced significantly and the demand for goods from those nations lowered[2]. This is in addition to a low-carbon energy transition and low- to zero

[1] Consumption here refers to goods and services consumed by UK households, government and purchased for capital investment.

[2] Reductions in imports from supplier nations, if replicated by other nations, would likely have negative economic implications for those nations.

growth in consumption[3]. Without such far-reaching change, the UK's consumption-based emissions will exceed the UK's contribution towards a reasonable probability of avoiding the 2°C rise.

Reducing emissions in line with 4°C is very challenging... Research on climate mitigation commonly uses '2°C' as a backdrop. There is much less discussion on what it means to mitigate to avoid 4°C. A common but misplaced assumption is that a 4°C rise is 'business as usual'. Yet limiting emissions in line with a 4°C global temperature rise is extremely challenging. For a nation such as the UK, cumulative emissions would need to be severely constrained, with reductions of at least 60% compared with 1990 levels by 2050 [2]. Avoiding 4°C is paramount but requires a step-change in action towards mitigation.

Agricultural emissions become more prominent in future... Mitigation is most commonly directed at CO_2 from fossil-fuel combustion. A transition to a decarbonised energy system by 2050 is considered feasible. But if this transition becomes a reality, emissions from sectors more difficult to mitigate will increase in share. Methane (CH_4) and nitrous oxide (N_2O) emissions from the food system fall into this bracket. Globally, ~13% of greenhouse gas emissions are from agriculture. Of this, less than 1% are CO_2, 53% CH_4 and 46% N_2O [17][4]. If the '2°C' scenarios are achieved, the UK's emissions profile will be increasingly influenced by CH_4 and N_2O[5] associated with food – a picture likely replicated elsewhere.

UK farmers express resilience... Farmers respond to weather on a daily basis. Their dominant perception of climate change is one of being able to draw on their flexibility to adapt to the changing environment. Farmers will continue to adapt, although use of indigenous knowledge will be challenged. Of greater immediate concern is how to 'adapt' to new lower-emission agricultural systems and how to respond to more frequent, recurring and extreme weather events.

The consumer vs retailer – a contested power relationship... The influence of key actors within the supply chain is of great importance for tackling food system emissions. Yet where the power resides in the chain is perceived differently depending on who is asked. While supermarkets highlight the power of consumers in driving and supporting change through lower-carbon consumption, producers tend to lay the balance of power at the door of supermarkets. New policy interventions should be considered from these different perspectives to ensure that, particularly voluntary measures are supported by those that can deliver success.

Information provision – necessary but not sufficient... A common response to addressing climate change through consumers is to provide information, in the form of marketing. However, whilst the level of knowledge may be a necessary condition of low carbon behavioural change, it is not sufficient as even those that are both knowledgeable and motivated face structural and cultural barriers to change. Given the deeply socially embedded and cultural nature of food and eating, information provision alone will not necessarily change food choices.

[3] As measured in the model in terms of £ spent

[4] These figures alter significantly if land-use change is included, with estimated shares of 57% CO_2, 23% CH_4 and 20% N_2O [38].

Livestock consumption may not be here to stay... Meat currently makes up ~14% of the daily UK calorie intake. The consumption-based emissions associated with unprocessed meat consumption are 15% of 'Food and Drink' emissions, excluding land-use change. However, meat is also consumed in combination with other ingredients in ready meals and other processed foods. 29% of 'Processed Foods' emissions are associated with meat, elevating the percentage of 'Food and Drink' emissions linked to meat to 28% under the consumption-based approach.

A shift towards a lower meat or a vegetarian diet is an obvious choice to reduce emissions. When consumers were asked to respond to this, they considered a 20% reduction potentially acceptable, but were reluctant to support a 70% cut, with concerns over maintaining an interesting and varied diet. Futuristic options such as laboratory grown meat received generally positive reactions with perceived benefits including improved animal welfare, standards and food safety. Meal pills didn't receive a warm welcome, with a lack of social aspect to enjoying a meal a reason to stick with more conventional fare.

We still have choices

The climate has begun to change because of our influence, and this will continue. The logic of this should be considered empowering. As citizens, professionals, decision- and policymakers we have the power to change and influence the prospective climate. **We have a choice**. This could be a high mitigation, low adaptation future – 2°C. Alternatively, it could be a low mitigation, high adaptation future, leading to 4°C of warming in the latter half of the century. The consequences of these futures are very different, and will remain uncertain. But the mitigation choices we are making must be commensurate with the advice and the communication of risk to those that will need to adapt to climate change. **Communicating the legacy of choices made in the short term to those in positions of influence needs much greater emphasis**.

The importance of food system emissions in the climate debate cannot be overstated. Only by acknowledging the extent of food-related emissions can we fully recognise the energy challenge, because all emissions are constrained by cumulative carbon budgets. Contrasting 2°C with 4°C futures goes some way towards achieving this goal. Currently we are implicitly mitigating for 4°C and adapting to 2°C; a complacent and precarious pathway. Instead, an explicit choice is needed given the implications of different climate futures for world regions. Moreover, if the international community considers 2°C to be a dangerous threshold, then new suites of policies and measures that can influence the full supply chain are required immediately.

[5] If land-use change is included, CO_2 emissions from agriculture will also be very important.

1. FOOD & CLIMATE CHANGE

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1.1 Introduction

Understanding climate change is pivotal to addressing the global demand for food. Although the extent to which climate change will exacerbate existing stresses or create new challenges for the food system is highly uncertain, finding ways to respond within this context is essential because:

1) A delayed response will lead to further accumulations of greenhouse gases and

2) The food system is inherently complex - eliminating uncertainty is not possible.

This leaves us with little choice but to devise novel strategies that can both support cuts to emissions, whilst protecting and improving the resilience of food systems in the face of escalating climate impacts.

The findings presented here are based on an interdisciplinary systems level scenario approach specifically designed to address complex societal problems. The project was funded by **the Sustainable Consumption Institute** to explore how the UK food system may develop and change in response to futures bounded by more or less extreme climate impacts and emission cuts.

Section 1 outlines the project framework – contrasting different climate futures from the perspective of both mitigation and adaptation. Tools to address the challenge – cumulative emissions and a consumption-based emissions accounting approach – are introduced and the specific case being studied – the UK's food system – is summarised. Section 2 describes the scenario approach and Section 3 presents five UK food system scenarios and associated consumer responses. Section 4 gathers together the key project insights and finally Section 5 concludes.

1.2 Challenges facing food systems

The necessity of coupling the challenges associated with climate change mitigation and adaptation is more pronounced for the food system than for most other sectors. Often areas with a rapidly rising demand for food are also susceptible to early climate impacts undermining growing conditions. If costs allow, one response to maintain supplies will be to increase agricultural inputs – but this will contribute to a rise in the greenhouse gas emissions for every kilogram of food produced, further increasing the risk of more severe climate change. Nonetheless, without action to improve yields, demand for food will either not be met, or prices will rise, with inevitable equity implications. This triad of challenges – ***rising demand***, ***adapting to climate change*** *and* ***reducing emissions*** – highlights the need for a systemic approach that can consider the dynamic and complex nature of the food system.

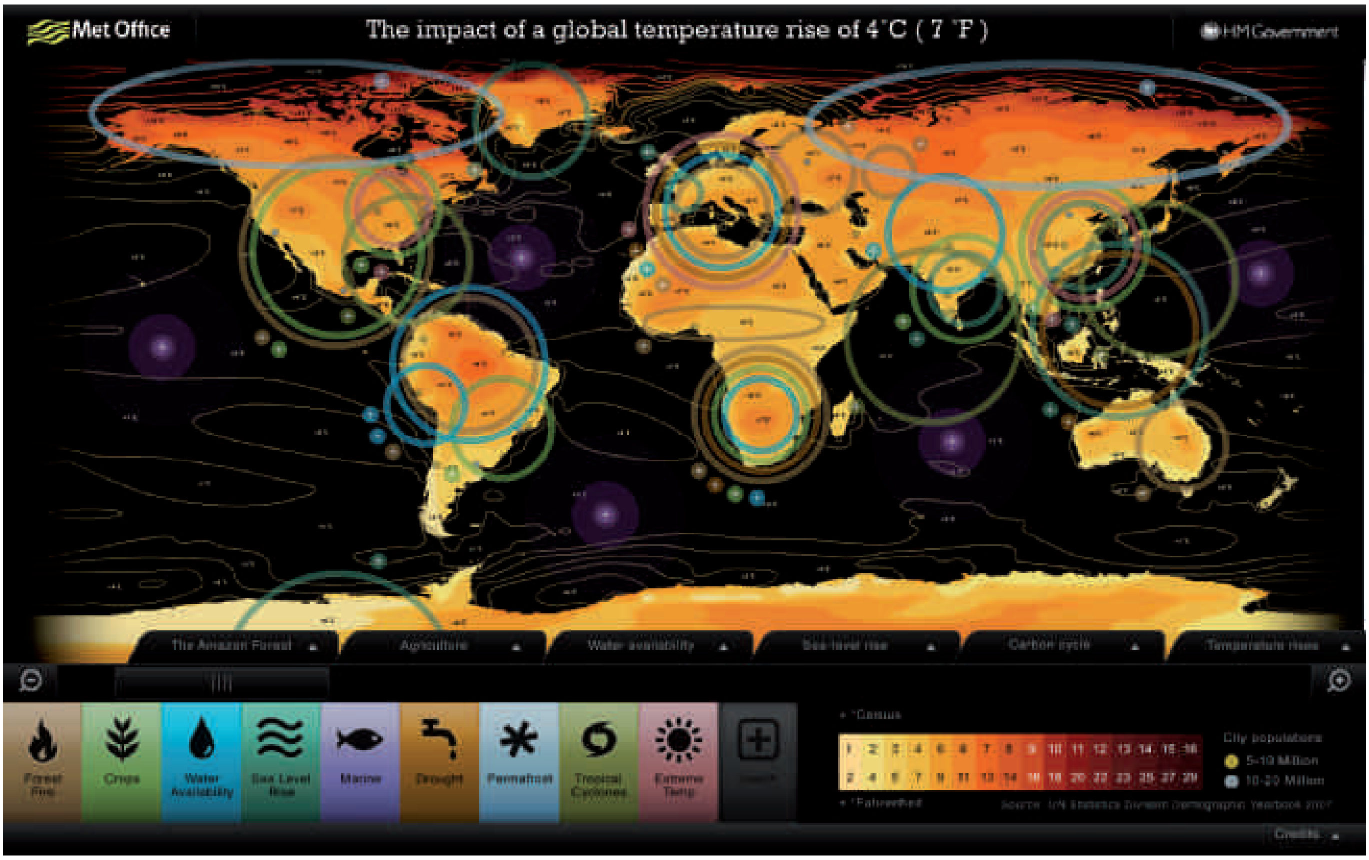
1.3 Contrasting 2°C and 4°C futures

Without knowing if and when there will be a global agreement to cap greenhouse gas emissions, it is increasingly unlikely that global mean temperatures will remain below the 2°C[6] threshold associated with dangerous interference with the climate system [1, 2]. Nevertheless, even at this level of global warming, there is a high likelihood of increased risks of extreme weather events, increased water stress, wildfire frequency and floods, widespread mortality of corals, as well as the possibility of reaching a tipping point[7] [4]. A more extreme, but still not a worst-case outcome of rising greenhouse gas emissions [5], would be a 4°C temperature rise over a similar timescale (by 2100). Studies suggest that with 4°C as a global average, impacts include temperature increases of 6 to 10°C compared with the current hottest days within cities such as Rome or Chicago [6] (Figure 1). Examples of other impacts include drought events occurring twice as frequently across southern Africa and the Mediterranean basin; a 40% reduction in the maize and wheat yields in low latitudes and a 30% decrease in rice yields in India, China and South East Asia. These extremely damaging impacts highlight the need to explore altogether more

[6] 2°C refers to the rise in global mean temperatures above the pre-industrial mean.

[7] A tipping point is when the climate system may flip into a new equilibrium state. For more information see Lenton et al., (2008) [3].

Figure 1:
UK Met Office and Foreign & Commonwealth Office's Google Earth 4°C Interactive Map [6]



radical futures. Depending on the level of future climate impacts, regions currently productive and serving global and regional food demand may no longer be able to provide the same crops, or provide at all.

1.4 Where is current policy leading?

A common discourse when engaging with stakeholders is around two potential futures:

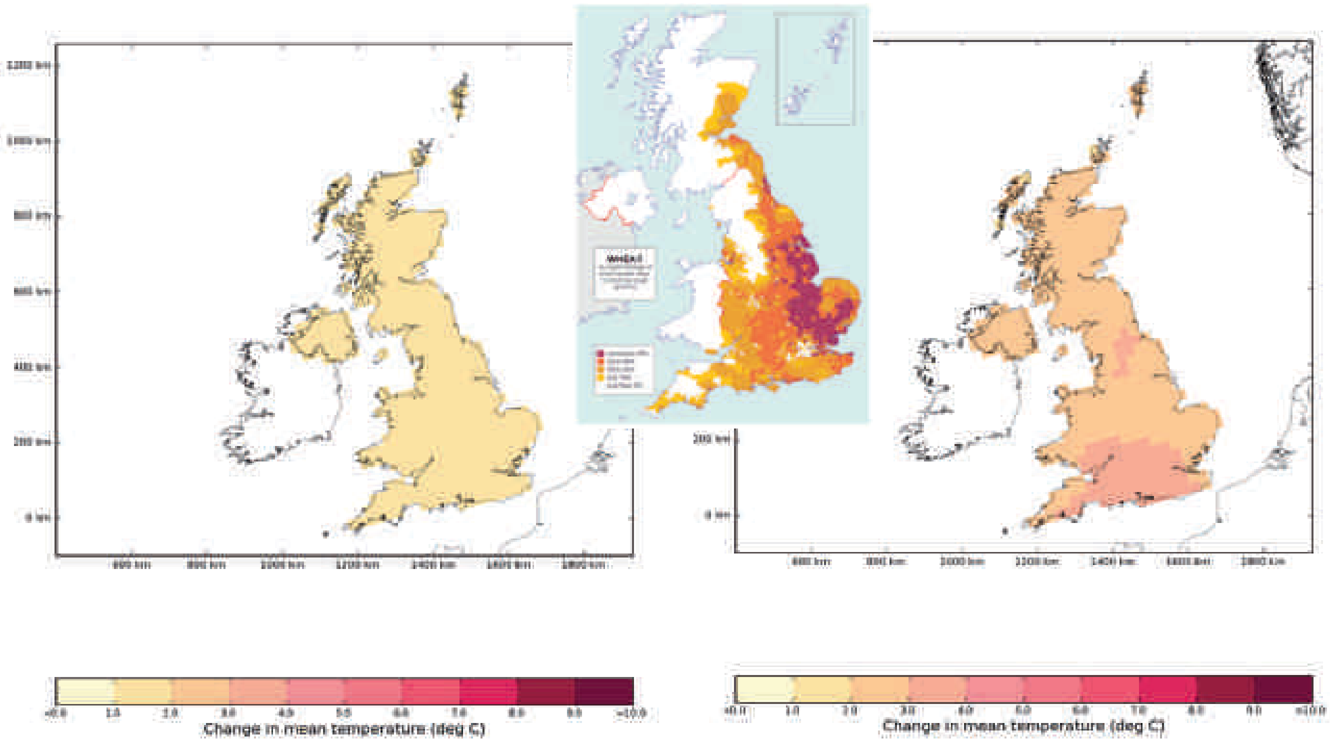
- Avoiding climate change
- Experiencing global average temperatures rising by 2°C[8]

In other words, 'no climate change' or 'some climate change'. However, at the Durban 2011 climate negotiations a decision was taken to adopt a legal agreement to cut emissions "as soon as possible and no later than 2015" [7]; a step in the right direction? Unfortunately, climate science shows us that to limit temperatures to a 2 to 2.4°C rise above pre-industrial levels, emissions globally must reach a peak by 2015 [8] – which would be well before a legal agreement takes effect. This means that the world is failing to mitigate emissions even in line with avoiding 2°C implying widespread impacts necessitating disruptive levels of adaptation. Questioning if an alternative low adaptation future remains is legitimate, but conventional political constraints on feasible rates of emission reductions need to be put to one side, and the physical constraints on emission cuts to rise in importance.

[8] Sometimes stated as above pre-industrial levels and other times above 1990 levels.

FIGURE 2:

Contrasting impacts on UK temperatures for two scenarios from UK Climate Projections 2009 [9] and the current main wheat producing regions [10]



As an illustrative example: temperatures associated with '2°C' may favour growing conditions for wheat in the UK. To produce the same amount of wheat, less fertiliser per kg of grain is likely required. But, if the UK experiences temperature rises in line with a global 4°C rise, UK wheat production will likely become disadvantaged. Greater inputs would be needed, emissions higher, and yields lower [11]. The UK Climate Projections 2009 illustrate how the UK's temperatures will differ under alternative scenarios, and the graph of the UK from the Home Growers Cereal Association [10] shows where wheat is currently grown in the UK for comparison.

A **no climate change** versus **some climate change** choice is not available, rather 'lower mitigation, higher adaptation' (e.g 2°C)[9] versus 'higher mitigation, lower adaptation' (e.g. 4°C), and these paint very different pictures of the future. Contrasting 2°C with 4°C, from both a mitigation and adaptation perspective, avoids the misconception that there is a 'no climate change' future and ensures (AB) efforts are not wasted on idealised, unrealistic solutions to either mitigation or adaptation in isolation from each other.

1.5 CARBON BUDGETING

To explore what different futures imply in terms of the constraints on emissions and timing of policy responses, a carbon[10] budgeting framework is used. This assumes that, for certain levels of climate change, a limited amount of greenhouse gases can be released [12, 13]. Within certain bounds, the higher the carbon budget, the higher global temperatures rise. The carbon budget works in a similar way to a monthly salary – the more spent in the first few weeks, the less available at the end. So, for the same climate impact, if emissions are not cut sufficiently in the

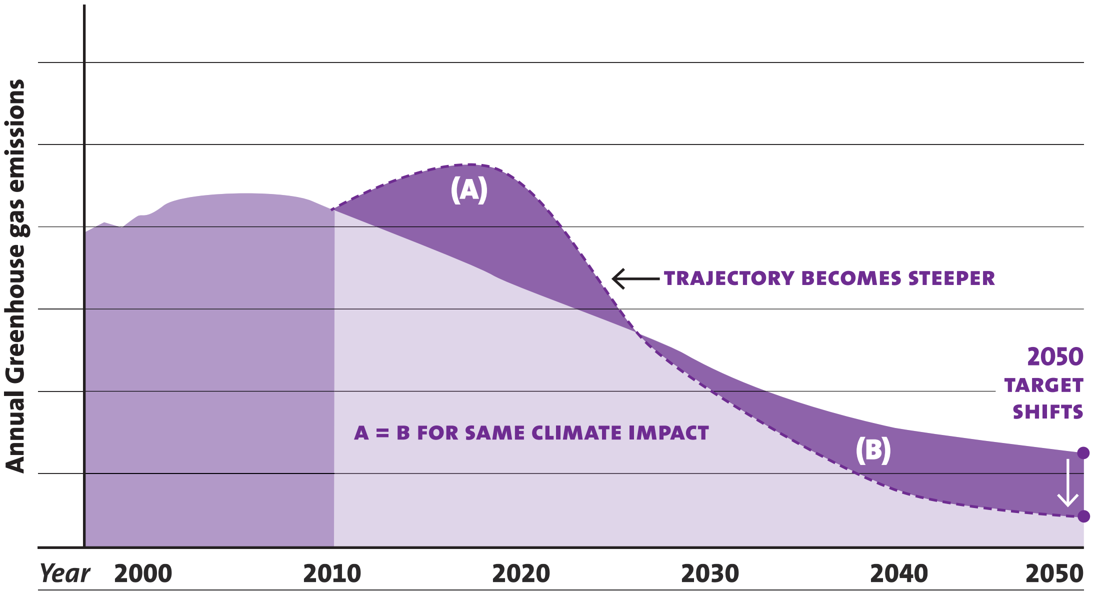
[9] Note that in this case it is assumed that there is only a low to moderate chance of avoiding 2°C.

[10] Here used as short-hand for greenhouse gases.

FIGURE 3:

Schematic of the implications of the cumulative emissions framework

Based on Bows et al., 2006 [14] and related research



early years, more rapid rates of reduction are needed to remain in budget. This also affects long-term targets. For instance, the UK's 2050 target of reducing emissions by 80% from 1990 levels (70% for agriculture) will need to be strengthened if emissions are not cut sufficiently early on (Figure 3).

This budgeting approach has been particularly influential when considering low carbon energy system transitions [15, 16] where the dominant gas is carbon dioxide (CO_2). However, when it comes to the food system, there are other gases that consume significant portions of the available budget – methane (CH_4) and nitrous oxide (N_2O). The long life-time of N_2O makes it particularly appropriate for considering in the budgeting approach. But doing so points the finger towards a looming challenge...if demand for food continues to grow, additional agricultural inputs such as fertiliser will increase N_2O year on year. As it accumulates in the atmosphere, the available budget dwindles, leaving even less room for energy-related CO_2 (Figure 4).

On a global scale, ~66% of greenhouse gases are CO_2 from the combustion of fossil fuels and industrial processes, 12% CO_2 from deforestation, and the remaining 22% are non-CO_2 greenhouse gas emissions associated primarily with agriculture, waste and industry [17]. The importance of these non-CO_2 gases has arguably been overlooked when it comes to carbon budgeting, as illustrated in Figure 4. Moreover, although the N_2O is less dominant, currently at ~34% of the non-CO_2 gases, options to reduce CH_4 particularly from waste, are more forthcoming than mitigation options for N_2O [18]. Plus, population and food demand projections suggest significant increases on today's global food production will be necessary. This implies that in future, the greatest proportion of non-CO_2 emissions is likely to be from agricultural N_2O.

1.6 CONSUMPTION-BASED APPROACH

The carbon budgeting framing of the problem highlights the need for policy measures that deliver short-term emission reductions. Without such measures, the mitigation challenge becomes more severe, with more adaptation necessary. Reducing levels of absolute emissions

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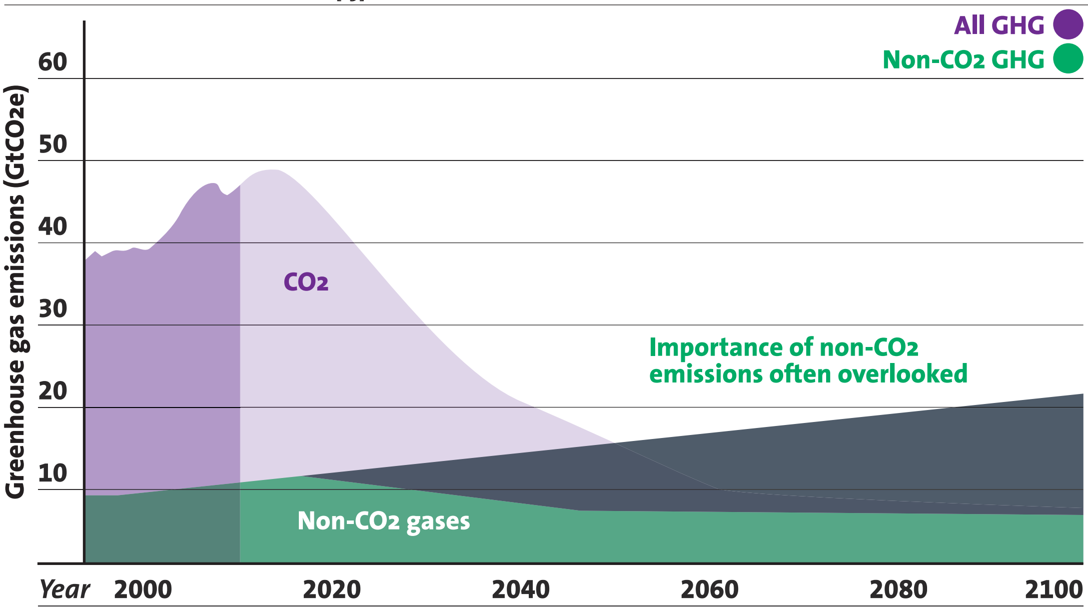
FIGURE 4:

Schematic illustration of the implications of a growing amount of non-CO_2 emissions on the overall carbon budget

Based on Anderson and Bows, 2008 [13] and associated research



The area under the curve represents cumulative emissions. The green area represents non-CO_2 greenhouse gases. The dark grey triangle is the area required for non-CO_2 greenhouse gases, if they continue to grow at current rates.

in the near term will not be achieved through the development and deployment of large-scale energy infrastructure, or new technologies designed to reduce agricultural inputs, because these measures take many decades to be realised. What can take effect in the here and now are changes to patterns and levels of consumption, be it energy or food. This is not to suggest that social practices or behaviours will alter swiftly, easily or voluntarily, but that a focus on consumption, in addition to production, offers complementary opportunities and scope for change.

Taking this approach down to a national scale, a consumption-based emissions inventory is used here to illustrate the important contributions to UK emissions, both across the entire economy and in particular, related to agriculture and food. The contrasting picture from a 'production-based' perspective is shown for comparison in Figures 5.

The consumption-based approach [19] is used throughout this report because of its ability to trace the drivers of greenhouse gases down supply chains, and provide insights into the importance of emission reductions in nations from where the UK is importing goods. For example, for the UK to severely cut its consumption-based emissions, it must also take into account how well importer nations are doing at cutting their own emissions. Although a consumption-based approach encompasses the emissions associated with all the goods and services that are bought in the UK, this report focuses on the implications of climate change for the UK food system.

The 'Food and Drink' category in Figure 5a is the most important aspect of this. Making up 11% of total UK consumption-based greenhouse gases, it incorporates emissions associated with the food and drink consumed by UK households and government.[11]

[11] In keeping with a consumption-based accounting framework, emissions associated with food consumed in restaurants and cafes are classified within the 'Commercial Services' category and those food emissions are not included in the 11%. Similarly the emissions associated with food consumed at workplace canteens etc are classified within the sector of the respective workplace.

FIGURE 5A:
UK emissions from a consumption-based accounting framework

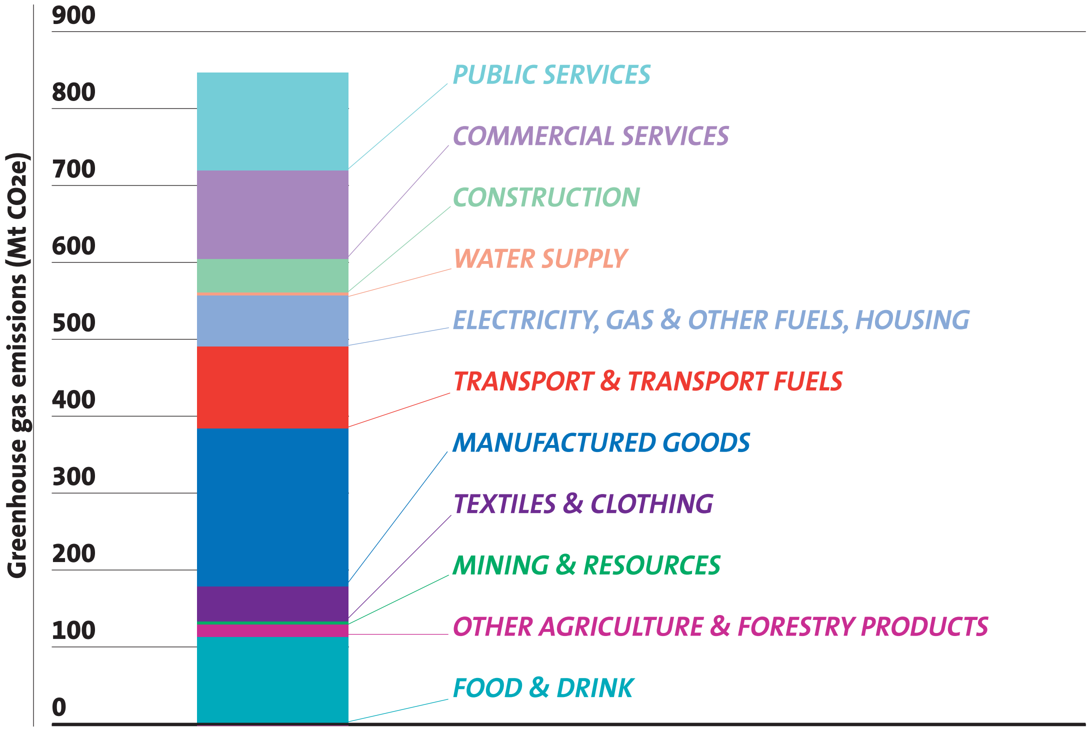
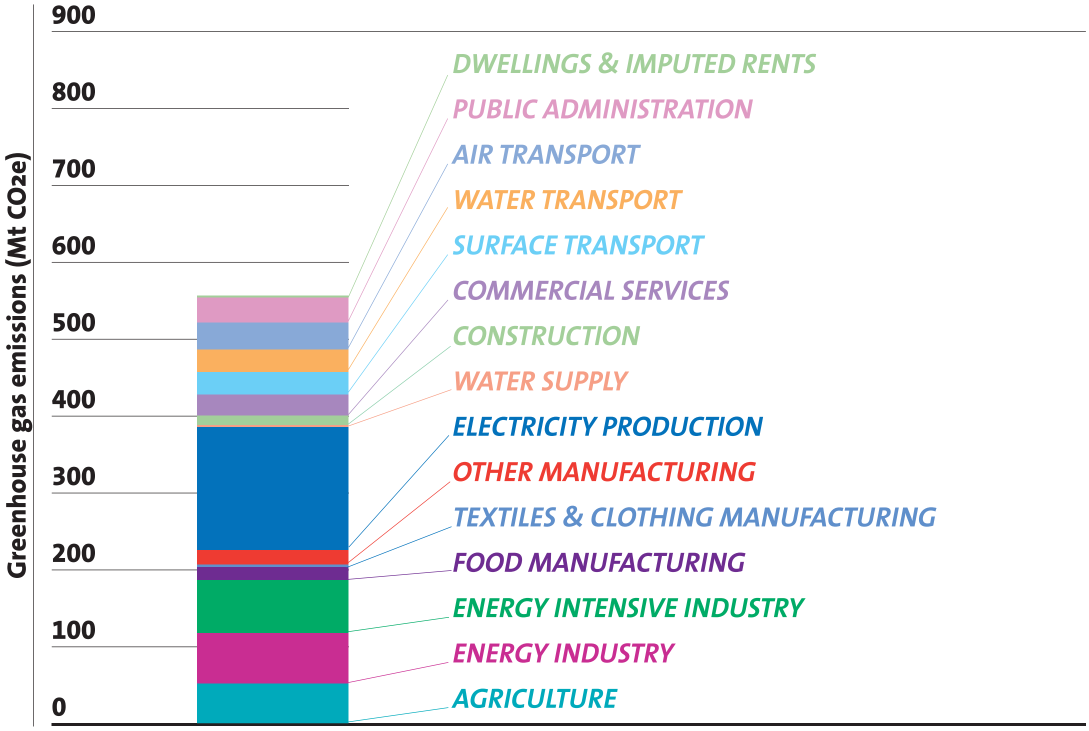


FIGURE 5B:
UK emissions from a production-based accounting framework



2. THE SCENARIO PROCESS

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2.1 What are scenarios?

A scenario is a vision of the future, a synopsis of what may happen when given assumptions about future trends and drivers. With a long history of use across many fields, including business and policy, scenarios can support strategic planning in the face of uncertainty. Their purpose is not to predict the future but to facilitate a better understanding of alternative futures [20]. They are particularly useful in considering complex issues and the interactions between facets of society.

The evolution of the UK food system, and the impacts of climate mitigation and adaptation upon it, exhibits a complexity that makes it well-suited to scenario analysis. Food producers must respond to changing market conditions whilst being impacted by the weather and, in the longer term, a changing climate. Climate change impacts will be felt throughout the food system as, for example, retailers try to secure their supply chains, or consumers face the prospect of novel foods, less variety or higher prices.

Our food habits are also a reflection of the wider socio-cultural setting. Food is both a necessity and means of expression of wider beliefs, values and enjoyment; food prices and income can have a huge impact on health and happiness. Through scenario development, this complexity and interaction between elements of the food system can be illustrated in an understandable way. Scenarios have been used to explore food futures

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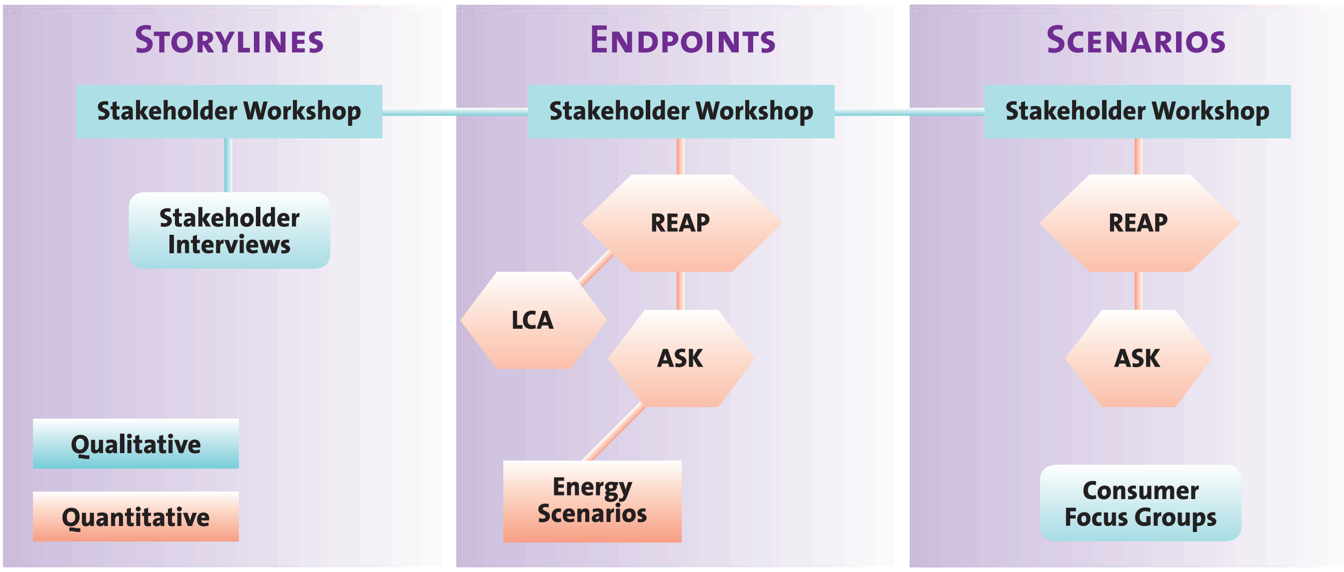
FIGURE 6:
Scenario development process diagram, where ASK is the Tyndall Energy Scenario tool, REAP is the Stockholm Environment Institute's Environmentally Extended Input-Output model and LCA reflects greenhouse gas balancing done for a selection of agricultural products.



in the context of climate change by a variety of organisations including the UK Government, the Food Ethics Council and the Food and Climate Change Research Network [21-23].

There are many different types of, and approaches to, developing scenarios[24]. Sometimes they appear to be caricatures, which can be useful to explore extremes and clearly distinguish the influence of features or events; whilst they must always be credible, they may challenge how people view the future and what's possible.

The **SCI's Food System Scenarios** are developed by an interdisciplinary team using a participatory approach, combining qualitative and quantitative analysis (Figure 6). Five scenarios have been developed, two exploring strong efforts to mitigate climate change and three featuring greater emphasis on adaptation, each focusing on the UK food system. They begin with a set of 'endpoints', expressed as a descriptive 2050 narrative and backed up with detailed quantitative emissions analysis. A backcasting process is then adopted to devise realistic pathways from the present to 2050. This analysis also considers how the food system is embedded within the wider economy and energy system and the implications for cumulative emissions.

This methodology is designed to exploit the expertise of both food system stakeholders and the project team. Stakeholder engagement in the process enriches the scenarios by the inclusion of a wide range of knowledge and perspectives. The process can be as significant as the outcome, providing learning opportunities for both stakeholders and researchers, extending understanding across supply chains and exposing the bigger picture. Outputs are likely to be more grounded and useful beyond academia when a diverse community contributes to their development. The scenarios are, however, a product of the project team's interpretation of the stakeholder inputs and thus implicitly influenced by their values.

These scenarios are not predictions but describe five visions of very different possible futures and routes by which they could materialise.

2.2 SCENARIO INPUTS

A broad range of quantitative data and qualitative analysis grounds the **SCI's Food System Scenarios**. Scenario inputs include information on the current and future state of the UK's energy system, levels of emissions intensity of goods purchased from overseas, assumptions regarding developments in the agricultural sector and related supply chains, and the type and quantity of demand for consumer goods. A schematic outlining the information flow from the different engagement activities into the development of the scenarios is presented in Section 2.2.1. This includes some of the most pertinent findings from each stage of engagement. An accompanying diagram for the quantitative modelling framework is shown in Figure 8.

2.2.1 Scenario stakeholder engagement

STAKEHOLDER ENGAGEMENT PROCESS

Stakeholder interviews focused on current pressures on the food supply chain to inform initial scenario development

Scenario workshop 1
Stakeholders gave feedback on the project framing and considered characteristics of the 2050 UK food system in 2°C and 4°C worlds

Four end-point scenarios were drafted, incorporating stakeholder views and experience

Scenario workshop 2
The draft end-point scenarios were presented to stakeholders from across the food system. Participants were asked for feedback and to share opinions and knowledge on the pressures affecting the food system in general

The end-point scenarios were revised on the basis of stakeholder feedback and an additional scenario developed; the scenario emissions were quantified using the 'ASK-REAP' model

Backcasting workshop
Five finalised end-point narratives and emission profiles were used as the basis for a backcasting process where stakeholders identified the most challenging and different elements of the scenarios before devising policy, technical and behavioural pathways to deliver the scenario endpoints

Pathways narratives were written by the SCI project team and cumulative emissions estimated

FINDINGS FROM STAKEHOLDER INTERVIEWS

Climate scepticism – are extreme weather events evidence of a changing climate or just 1/100 events?

Climate change considered an opportunity for the UK as competitors suffer more severe impacts

Agricultural land considered a 'sink' for CO_2

Some areas already highly efficient due to cost pressures (e.g. pig and poultry farming)

Accurate data collection on farm emissions and mitigation measures is challenging

Pressure of producing more food as global population rises

Genetically modified (GM) foods may become a necessity – lose the "luxury" of objecting

Language of win-win or retailer demand necessary to get many actors engaged

Many SMEs too focused on survival to divert resources to longer term and strategic issues

INSIGHTS FROM SCENARIO WORKSHOP 1

"UK wheat production is already very efficient but with scope to improve yields further"

"Climate change impacts will affect the distribution of wheat production, yields and choice of varieties"

"Consumption and lifestyle changes may be necessary for climate impacts on production and mitigation"

"Mitigation measures for livestock production could raise consumer animal welfare concerns"

"Agricultural breeding programmes can develop crops more suited to a changing climate"

"GM offers the potential to aid mitigation and adaptation, if opposition can be overcome"

"Intensification of agriculture and supply chain consolidation will occur, but to an unknown extent"

Visions of a 2°C world

The integration of bio-energy and livestock farming offers the potential for a win-win mitigation option

Some mitigation approaches could conflict with other concerns e.g. biodiversity or animal welfare

2°C offers opportunities for low investment technological mitigation solutions (e.g. precision farming)

A high carbon price to support mitigation could lead to increased forestry

Good agricultural conditions could lead to new crops and markets improving UK self-sufficiency

Visions of a 4°C world

Water availability will be an issue and a deciding factor on crop choice

Crop choice may be restricted by weather, but impacts could be lessened by controlled environments

Diet restrictions may be enforced due to weather influencing the crops that can be grown

Countries may reduce exports to protect their own food supplies

Increased adaptive capacity will be required to respond to an uncertain climate future

ADVICE FROM SCENARIO WORKSHOP 2

"Choose scenario names that better reflect content; simplify diagrams"

"Avoid assuming high tech supply chains mean complicated or heavily processed products"

"Include innovative applications of traditional technology such as vertical farms and permaculture"

"Better develop meat storylines in many of the scenarios e.g wealth/consumption; diary/red meat"

"Add a more technologically 'radical' scenario"

Missing elements from the scenarios identified:

- eating outside the home
- the influence of supermarkets
- biotech farming of high tech foods
- improved fertiliser efficiency
- more radical changes to consumption

The scenarios were revised in response to the Workshop 2 outcomes and advice

OUTCOMES FROM THE BACKCASTING WORKSHOP

Key features of the scenarios were identified focusing on:

- what is "most different" from today?
- what is the "most challenging" to achieve?

Using these features, visual timelines were devised describing:

- how to reach each endpoint
- transition points
- drivers
- changes that take place

The timelines were interpreted by the team into additional narratives and indicative emission pathways

FIGURE 7:
Schematic to illustrate the quantitative modelling underpinning the scenarios

Change in emissions in the production of goods and services

Future emissions embodied in goods and services

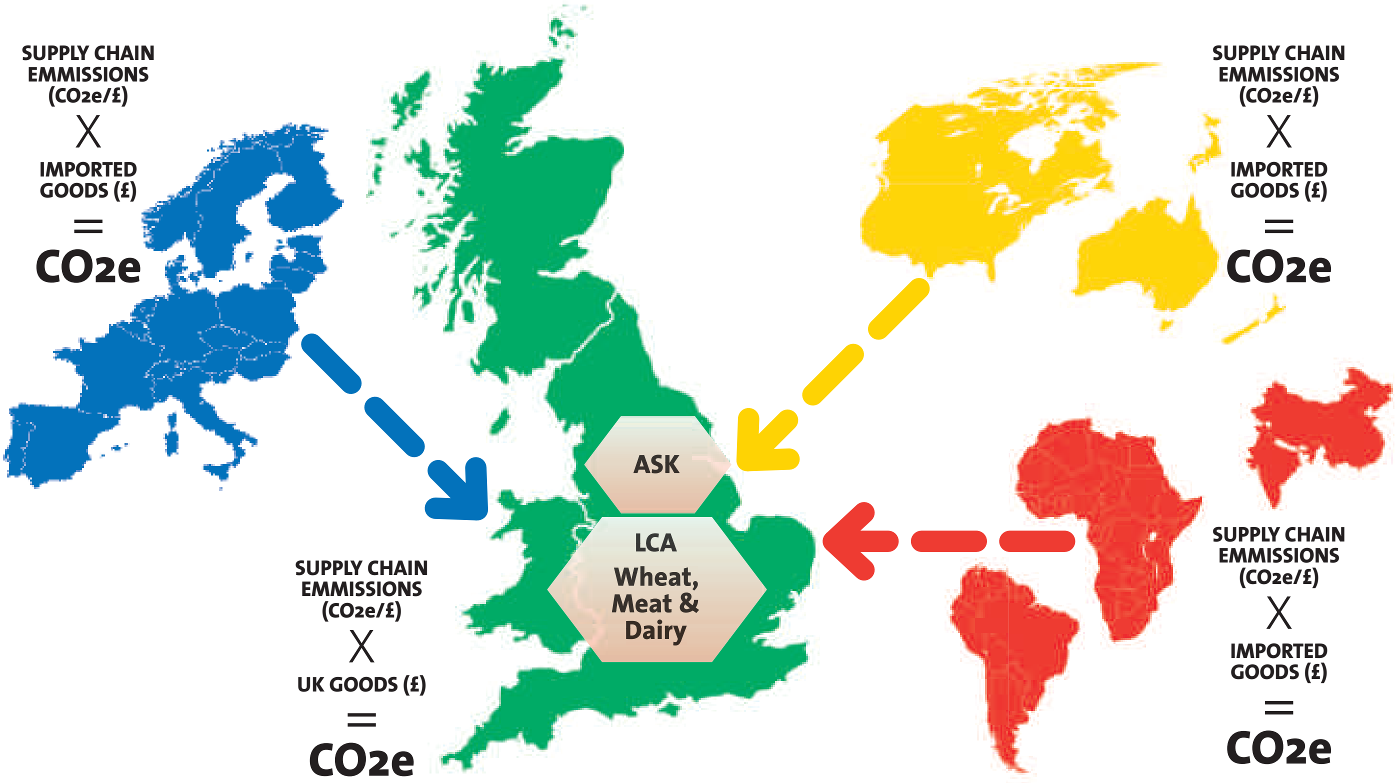
X

Future Consumption

=

Future Consumption Emissions

FIGURE 8:
Principle steps of the emissions quantification process using ASK-REAP



2.2.2 QUANTITATIVE MODELLING

The emissions for each scenario are quantified using a consumption-based accounting tool - REAP*. REAP is a global economic trade flow model that reallocates supply chain emissions to the final 'consumer'[12] (Figure 8). Using an input-output framework, the tool includes all contributions to producing a good or providing a service, wherever in the world they originate[13]. While REAP allows exploration of the impact on emissions of consumer goods and service choices, additional manipulation is required if the future emission intensity of production changes. To address this, the Tyndall Centre's energy scenario generator, ASK, is soft linked to REAP. The new model is called ASK-REAP.

ASK-REAP quantifies emissions across the entire economy, but more in-depth analysis for the food system was deemed necessary in the first instance, to ensure consideration of future climate impacts. Thus stakeholder insights were combined with greenhouse gas balancing to quantify the implications for global agricultural production of changing temperatures and precipitation, new technologies and agricultural practices.

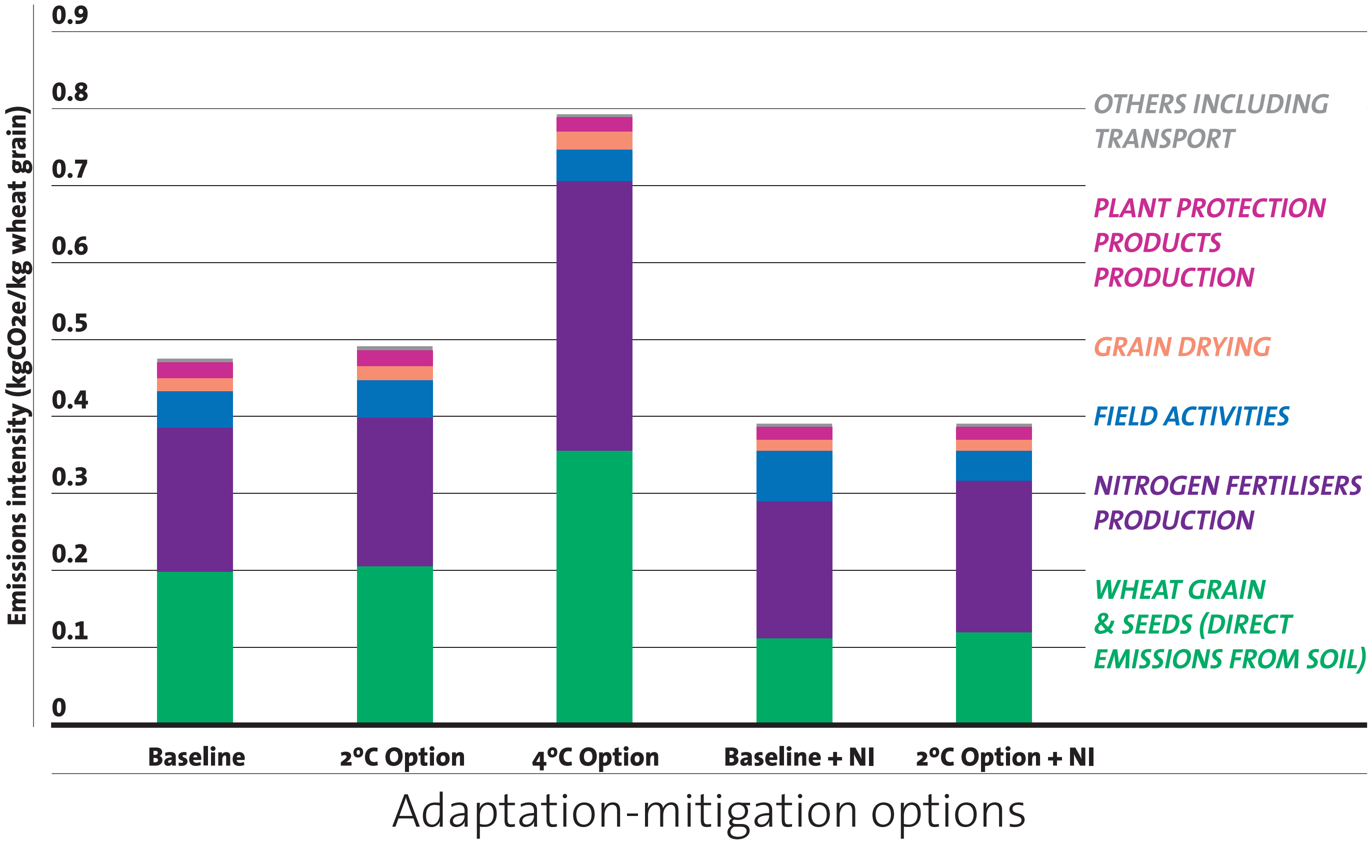
Results from this first stage highlight that for the UK, temperature increases up to 2°C can lead to cereal crop yield improvements. But, to access higher yields, more fertiliser input is needed. Although emission intensity reduces (per kg), the overall increase in fertiliser use elevates absolute emissions (Figure 9).

* REAP is a multi-regional input-output model developed by Hertwich and Peters [43] that uses a Global Trade Analysis Project (GTAP) dataset [44].

[12] 'Consumer' is householder, government or capital spend.

[13] For this analysis a four region input-output model is used. The regions are UK, EU excluding the UK, other Annex B and non-Annex B nations.

FIGURE 9:
Greenhouse gas balance for wheat in terms of global warming potential



In some other production regions, even moderate temperature increases require additional fertiliser just to maintain yields. The higher temperatures rise, the more pronounced this becomes. Growing food demand needs production and hence emissions to increase, despite improved yields in places like the UK [11]. A rise in UK agricultural emissions is inconsistent with its emission targets, yet failure to increase production could negatively impact on food security in vulnerable regions.

Combining these insights with estimates of emissions savings delivered through a variety of agricultural technologies and practices (see Table 1) provides the emission intensity of agricultural production in the scenarios. Existing suites of energy scenarios (e.g. [14, 25, 26]) were then incorporated to quantify the energy-related[14] emission reductions from food processing, distribution and retail. Finally, scenario narratives were used with REAP to relocate production-related emissions to the final goods and services consumed to give the emissions associated with UK consumption (Figure 7).

[14] The release of HFCs and PFCs from refrigerants was not included in the study. By 2050 it is assumed that alternative coolants or cooling methods are universally adopted.

3. FOOD SYSTEM SCENARIOS

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The process of developing the SCI's Food System Scenarios requires a solid understanding of the defining characteristics of the present UK's food system. Section 3.1 highlights a selection of 'baseline' indicators, and uses the power of the input-output approach to show how the food system's emissions spread well beyond the 'Food and Drink' category, through the supply chain, and across the world.

3.1 UK food system characteristics[15]

Shopping habits are influenced by many factors including: affluence, food prices, food availability, eating habits and lifestyle, household make-up and ethnicity. In 2009, UK households spent £23.86 per person per week on food and non alcoholic drinks, with total consumer expenditure on food, drink and catering amounting to £182 billion in 2010. Food prices for UK consumers have been rising since 2007, after falling between 1998 and mid 2007. Prices peaked in 2009 due to rising fuel and agricultural commodity prices, and following a small fall, are continuing to rise in line with inflation. Initially consumers reacted to increases by cutting back and purchasing less food, but demand has started to rise again, suggesting that consumers are coming to terms with higher food prices.

Although eating patterns can follow a routine, they are not set in stone. Traditional eating patterns of 3 meals a days are changing and people are more likely to snack or eat smaller meals throughout the day. Growth in convenience food has resulted from the demand for meals that are easy to cook so that family members can eat at times that suit them (to fit in with a daily routine for example), or which require little skill in cooking and preparation [27]. A desire for convenience and the significance of food for pleasure and lifestyle are reflected in a trend towards increased eating out[28]. The restaurant sector in the UK is diverse, offering a huge variety of cuisines and types of outlet.

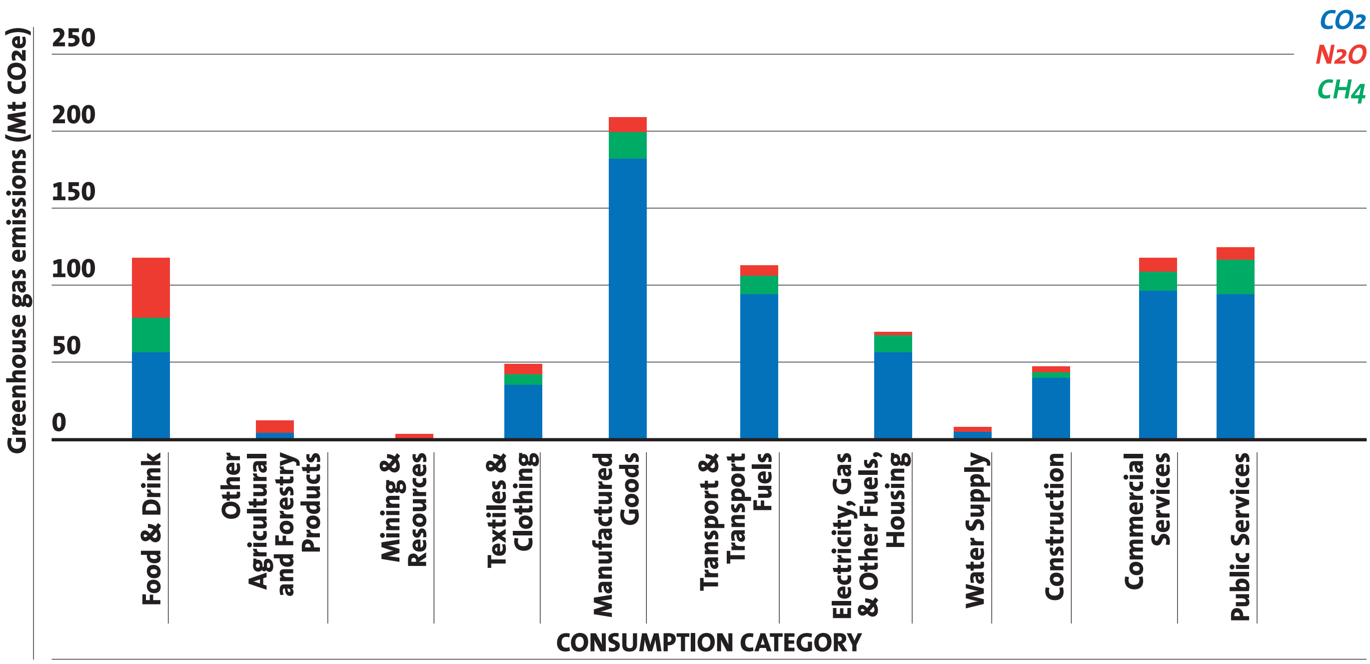
In England in 2009, 61% of adults and 30% of children were overweight or obese. UK food purchase data indicates that, with respect to dietary needs, consumers are buying too little bread, rice, potatoes, pasta and other starchy foods and too little fruit and vegetables. The proportion of protein such as meat, fish, eggs or beans is about right but too much milk and dairy products and foods and drinks high in fat and/or sugar are purchased. Only a quarter of people manage to eat the recommended 5 portions of fruit and vegetables a day and consumption is falling. Not only are not enough purchased, but fruit and vegetables are, together with bread, the food most likely to be wasted by households; overall 17% of food purchased is thrown away.

The UK grocery market is relatively concentrated in the hands of major retailers compared to many other European countries, with the four largest retailers accounting for approximately two thirds of food sales. In the UK, this process of consolidation began in the 19th century, driven by urbanisation, rising incomes and technological advances [28]. During the 20th century, planning regimes, changing consumer demands, self service and growth in car, fridge and freezer ownership all underpinned a shift from frequent trips to several high street retailers to bulk-buying and less frequent trips to a single store. Bulk shopping tends to take place in large supermarkets, where shoppers can get everything under one roof, but there has been recent growth in top-up shopping in convenience stores [27] which is more likely to take place in city centres [29]. This growth can be attributed to changing lifestyles, such as longer working hours and an increase in working women.

Consolidation has shifted power within the supply chain towards major suppliers. Pressure to reduce costs, ensure continuous availability of products and streamline distribution has enabled large retailers to exert huge

[15] Unless otherwise referenced, all figures from DEFRA Food Statistics Pocket Book, 2011, [30].

Figure 10:
Greenhouse gas emissions associated with the 2004 UK split by consumption category



pressure along the supply chain[29]. Supermarkets are also adept at marketing of products, and are able to offer prime spaces on shelves, or special offers to competing suppliers in return for favourable prices or other concessions.

Just under half of food consumed in the UK is supplied from domestic sources and 90% of food is sourced from 27 countries including the UK. Diversity of supply is deemed necessary to enhance food security[30] and varies across categories:

- 24 countries accounted for 90% of fruit and vegetable supply (UK supplied 23%)

- 4 countries accounted for 90% of dairy produce and egg supply (UK supplied 81%)

- 11 countries accounted for 90% of supply of cereals and cereal preparations (incl. rice)

With imports in 2009 valued at £32.5 billion compared to £14 billion for exports, the UK has a trade gap for food of £18.5 billion. The trade gap has more than doubled since 1995 reflecting changes in competitiveness and consumer taste. The impact of mad cow disease, stronger sterling and foot and mouth were key factors limiting exports after 1995.

3.2 UK baseline emissions

The emissions associated with the UK food system can be more readily understood if embedded within the other sectors of the economy. Figure 10 shows the greenhouse gas emissions associated with supply chains of goods and services consumed. What is particularly noticeable about 'Food and Drink', is that more than any other sectors, a high proportion of the emissions are the non-CO_2 gases, CH_4 and N_2O.

Unpacking the data a stage further, it is possible to identify firstly, what sub-categories and which gases contribute to the emissions from 'Food and Drink' (Figure 11).

The dominant sub-categories differ depending on which gas is being considered. The energy use in 'Processing Food' is visible in the CO_2 emissions, whereas 'Meat' (after processed foods)

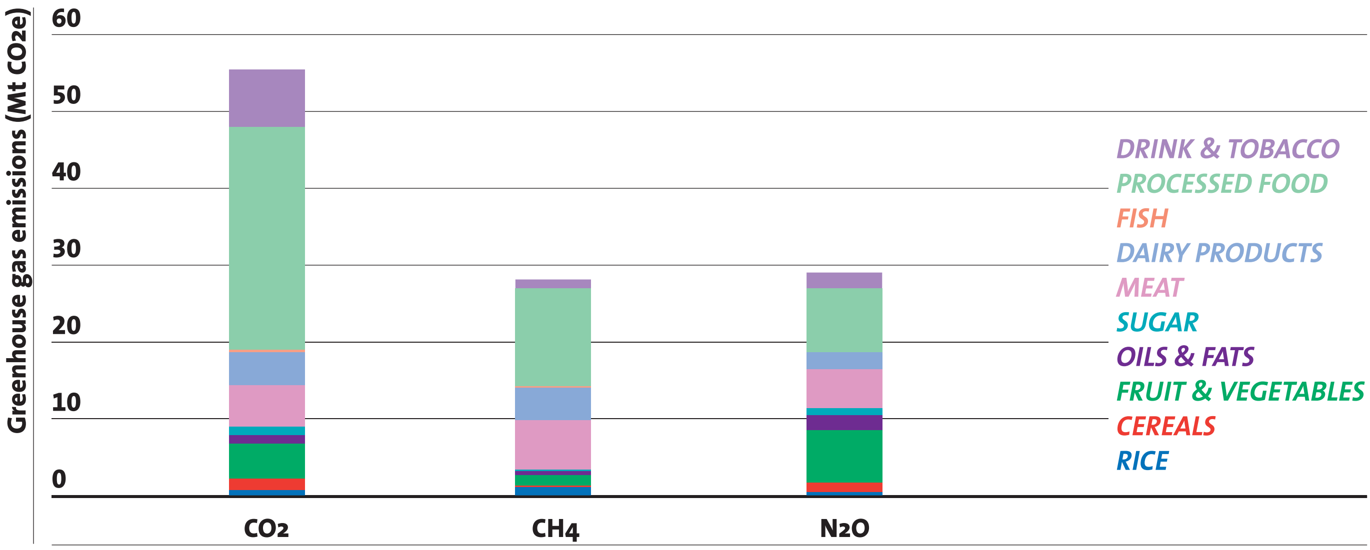
TABLE 1
SCI SCENARIOS FOR THE UK FOOD SYSTEM

	BUBBLE & SQUEAK	MASH & BANGER
GLOBAL TEMP CHANGE	+2 Degrees	+2 Degrees
ANNUAL GPD CHANGE	0.7%	1.6%
SOCIETAL CONTEXT	Government led change with public support	Government and society move together towards lower carbon diets
RESPONSE TO CLIMATE CHANGE	Strongly proactive towards mitigation through measures tackling consumption Proactive consumption changes shield UK from unstable climatic conditions overseas	Strongly proactive towards mitigation through a push down supply chains and response to food safety concerns Use of technology to proactively shield UK from unstable climatic conditions overseas
R&D INVESTMENT	Public funding for skills and training used in UK and exported	Public and private investment in wide range of food-system technologies
INTERNATIONAL CONTEXT	Increased exports of crops Towards self-sufficiency in meat Reduced vegetable imports from outside EU – low carbon domestic products preferred	Reduced imports from nations impacted by climate change Towards self-sufficiency in meat and wheat Imports meet strict UK emission standards
FOOD PRODUCTION		
TECHNOLOGY	Revival of robust varieties with good yields Focus on best practice and integrated systems	GM crops and livestock Widespread use of enclosed environments
CROPS (production)	Dominance of conventional production but increasingly extensive, integrated and organic Legume rotations Cover crops Low tillage Zoning optimised for low-emissions and increased yields	Widespread enclosed production of veg & fruit Vertical urban farms for suitable crops Precision farming through computerised crop management of inputs to optimise nitrogen uptake Closed yield gaps
CROPS (fertiliser)	Increased use of plant-based and manure fertiliser Nitrification inhibitors combined with conventional mineral fertiliser	GM and precision farming reduces fertiliser inputs Nitrification inhibitors combined with nitrogen fertiliser
LIVESTOCK (production)	Dual purpose meat and dairy cows reduce meat yields Methane reduction through diets, breeding & vaccination to improve digestion and prevent micro-organism activity Increased dairy and poultry production	Separate meat and dairy herds Methane reduction through GM, diet and fertility improvement Animals reared indoors and emissions captured Air filtration in animal enclosures for ammonia & methane capture
LIVESTOCK (manure)	Best practice – avoiding anaerobic conditions for solid manure Anaerobic Digestion treatment Integrated production systems	Controlled indoor environment Air filtration in manure sheds for ammonia capture Anaerobic digestion treatment
FOOD CONSUMPTION		
PER CAPITA CONSUMPTION[16]		
CEREALS	Small decrease (10% wheat)	Moderate increase (20%)
MEAT	Moderate decrease (20%)	Very large decrease (70%)
DAIRY	No change	Moderate decrease (20%)
FRUIT & VEGETABLES	Very large increase (75%)	Very large increase (100%)
PROCESSED FOODS	Small decrease (10%)	Moderate increase (20%)
CONSUMPTION BEHAVIOUR		
MEALTIME CULTURE	Eating houses	Same meals, more kitchen gadgetry
ETHOS	Sustainability	Safety consciousness
SHOPPING	Only buy what you need Make use of leftovers	Conventional food purchased online
DIET	Well balanced and less red meat	Vegetarian and high fat

PASTA & PESTO	CHICKEN TIKKA MASALA	LAB CHOPS
+4 Degrees	+4 Degrees	+4 Degrees
0.9%	1.4%	1.45%
Market dominance driven by price volatility and lack of availability	Partnerships between private and public sectors	Government led change with private sector support
Reactive to severe climate impacts in UK and overseas Weakly proactive action to mitigate emissions Practices respond quicker than technology to change	Strongly proactive towards adapting to severe climate impacts through technological solutions that protect UK food-systems Proactive towards mitigation through technological changes suited to new protected growing environments	Strongly proactive to adapting to severe climate impacts in UK and overseas through a managed transition in agriculture Proactive towards mitigation through whole-system shift in food-system provision and roll out of personal carbon budgets
Investment where market dictates	Private sector investment in protected growing environments and maintaining food supplies	Private sector investment in artificial meat and pill replacements
Ever changing patterns of international trade Climate impacts drive severe market volatility Imports according to availability	Approaching self-sufficiency Imports meet strict UK emission standards	Increased trade with EU Imports from beyond EU limited to luxury foodsEU emission standards extend beyond EU
Traditional breeding Moderate technology developments highly cost dependent	GM crops Widespread use of enclosed environments	GM for fuel crops Specialised crops and livestock bred to resist high temps and water stress Laboratory-grown meat and pharmaceutical meal pills
Intensive large farms Higher inputs per unit of output Climate impacts yields Widespread best practice Widespread protected (enclosed) production	Outdoor crops impacted by extreme weather events Indoor production allows optimal yields, outdoor production suffers reduced yields	Agro-forestry and intercropping widespread for food and fuel Higher inputs per unit of output Reduced yields
Nitrification inhibitors combined with mineral fertiliser Higher temperatures require more organic and mineral fertiliser	Outdoor crops require more fertiliser GM and precision farming reduces relative fertiliser inputs	Higher temperatures where conventional crops remain require more fertiliser
Climate reduces pasture quality Climate increases risk of disease Practices focus on reducing emissions Decreasing meat and dairy yields	Animals reared in protected indoor environments Air filtration in animal enclosures for ammonia & methane capture Yields maintained	Specialised livestock breeds within forest Greater risk of disease for livestock Reduced yields Increased game production
Temp-induced increases in emissions	Controlled indoor environment Air filtration in manure sheds for ammonia capture Anaerobic digestion treatment Temperature control of stored manure	Only managed where livestock is kept at farms Emissions from free-range animals reduced due to natural recycling in forests
Same as 2004	No change	Moderate decrease (20%)
Small decrease (10%)	No change	Very large decrease in animal meat (80%)
Small decrease (10%)	No change	Very large decrease (80%)
Small increase (10%)	No change	Moderate decrease (20%)
Small increase (10%)	No change	Large increase (50%)
Fuel not fun	Cafe culture and ready meals	Quick fix pills, shakes and lab-grown products
Apathy	Choice and convenience	Functionality
Buy what you can get Predominance of long shelf life goods	Pre-prepared food purchased online	Meal replacements supplied to match personal needs Traditional foods more scarce
Meets calorific rather than nutritional needs	Varied	Well balanced

[16] Population is rising according to Median UN projection [31] therefore total consumption may increase.

FIGURE 11:
Sub-sets from the Food and Drink category for CO_2, CH_4 and N_2O for the UK in 2004



is an important contributor to the CH_4 emissions through enteric fermentation, and 'Fruit and Vegetables' lead to the production of a large proportion of the N_2O emissions from the direct emissions from fertiliser use.

A further disaggregation highlights the most important supply chain contributions to the production of emissions. This is made possible through the use of REAP. For instance, the CO_2 emissions from UK electricity use are important, as is electricity use from the other three world regions (Figure 12). This is linked in particular to the electricity required to process food.

For the CH_4 emissions (Figure 13), the dominant supply chain contributions come from UK and non-Annex B livestock production, followed by milk production in the UK. This means that to cut the UK's consumption-based CH_4 emissions, the supply from non-Annex B nations either needs to be addressed through supply chain influence, or if that was deemed too challenging, consumption of those products reduced.

Finally, a different picture is observed when considering the N_2O emissions (Figure 14). In this case, the contribution from the production of imported fruit and vegetables takes the largest share. The UK's own livestock production comes a close second.

What this baseline analysis illustrates is the important contribution made to the 'Food and Drink' category through the supply chain world-wide. This consumption-based accounting approach – which includes the emissions embedded in imports but excludes those from exports – shows that for UK 'Food and Drink', 24% of CO_2 emissions, 38% of N_2O emissions and 29% of CH_4 emissions are associated with imported products – an average of 29%. This compares with 21% for the entire economy.

It is the significant contribution of these supply chain contributions that makes it particularly challenging for the UK to reduce its consumption-based emissions to the same extent as can be achieved through a UK-alone transition to a low-carbon economy – particularly when addressing the food system. The constraints that this places on mitigating emissions, but also the opportunities for change, are highlighted through the presentation of the scenario results.

Figure 12:

Baseline (2004) supply chain CO2 emissions from the Food and Drink category

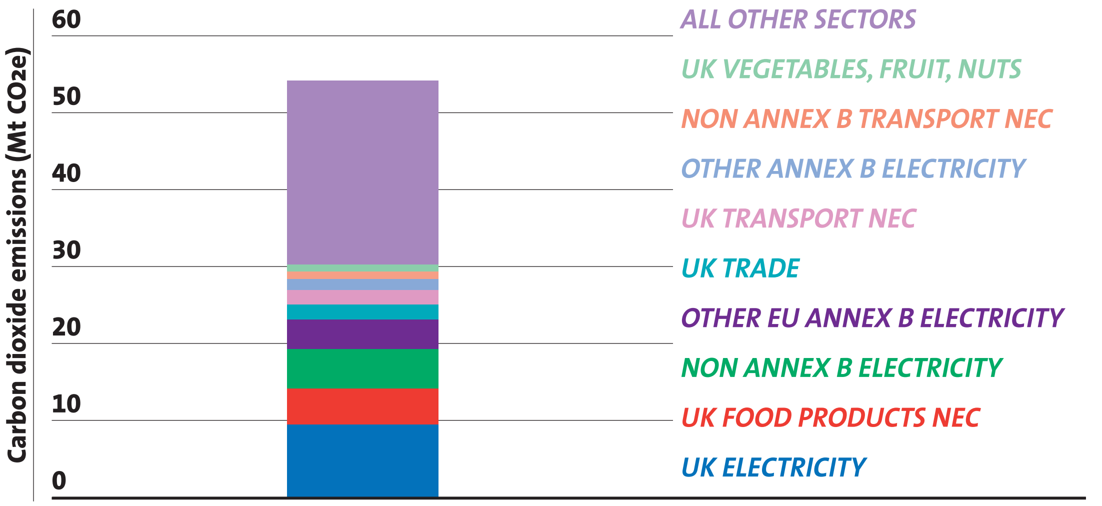


Figure 13:

Baseline (2004) supply chain CH4 emissions from the Food and Drink category

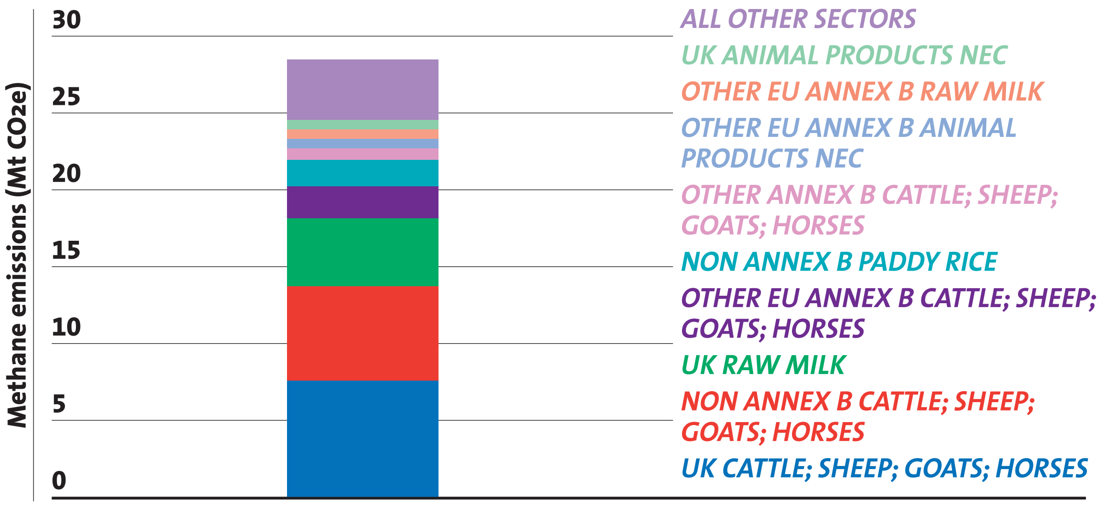


Figure 14:

Baseline (2004) supply chain N2O emissions from the Food and Drink category

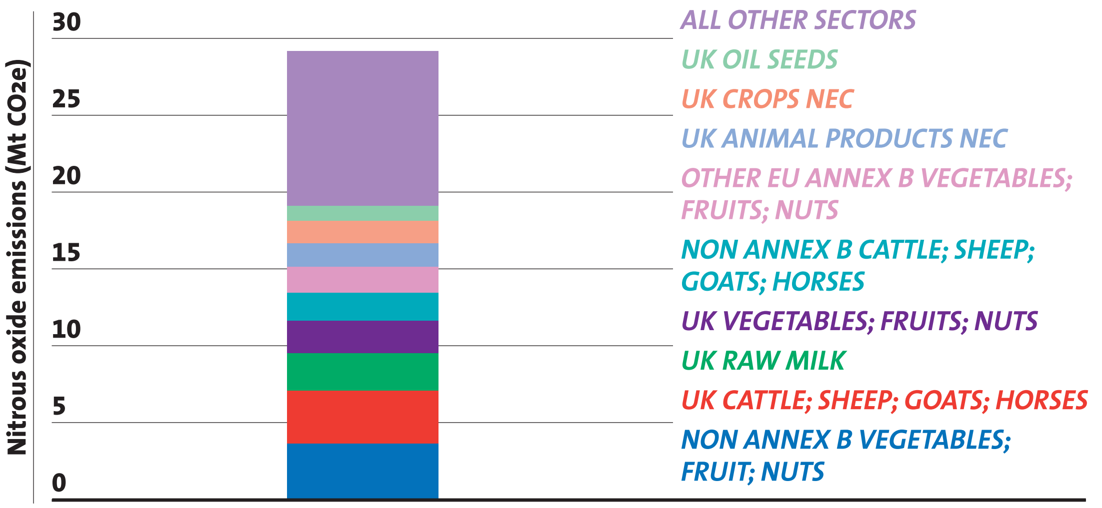


FIGURE 15:
Economy wide greenhouse gas emissions for the baseline year and five SCI Food System Scenarios

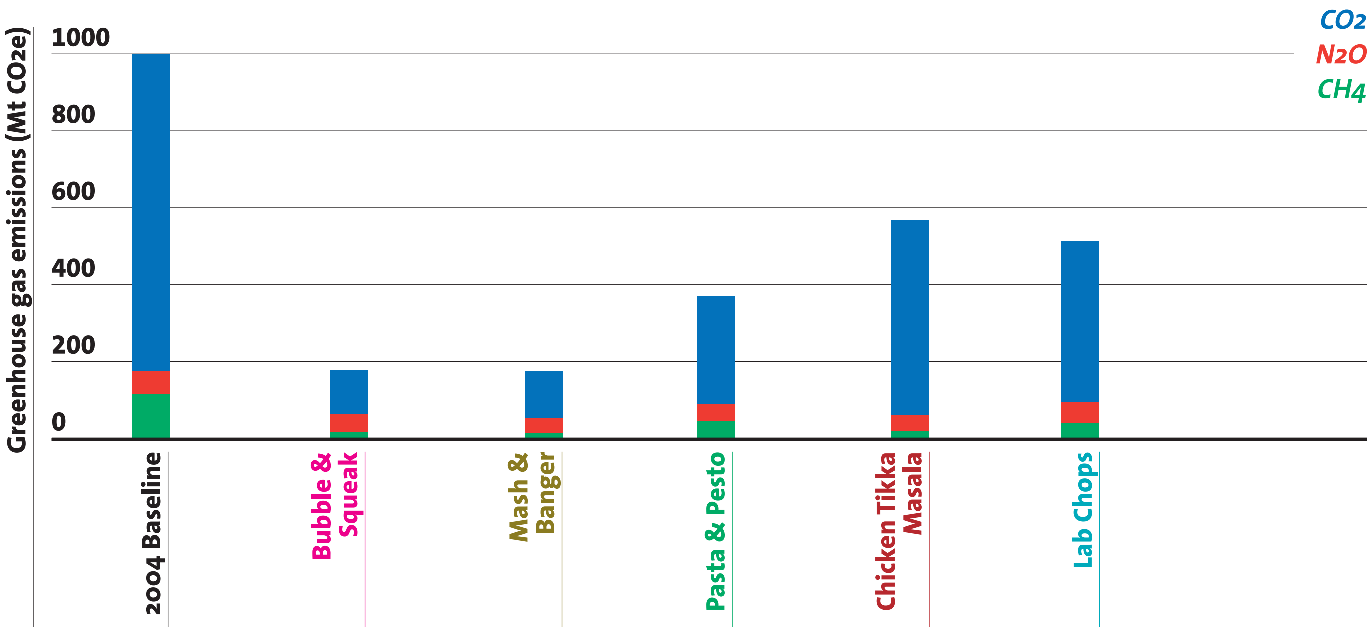


FIGURE 16:
Greenhouse gas emissions from the SCI Food System Scenarios and baseline split by consumption category

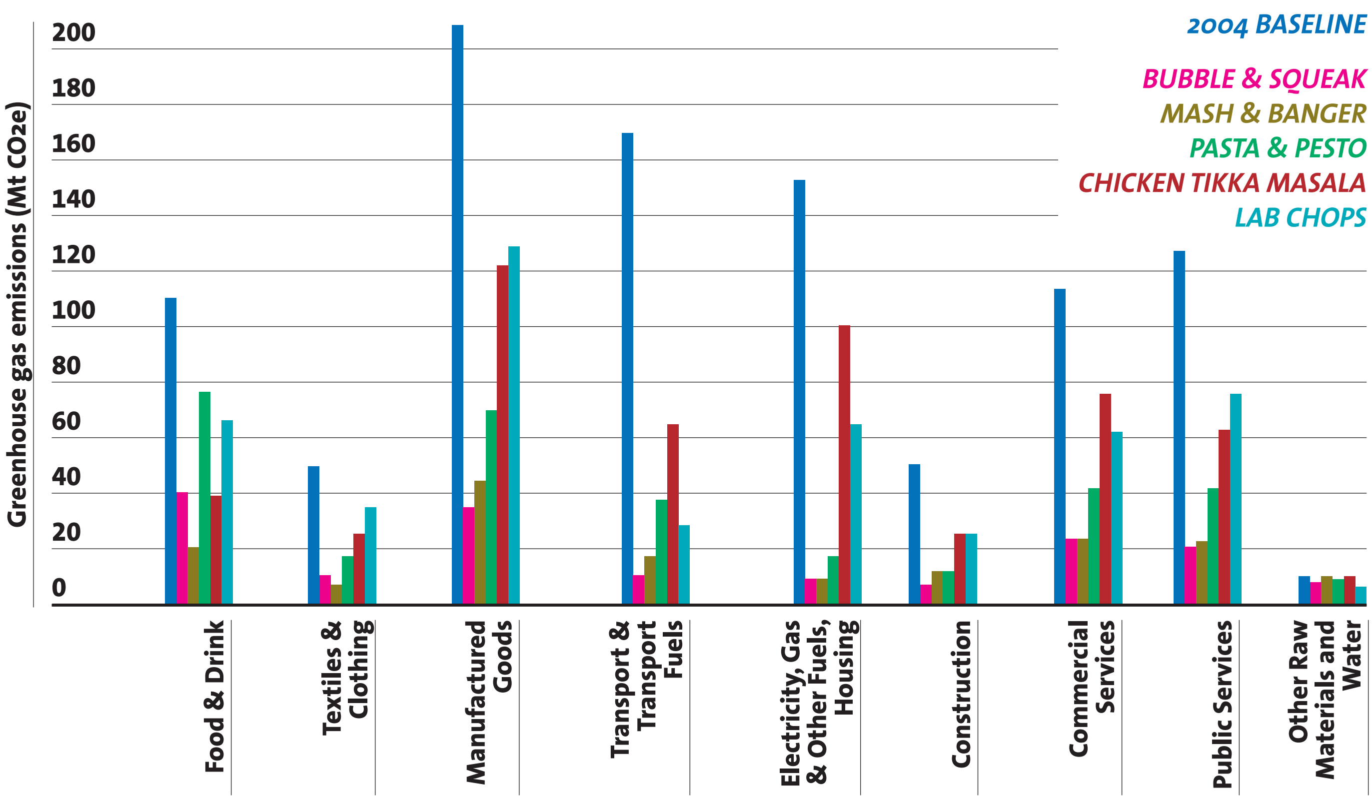
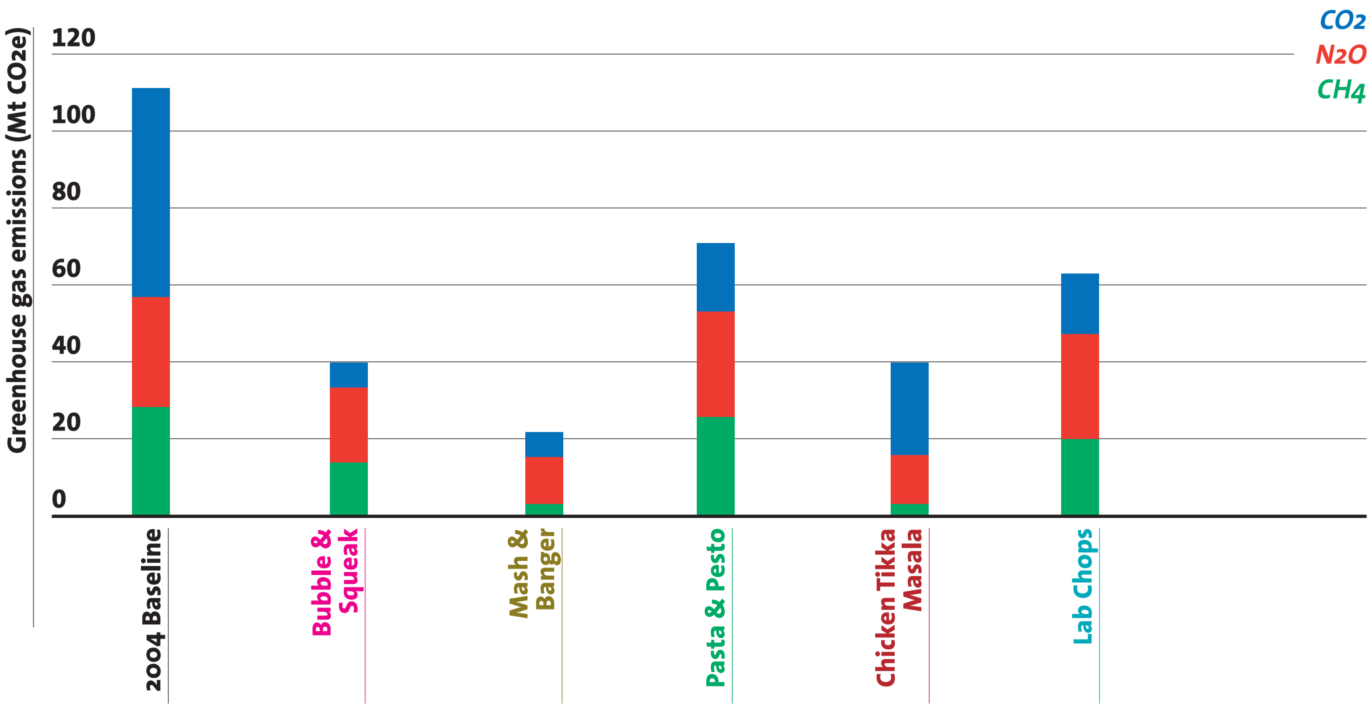


FIGURE 17:
Scenario and baseline Food and Drink emissions split by gas



3.3 SCENARIO DESCRIPTIONS

The following section presents some key indicators from the **SCI's Food System Scenarios**. Of the five, two have 2°C futures and three 4°C futures. Each is named after a typical meal: **Bubble & Squeak** & **Mash & Banger** (2°C), **Pasta & Pesto**, **Chicken Tikka Masala** & **Lab Chops** (4°C) (Table 1).

The emission cuts across scenarios show the difference between strong mitigation (2°C) and moderate mitigation (4°C) futures (Figure 15). Even at this aggregated level, the influence of the food system is apparent. For instance, scenarios with enclosed livestock to capture CH_4, driven by either a need to dramatically reduce emissions or to protect livestock against higher temperatures, both result in very low CH_4 emissions.

Although the 2°C scenarios have lower emissions than those at 4°C, replicated across many categories, it differs for 'Food and Drink' (Figure 16 and 17). This reflects how agriculture is particularly affected by climate change, hampering deep emission cuts. If temperatures are higher and crops unprotected, increased fertiliser application is needed (**Pasta & Pesto**). By contrast, the lowest emissions in the 'Food and Drink' category come from a reduction in meat consumption coupled with enclosed livestock (**Mash & Banger**). Similarly, an adaptation strategy to protect agricultural assets from climate impacts facilitates precision nitrogen fertilising and emission capture, cutting non-CO_2 (**Chicken Tikka Masala**).

A limitation of using ASK-REAP to describe changes to future emissions is that the approach assumes the same economic structure in 2050. This means new sectors are not characterised, necessitating assumptions. Thus, artificial meat continues to rely on supply chains currently linked to meat production, which may no longer be the case. On the other hand, laboratory grown meat will continue to require protein inputs, which could be agricultural products.

Differences also stem from the underpinning energy scenarios impacting emission intensity of UK production and imports.

MANCHESTER
1824

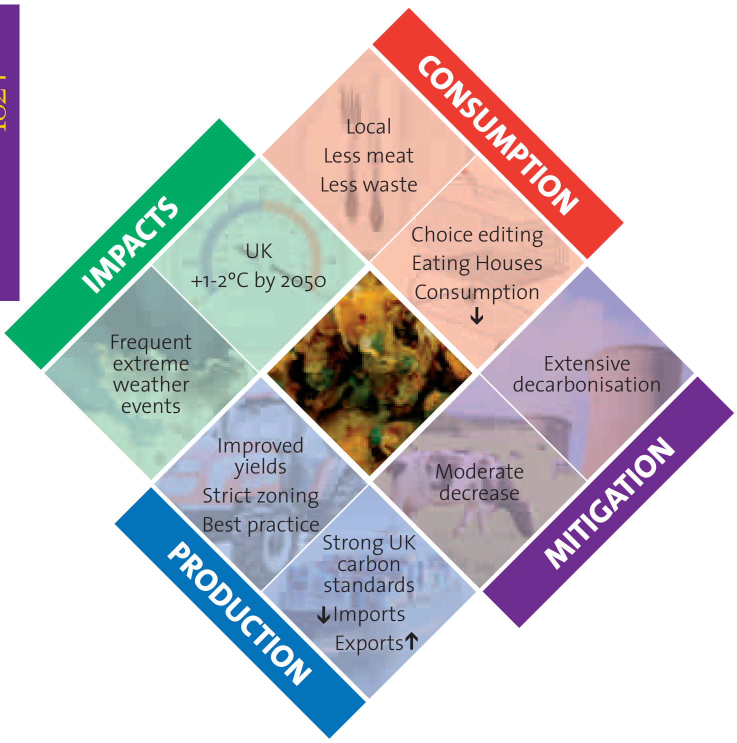
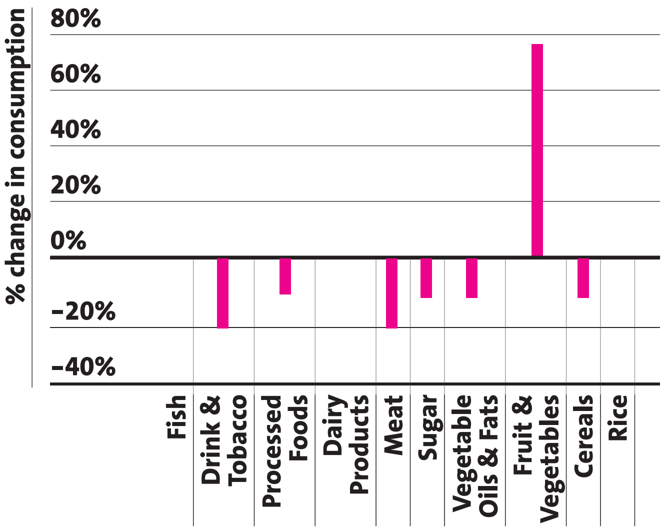


FIGURE 18:
Bubble & Squeak per capita consumption change



BUBBLE & SQUEAK
"2 degrees"

BUBBLE & SQUEAK'S ENERGY SYSTEM

The energy scenario in Bubble and Squeak is a very low-carbon scenario, following the **Living Within a Carbon Budget's** –"Today Mobility" scenario by Bows et al 2006 [13].

The UK makes substantial emission reductions from production, energy efficiency of agriculture improves at around 3-4% p.a.

15% of domestic heating is provided by gas, the remainder from onsite renewables, electricity or hydrogen.

Large point sources including the iron and steel industry use carbon capture and storage (CCS) technology.

Rates of improvement to the UK's carbon intensity are replicated worldwide.

BY 2050...

Significant widespread climate change mitigation efforts result in the global average temperature increase limited to 2°C by 2100 (equating to 1-2°C above UK 1990 levels by 2050). This scenario is characterised by fundamental changes across society, and the behavioural practices embedded within it, without relying on new high tech solutions.

A favourable UK climate compared to other countries and moderate reductions in consumption supports a dominance of UK and EU food suppliers. With per capita red meat consumption reducing by a fifth and greater emphasis on vegetarian food (Figure 18), calorific and nutritional needs are satisfied and overconsumption uncommon.

UK production in red meat declines, balanced by a slight increase in poultry and a large increase in vegetable, crop and bioenergy production (boosted by new overseas markets); few meat or animal products are imported from outside the UK.

Developments in retail revolve around the drive to reduce waste, packaging and emissions which is both politically and socially embraced. Rather than shopping for individual food items, customers specify meals for which shops supply ingredients. As retailers take a proactive approach to inspiring innovative meals using surplus food, the extensive use of choice editing and a reduction in packaging is possible. Leftover roast dinner transforms into bubble and squeak, chicken karahi and stock for soup. With changes in infrastructure and working patterns comes a trend for reasonably priced 'eating houses', linked to schools or large businesses; particularly popular with younger workers and families, as new homes are built 'with or without' the full kitchen option. The individualistic older generation are less inclined to frequent eating houses, preferring instead to order old favourites at home such as pad thai and Fiorentina pizza.

Extreme weather events are beginning to occur more frequently. Despite deleterious effects in other regions, temperature

FIGURE 19:
Bubble & Squeak emissions intensity change

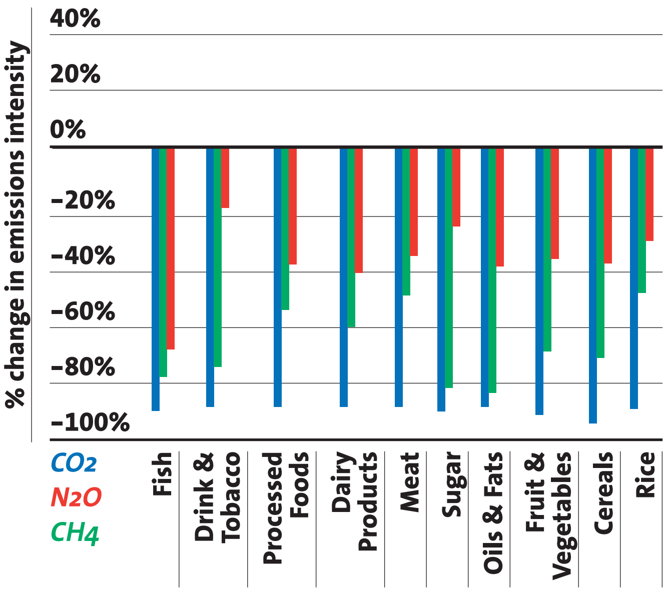
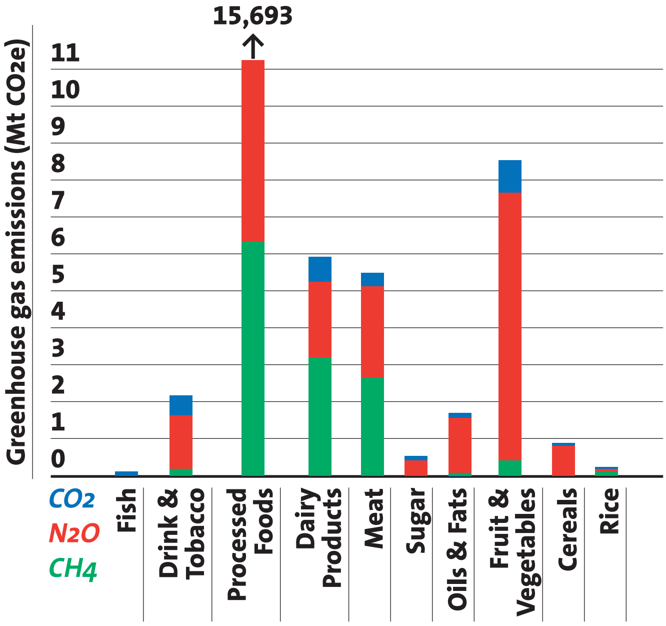


FIGURE 20:
Bubble & Squeak greenhouse gas emissions



increases are generally beneficial to farming in the UK, resulting in improved yields for wheat, fruit and vegetables. Farming of crops and livestock are strictly enforced where yields are likely to be highest and environmental impacts lowest (zoning) with small-scale permaculture finding its niche, as more land is required for a rise in UK production. Best practice and integrated production methods together with reduced consumption, enables a more extensive farming approach to prevail.

An average economic growth of <1% p.a. reflects a shift from technological solutions towards a behavioural response to global pressures. Waste reduction campaigns successfully achieve dramatic changes in attitudes and the energy system is highly decarbonised. A strong regulatory regime on greenhouse gas emissions and a high value placed on corporate social responsibility results in a widespread preference for suppliers that meet the UK's carbon intensity standards. This influence prevails through two-way technology and practice transfer.

HOW DID THIS HAPPEN?

Waste not want not

To promote low impact production methods, explore alternative ways to mitigate emissions in agriculture and to preserve cultural and landscape heritage associated with small scale farming, the government invests in skills exchange and training schemes.

As knowledge transfer improves across farming communities, proliferation of best practice to improve productivity helps small-scale farmers thrive within tightly regulated and constrained supply chains. Communities combine to operate integrated farming systems, exploiting highly skilled practices and techniques at low cost.

Waste is seen as a valuable resource and, knowing that material will be re-used or recycled, consumers become more responsive to waste management initiatives. By the 2020s, national and EU regulation is adapted to allow household food waste to be collected for agricultural applications, including anaerobic digestion, and to contribute to improved yields. As agriculture becomes smaller scale, community-based and more "joined up", the 2020s sees a cultural shift emerging as businesses and households are more connected to the food production system.

Reinforced by extensive research into integrated systems, backed by government incentives, confidence grows in the ability of diverse small-holdings to produce sufficient food and work together within closed protein cycles; e.g vermiculture delivering fertilizers and feedstocks for fish farms. The early emphasis on training and education results in an approach to food production and consumption that is small scale, resource efficient, low carbon and best practice.

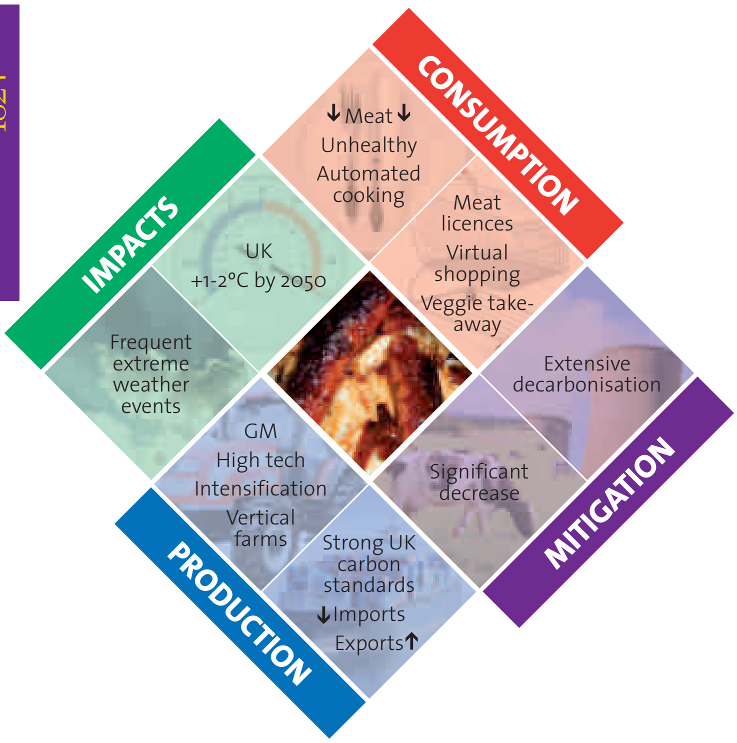
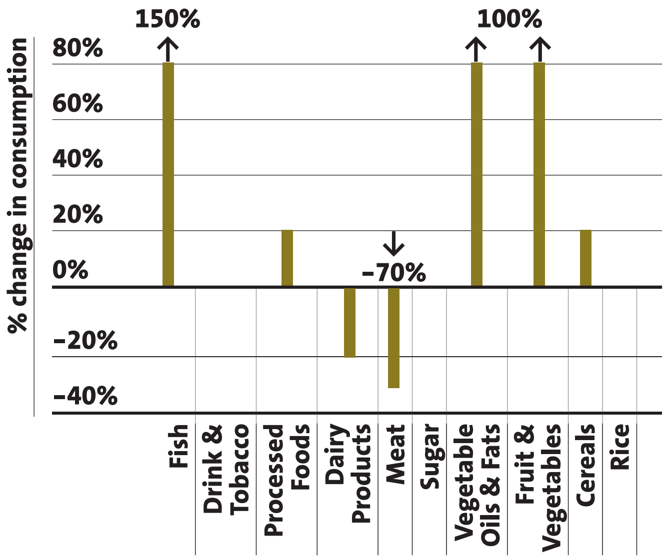


FIGURE 21:
Mash & Banger per cap consumption change



MASH & BANGER "2 degrees"

MASH & BANGER'S ENERGY SYSTEM

The energy scenario in Mash and Banger follows that described by **Living Within a Carbon Budget's** –"Today Mobility" scenario by Bows et al 2006 [13].

UK production is very low carbon, agricultural energy efficiency improves at ~3-4% p.a.

Hydrogen, generated by coal gasification coupled with CCS and electrolysis, is used to supply both domestic heat and surface transport activities.

Large energy intensive point sources use CCS.

All imports meet the UK's energy intensity standards.

BY 2050...

This is a scenario with significant climate change mitigation efforts characterised by a high tech approach that limits the global average temperature to a 2°C increase by 2100 (equating to 1-2°C above UK 1990 levels by 2050). Concern over climate change, an upsurge in lifestyle vegetarianism and a series of meat crises come together in a perfect storm transforming the UK's food system.

There is a big reduction in meat consumption (Figure 21) to the extent that feeding children red meat is as socially unacceptable as passive smoking in 2012. A government campaign for a 'meat free work week' is accepted; outlets selling meat are required to prove meat complies with emission and health standards.

Despite a move towards both fish-based and vegetarian cuisines, cheese is commonly substituted for meat contributing to average diets much higher in fat compared to 2012. A desire to replace meat with other foods, combined with concern over food security and emissions, leads to wider public acceptance of GM technology and an emphasis on UK production.

Technological developments have proliferated throughout the retail, cooking and eating experience. Virtual shopping dominates and industrial estates are occupied by large indoor vertical farms producing the nation's fruit and veg. Kitchen technology has boomed following the decarbonisation of electricity in the UK. Despite the influx of household gadgetry, the end result is, to all intents and purposes, familiar UK fare, with dishes such as vegetable curries, mash and banger and fish and potato pie. The changes in attitudes to meat have had a significant impact on fast food outlets, so there is a proliferation of pescatarian and vegetarian restaurants such as 'Falafel Frydays', 'Stir Fry Sallys' and 'Fishsteak houses' nationwide.

The UK is a world leader in advanced biotechnology, selective breeding and the use of enclosed as well as vertical farms. Precision farming in conjunction with greater intensification enables yield gaps to be closed whilst cutting emissions

Figure 22:
Mash & Banger emissions intensity change

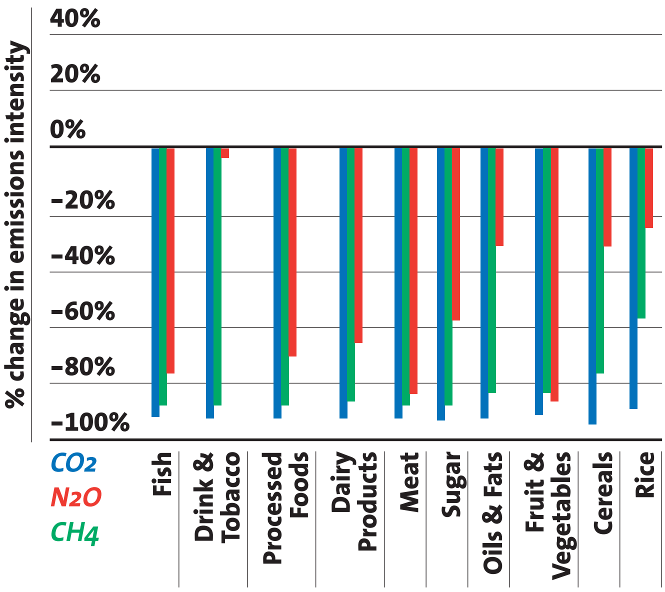
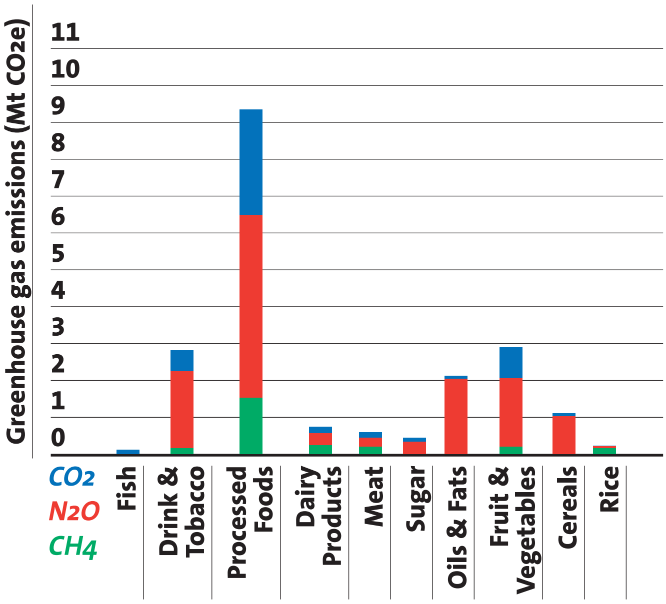


Figure 23:
Mash & Banger greenhouse gas emissions



(Figure 22). While water availability is not a major concern in the UK, water shortages overseas, along with other climate impacts, affect some traditional growing areas with consequences for UK imports. The frequency of storms and heavy rainfall increases during all seasons affecting crop production. Methane capture at intensive farms combined with reduced meat consumption delivers big emission cuts, alongside almost complete decarbonisation of the UK's energy system by 2050.

Economic growth of 1.5% p.a. supports a high industrial technology approach to change. UK Government introduces legislation for farmers and retailers to ensure greenhouse gas emissions associated with the full supply chain reduce, thus regulation extends throughout the supply chain with product categories subject to greenhouse gas limits.

How did this happen?

GM technology and low meat consumption

Food prices continue to rise from the start of the 2010s, caused by increasing global demand for processed 'western' foods, energy prices and climate impacts. The pressure for climate mitigation measures pervades all sectors – the food supply chain is no exception; advanced crop development and genetic modification (GM) are considered crucial. The realisation that GM technology is used successfully outside the UK leads to its gradual acceptance, creating the space for domestic regulations to be amended. Initially limited to fuel and non-food crops, R&D trials for GM foods begin in the early 2020s to keep food costs down whilst reducing emissions and adapting to climate change. Meanwhile, mitigation policy tightens significantly, the EU ETS cap is reduced in line with the 2°C goal and carbon pricing and labelling becomes more prominent around 2015.

As prices rise, a phenomenon described at the time as the "vegetable spring roll out" takes hold amongst a carbon literate population open to a diet featuring less meat. Initially mediated through social networks but soon taken up by successful marketing campaigns from big brands and celebrity endorsements, it marks one strand of a comprehensive push to reduce emissions. The trend continues as the balance shifts away from meat-based meals and reinforced by a variety of high profile health scares (food poisoning cases, communicable animal diseases, inter alia).

By 2030, the UK diet has undergone a fundamental change. A strong drive towards technologies to address concerns in the food sector has led to earlier investment in plant breeding placing the UK at the forefront of seed production by 2030. A variety of less traditional farming techniques such as virtual farms, integrated systems and novel technologies are now widespread in urban environments and accommodate high yielding, cheap to produce GM crops.

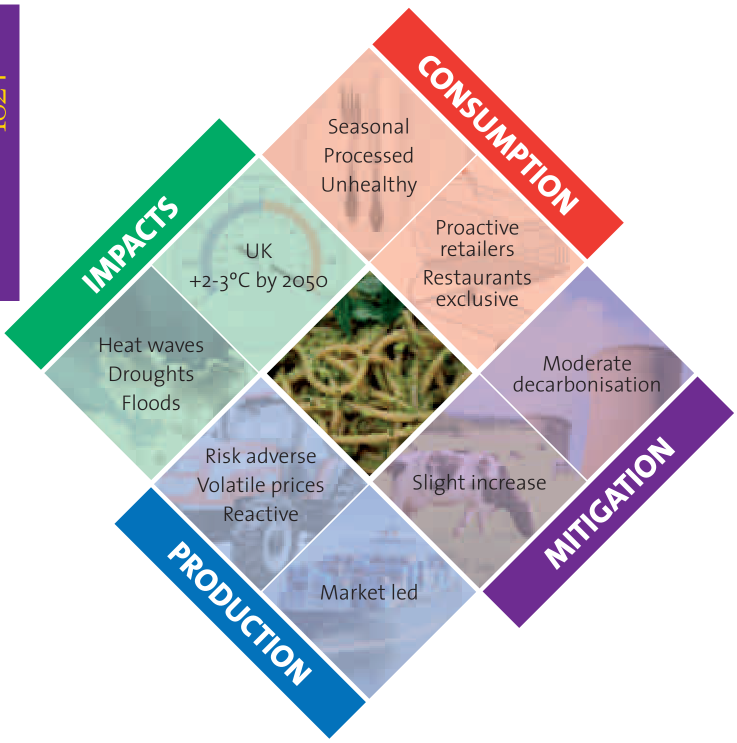
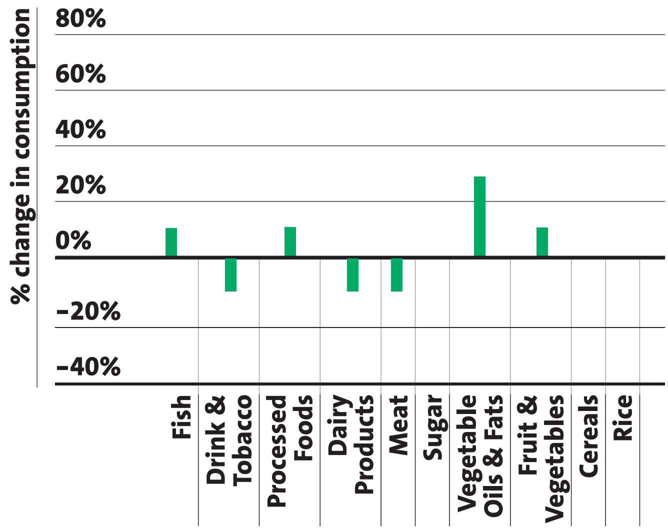


FIGURE 24:
Pasta & Pesto per cap consumption change



PASTA & PESTO "4 degrees"

PASTA & PESTO'S ENERGY SYSTEM

The energy scenario for Pasta & Pesto is based on the **Decarbonising the UK** *"Blue Scenario"* by Anderson et al 2005 [25].

UK production makes moderate improvements in efficiency and agriculture improves its energy efficiency by 1.5% p.a.

Gas fired power stations dominate electricity supply combined with nuclear power and coal fitted with CCS.

Hydrogen, produced by coal gasification with carbon capture and storage is used for surface transport.

The UK's rate of improvement in emission standards are also followed by other Annex B countries. Non-Annex B countries make more moderate improvements.

BY 2050...

Mitigation efforts have not been sufficient to prevent global average temperatures increasing to 4°C by 2100 (equating to 2-3°C above UK 1990 levels by 2050), resulting in a need for significant adaptation. Social practices alter to reduce emissions and adapt to a rapidly changing environment.

Diets adjust to availability, with a revival of traditional food preparation methods and greater seasonal influence. The unpredictable climate makes fresh food supplies harder to guarantee, resulting in a greater emphasis on processed, pre-prepared and canned foods with higher additives to prolong shelf life.

As food becomes more expensive, price and availability are key drivers of choice, with an emphasis on satisfying calorific needs over achieving nutritional balance. As some foods become scarce, retail campaigns encourage innovative meal ideas around readily available items; choice editing focuses on sustainable foods in response to consumer pressure. With rising food prices, restaurants wishing to serve a wide-ranging menu become exclusive, available to only the richest in society.

Climate impacts significantly alter the global distribution system and geographical extent of food production, although supply chains are slow to successfully adjust. UK summer droughts are common and water shortages a problem for people, agriculture and industry. Precipitation events are heavy and unpredictable, leading to severe impacts on vegetation and soil. Decisions on what or how to grow are market led, with farmers being averse to risk and going for 'safe' options. Production systems are generally reactive, causing high amounts of volatility around the type and price of imports. Heat waves interrupt plant development and crop production, which becomes more expensive in the UK, elevates imports from the EU and beyond. Conversely, UK meat exports increase to balance shortages further afield where temperature rises have become prohibitive. While overall levels of meat consumption have not altered dramatically, there is a shift from red to

Figure 25:
Pasta & Pesto emissions intensity change

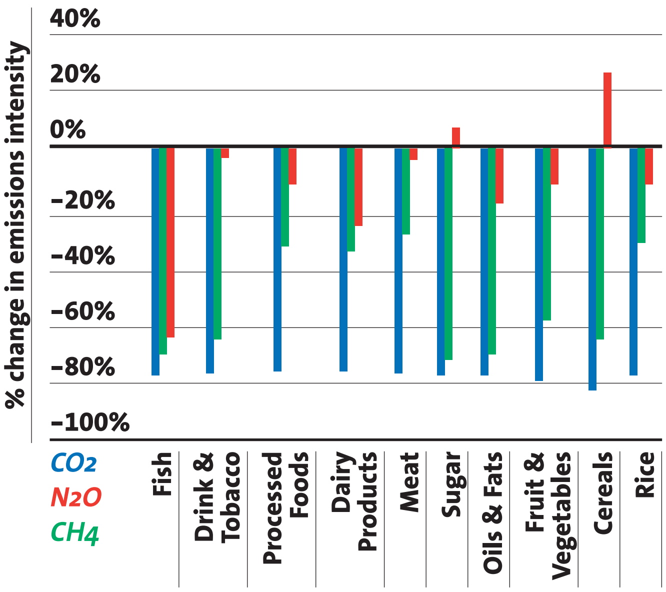
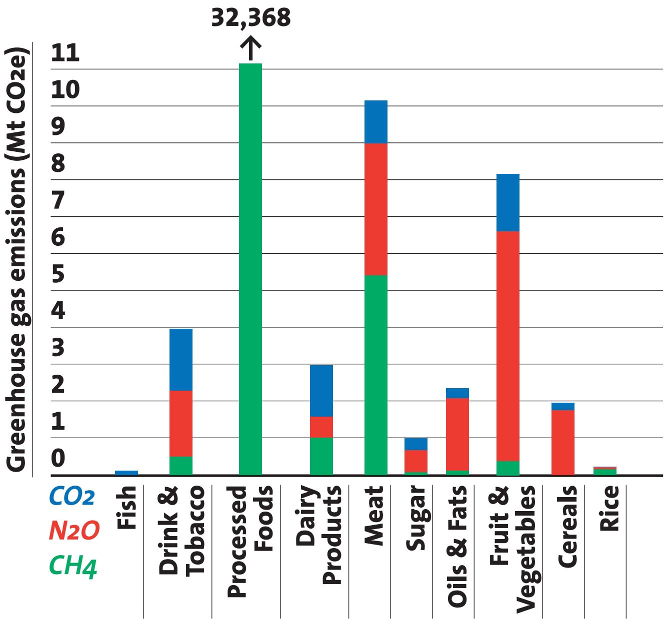


Figure 26:
Pasta & Pesto greenhouse gas emissions



white meat and some (farmed) fish consumption. Higher temperatures also bring a reduction in consumption (and production) of dairy products (Figure 24) as the challenge of maintaining a fresh supply increases.

Economic growth is at ~1% p.a. as technology struggles to keep pace with changing conditions. Imports of fruit and vegetables from large scale farms in the EU and US increase due to greater land availability and better use of technology to increase yields; a similar shift is seen for other crops, reflecting yield reductions in lower latitude countries.

Markets determine food availability but with high price volatility and international trade continuing to grow, so too do smaller scale, local markets. This scenario evolves away from a society accustomed to low food prices, and extensive choice where mealtimes had a cultural as much as a nutritional function. There is a gradual decline in fresh fruit consumed as prices rise.

How did this happen?

Reduced choice and changing attitudes

With little investment in greenhouse technology, intensive hydroponics and drip irrigation systems remain the state of the art and struggle to satisfy demand. In the early 2020s, several extreme weather events coincide, exposing a need for adaptation in the food supply chain. New crop varieties are introduced and novel growing systems explored, but the full extent of the problem, notably with respect to water conservation, is not recognised. Improvements are made in waste and residue recycling to achieve 'closed-loop' indoor systems.

As food availability suffers, variety attracts a premium both on supermarket shelves and in restaurants. Flexible approaches to eating are a pre-requisite for thrifty households. Consumers adjust to restricted choice and price fluctuations, benefits of supermarket visits diminish and delivery of food boxes reflecting current availability become popular, with a knock on effect on cooking; people purchase meals rather than ingredients. With choice disappearing, jam-making parties and pop up restaurants selling available foods replace traditional dinner parties.

By the 2030s, marked social changes are emerging across the land and in the home. The regional balance is very different as the climate in the north and west becomes more favourable, particularly with respect to water resources. By the 2040s the effects of climate change are hitting hard. Public education campaigns become more concerned with reducing consumption, waste and living within our means than with nutrition.

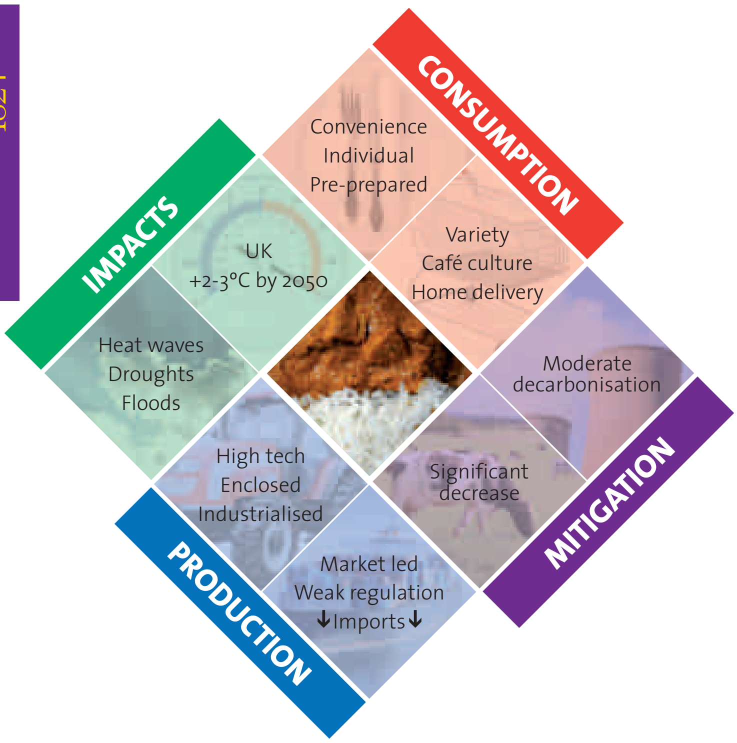
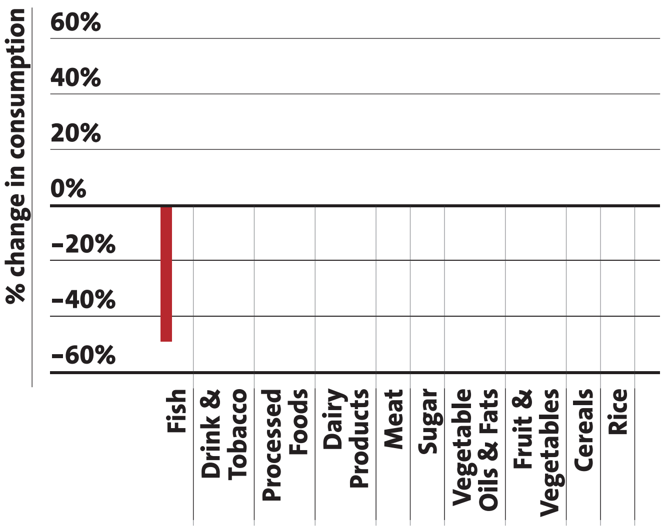


FIGURE 27:
Chicken Tikka per cap consumption change



CHICKEN TIKKA MASALA "4 degrees"

CHICKEN TICKKA MASALA'S ENERGY SYSTEM

The energy scenario for Chicken Tikka Masala is based on the **Decarbonising the UK [25]** *"Red Scenario"* by Anderson *et al* 2005.

UK production is very efficient with annual improvements of between 2-3% p.a., agriculture performs beyond this at 4% p.a. However, production still relies on fossil fuels.

Significant proportions of coal, oil and gas are used to supply much of the remaining energy demand from UK industry.

All imports meet UK production energy emission standards.

BY 2050...

Insufficient progress on mitigation has resulted in a 4°C global average temperature rise by 2100 (equating to 2-3°C above UK 1990 levels by 2050) and an extensive programme of technological adaptation in the UK.

Widespread use of high-tech protected growing environments needed for agricultural adaptation enables diets in 2050 to remain similar to 2012 (Figure 27). By bringing crops indoors and artificially optimising production, the climate is no longer a constraint, although higher ocean temperatures have reduced fish stocks; variety in available foods is maintained without reliance on imports.

Consequently, a higher proportion of household expenditure goes on food. Consumer priorities are for convenient, functional foods. Intelligent packaging and preparation of products and food delivered to order are commonplace, reducing waste.

Households no longer plan meals and choice is extensive; dishes such as jerk chicken, lamb tagine and yaki udon are common alongside traditional foods. Acceptance and popularity of technological solutions to climate problems permeates many aspects of life, encouraging general apathy towards food preparation and the mundane weekly shop. Virtual shopping of highly prepared foods is commonplace and household kitchen space significantly downscaled. Boosted by a warmer climate, the UK has a booming urban café culture but land given over to industrial-scale farms has led to a loss of outdoor space for recreation and exacerbated impacts on biodiversity.

Temperature rises drive frequent extreme weather events, but enclosed food production limits and controls effects on agriculture. Impacts are felt more strongly overseas with major implications for the predictability of food production and prices. Food and energy security are therefore priorities for the UK which is now broadly self-sufficient.

UK agricultural practices adapt to cope with the changes in climate ensuring yields meet demand. Farms become large scale integrated food-energy production

Figure 28:
Chicken Tikka emissions intensity change

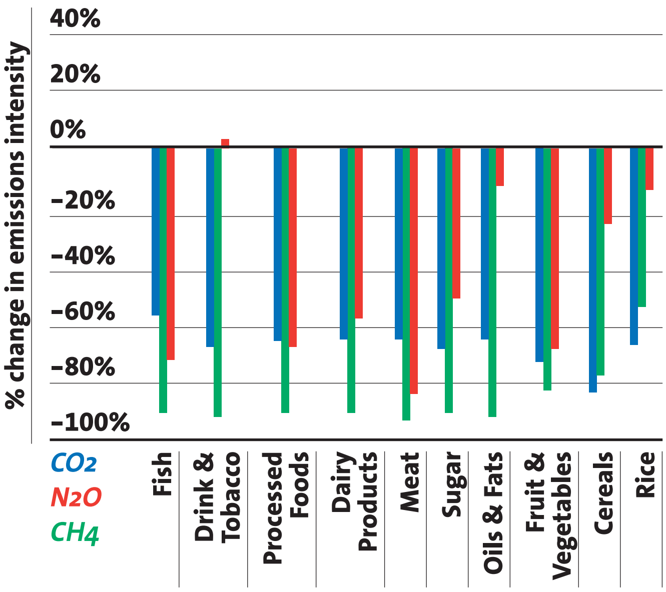
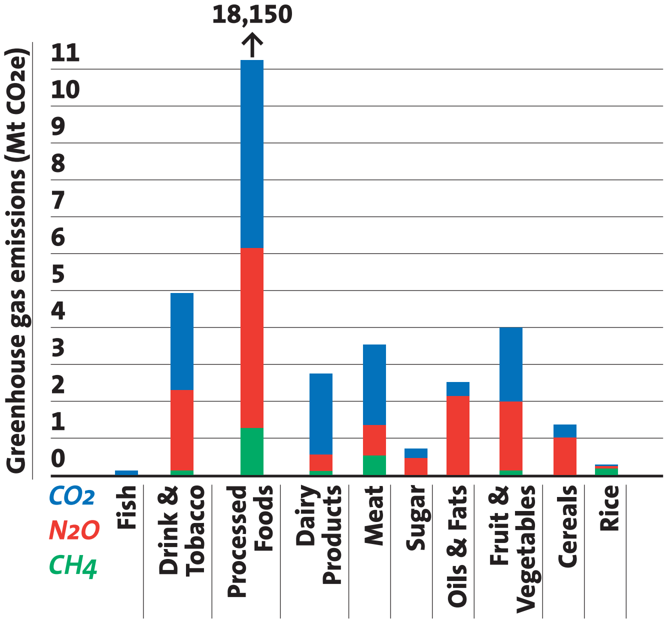


Figure 29:
Chicken Tikka greenhouse gas emissions



systems by exploiting, for example, opportunities for anaerobic digestion. Enclosed 'animal friendly' environments, multi-story vertical farms,

improved storage and protected growing areas allow yield gaps to be closed and produce a strong sense of national pride in 21st century British farming methods.

Economic growth of 1.5% p.a. enables necessary investment in infrastructure to support the food system. Agricultural production is expensive and input-intensive but generates high yields. This, combined with improved quality, makes higher prices acceptable. Expectations of crop failure using conventional farming, and requirements to demonstrate climate resilience to secure insurance, whilst mitigating, drive changes within a weak regulatory environment.

How did this happen?

Protected growing environments

The early years see many smaller firms fold or become subsumed by a handful of large retail chains which extend control over supply chains. These companies invest and provide seed-corn funding for trials of sophisticated protected growing environments. The first large scale indoor farming pilots become operational by 2015 and success grows from there. Initially, the variety of crops grown is relatively limited and, as imported foods become prohibitively expensive, consumers lament the loss of choice in the shops. Consultation and engagement programmes raise awareness of new protected farming technology, with the promise of a return to extensive variety and high welfare standards.

As confidence builds, larger retailers invest in their own farms. Retailers strive for greater control over energy costs and stability across the supply chain as climate impacts become increasingly unpredictable and harsh.

By 2020, specialised farming replaces a more mixed system. Small grower groups work with supermarkets to deliver products that meet their strict quality and emissions criteria. The gradual integration of supply chains continues, enabling reduced use of agricultural inputs through approaches such as integrating fish production with residues from anaerobic digesters and hydroponic growing. The landscape begins to look quite different by the late 2020s as ever larger greenhouses become common features on farms.

By the 2030s, a new generation of "i-farmers", economic leaders, stay up-to-date with developments in technology and techniques which quickly permeate the system. Towards the end of the 2030s, an urban ecology evolves delivering major financial returns on earlier investments in protected growing areas. By 2050, the dominant culture is for intensive indoor farms with low water requirements that recover waste for energy and nutrients for the growing system.

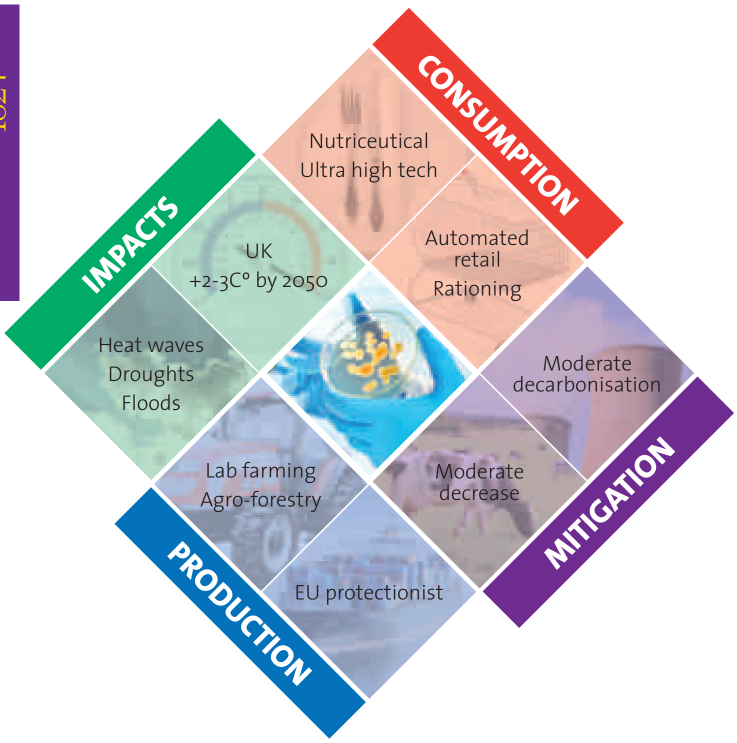
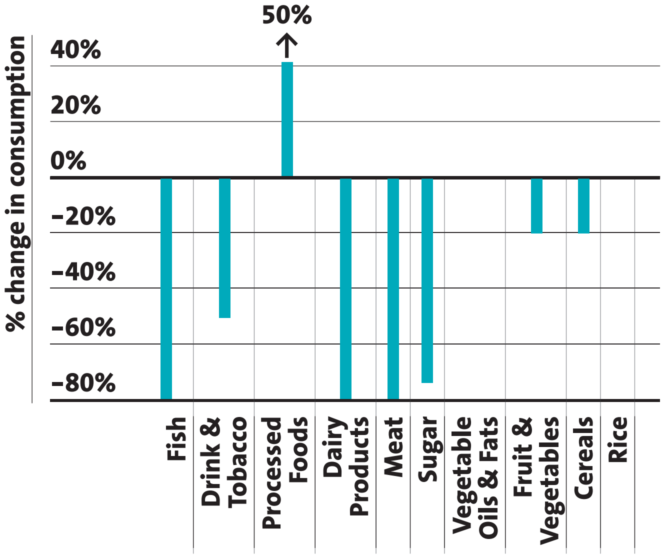


FIGURE 30:
Lab Chop per cap consumption change



LAB CHOPS "4 degrees"

LAB CHOP'S ENERGY SYSTEM

The energy scenario for Lab Chops is based on the **Decarbonising the UK [25]** *"Turquoise Scenario"* by Anderson *et al* 2005.

Improvements in the energy efficiency of UK production are between 1-2% p.a., agriculture improves at 3% p.a.

Gas and biofuel CHP plant and onsite renewables provide industry with power. Grid electricity is supplied by a combination of gas with and without CCS and nuclear.

The emission intensity of imports for other Annex B nations has improved at the same rate as the UK. Non-Annex B countries reduced the intensity of their emissions by 40%.

BY 2050...

Limited mitigation efforts have resulted in the global average temperature rising by 4°C by 2100 (equating to 2-3°C above UK 1990 levels by 2050), transforming UK agriculture, particularly livestock production and land-use.

Attitudes to foods have altered dramatically since 2012; consumers are happy to eat laboratory-grown meat, pop 'meal pills' or drink 'food-shakes'. With increasingly busy lifestyles, citizens welcome a one-stop fix to safe diets through government-issued tablet 'meals' that achieve recommendations for both health and emissions.

Consumers are now used to the relative scarcity of some previously popular foods (Figure 30).Some take advantage of trading their personal carbon points when they feel the need for a meat treat or old-style roast dinner - at the expense of road or air miles. Overconsumption and waste are things of the past and socialising is spent taking part in activities rather than over dinner. Sit down meals are saved for special occasions. The prevalence of the individually tailored diet has left many people unfamiliar with cooking and preparing conventional food. Physical supermarket shopping is a distant memory. Consumers simply input their weight, height and answer questions about their lifestyle via the web or by text and are sent regular supplies of 'meal' pills.

The climate in the UK has become untenable for rearing sheep without significant subsidies for high-tech climate-controlled indoor farming. An absence of enthusiasm from governments and high costs of conventional meat production, means that livestock farming has lost significant market share and producers switched to more specialised breeds.

The biochemical industry has taken up the mantle, developing a popular business in the production of laboratory-grown joints of meat, and vitamin substitutes for vegetables. The UK's agricultural system focuses on agro-forestry and chemical and biological feedstocks in the main, although open fields with specialist, very expensive, cattle breeds provide a novel interruption to the heavily forested

Figure 31:
Lab Chop emissions intensity change

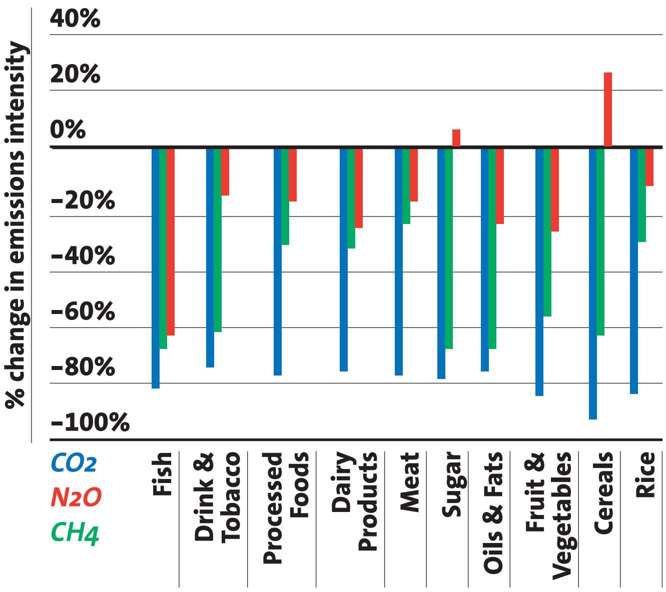
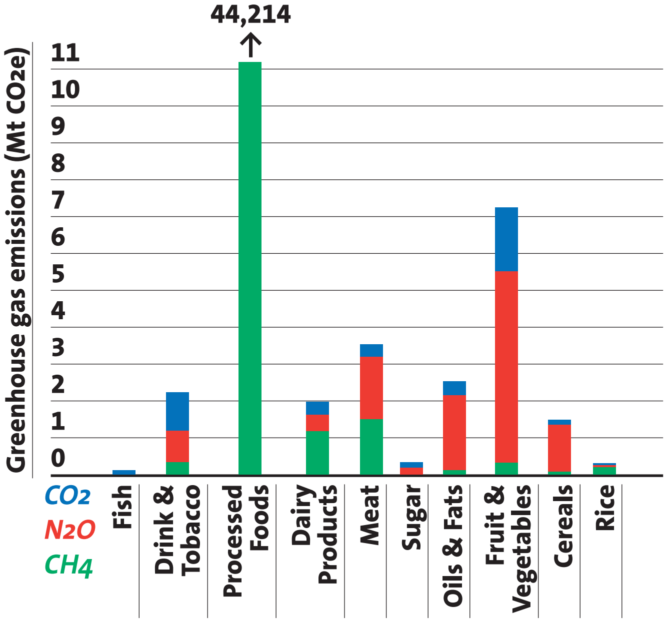


Figure 32:
Lab Chop greenhouse gas emissions



landscape. Partnerships between the biochemistry and farming sectors flourish, serving strong markets for food supplements, biofuels and clothing. Some conventional crop farming remains, albeit with a strong focus on speciality products and much degraded market for animal feed.

An economic growth of ~1.5% is supported by the strong biochemical and agricultural sectors. Government regulation around emissions is strict, but the severity of climate impacts equally influences popular choice and trends. The UK continues to trade with the EU. Although climate impacts elsewhere limit imports to an extent, the biofuelled shipping sector delivers luxury goods from extra-EU nations.

How did this happen?

Meal pills, lab meat and agroforestry

As climate impacts start to bite and food prices rise, the private sector funds R&D into low carbon food sources, including novel lab-based meat production. With a move to a consumption-based approach to emission targets, the direction of research is strongly influenced by both the prospect of tight carbon budgets being imposed on the food system and the Government's health agenda.

At the same time, agroforestry, in which trees, crops and/or livestock are farmed together, becomes important under a strict sustainability assessment framework within which humankind's dependence on natural ecosystems is recognised and ecosystem services highly valued. Although the UK population is initially not CO_2 conscious and relatively conservative in its approach to novel foods, five years of price rises and a "healthy new deal" (realised through the benefits system at first), see a new approach to diet management emerge.

In 2018, carbon budgets are introduced for home electricity and fuel. They are extended, initially to transport, and subsequently to all emission sources, including food, by 2030. A series of severe climate-related events and food scarcity seen around this time reinforces the government education programme and fosters a broad acceptance of the need for such personal carbon budgets.

The food industry is quick to pick up on incentives and recognise growing markets for manufactured "health foods" and nutraceuticals, following early successes with food designed to promote healing in hospitals. A variety of factory prepared novel foods are accepted as part of a daily diet and the first commercially produced lab steaks appear on the market by the late 2020s. By the 2030s, lab meat has penetrated the mass market and further R&D by large corporations responds to the strict carbon constraints to deliver a "lower carbon tablet" for a convenient and cheap means of staying both healthy and within a personal carbon budget.

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3.4 Focus groups

Focus groups were conducted to offer insights into consumer perceptions and reactions to some of the key elements of the scenarios relating to shopping and eating habits. The results provide an indication of consumer attitudes to future food developments. Participants discussed the main influences on their buying behaviour before considering the different elements of the **SCI's Food System Scenarios**. They were facilitated by the researcher in discussing various prompted issues relating to the future of the UK food system including: reduced choice, waste, level of meat consumption, seasonality, genetic modification, meal replacement tablets, eating houses and new types of agricultural production. Participants discussed the potential impact these areas could have on their current behaviour.

Forty participants were recruited into six focus groups through a mail shot to households in Greater Manchester postcode areas categorised as having high, middle or low carbon footprints by Mosaic UK Experian data [32]. Groups were separated according to their Mosaic carbon footprint category and gender to promote a positive and open atmosphere for discussion[33].

3.4.1 Influence of price on consumer behaviour

Consumers are influenced by a variety of factors when making their purchasing decisions. However, regardless of socio-economic grouping, price was a dominant theme in the way participants spoke about their shopping and eating habits. This is perhaps not surprising given the DEFRA Family Food report* revealed that the amount an average household spent on food and drink went up by 3% in 2010 to £39.23 per person per week. Andreyeva et al (2010)[34] reported the increasing price of food may create "pressures to purchase" low cost items such as processed, calorie dense foods. Yet participants, particularly those aged 25-44, said costs could be cut in other areas to ensure they could afford, in particular, good quality meat:

"You can cope with lower quality cereal or things like that, but if you have low quality meat, it can spoil the whole meal"

Participants were uncompromising on the quality of certain products and as a consequence felt forced to spend more on their weekly shop than they had in the past. Despite trying to stay within their usual budget, participants found this to be insufficient and had to make additional food purchases during the week. Numerous participants talked of switching to value retailers in an attempt to stretch their food budget, supplementing this with a visit to a mainstream supermarket. In other words, rising food prices are affecting where and how people shop. Similarly, the 2011 Which? report** on the impact of rising food prices found 29% of respondents have made a change in their food purchase decisions and plan more meals in advance. This not only cut costs but reduced waste by making consumers more aware of storing food correctly. The impact of rising food prices

* http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-food-familyfood-2010-120328.pdf

** http://www.which.co.uk/documents/pdf/the-impact-of-rising-food-prices-which-report-259301.pdf on current behaviour led to money saving suggestions from the participants including better meal planning, shopping in bulk and buying promotional items:

"I think since the whole problem with the economy, it's become much more fashionable to be price conscious"

The current financial climate also influenced participants views on sustainability, where many participants said that buying locally produced food, is seen as *"a bit of a treat"*. Indeed, participants were on the whole aware of ethical products, particularly fair-trade, and liked the idea of workers being looked after. However, many said that they simply couldn't justify buying such products given the current strain on their shopping budget, as they were considered more expensive than regular products. This contradicts results from the Fairtrade foundation who reported that worldwide sales of fair-trade products have increased during the recession [35]:

"I think if I had more money, then I would. But at the minute I'm just thinking, oh, I can't do that."

3.4.2 Consumer views on sustainability

Despite the prominence of sustainability in the media, many participants tended to be unsure of how to describe a 'sustainable food' product. When prompted over the meaning of sustainability, respondents across the groups focussed on issues such as: packaging, recycling, imports, food miles, local food and waste. The 2011 WRAP report[36] for household food and drink waste in the UK showed that annual UK household waste has fallen by 1.1million tonnes (13%) over a three year period. Participants reported that rising food prices and increasing financial pressures had led them to re-evaluate their consumption practices to reduce their food waste. Overall, the evidence suggests that rising food prices leads to more active engagement with waste. Participants said that they now produced more meals from scratch and in bulk, which made them more aware of what they were throwing away both in terms of food waste and packaging, resulting in a change in behaviour.

In addition to the participant's own role in reducing waste, the amount of food wasted by supermarkets was raised. Although efforts being made were recognised, such as discounting food to encourage shoppers to buy products with a short sell-by period or giving food past its sell by date to charity, participants said not enough was being done to avoid unnecessary food waste. They commented that supermarkets could do more to reduce waste by further reducing packaging, which was considered excessive at times, particularly in relation to fruit and vegetables. Pressure on them from local councils to recycle their domestic waste gave respondents a sense that levels of packaging were inconsistent with what they were being asked to do in the name of sustainability in their own homes:

"I know the product still has to look attractive, but people don't want all that packaging, especially when we're being sort of asked to recycle."

Celebrity campaigns, e.g. 'Hugh's fish fight'[17], have been successful to a certain extent in informing participants in the high carbon footprint groups about sustainability issues. However, across the groups there were participants who said they lacked the information to make the

[17] Hugh's fish fight – A campaign and Channel 4 documentary aired in 2011 fronted by Hugh Fearnley-Whittingstall promoting sustainable fishing.

'right' choice in terms of sustainability. Some participants reported that they used the internet and newspapers to search out information; however, it was more generally suggested that part of the problem lay in educating, particularly younger generations, in sustainable activities to reinforce these practices into everyday life as they grow. Among those aged 34 and upwards the absence of adequate home economic lessons at school was said to be producing a nation that lacked necessary cookery skills and thus relied on processed and packaged foods which were considered to be inherently less sustainable from a health and waste perspective.

3.4.3 Consumer perception and reactions to potential food futures

Participants were willing to reduce the amount of meat in their diets as a result of meat becoming too expensive and of perceived poorer quality. For many this was something they had already done to a certain extent by shifting from red to white meat or to vegetarian alternatives such as lentils or Quorn. The main barriers in making a bigger change were a lack of knowledge of meat-free recipes and the predicted reluctance by other family members:

"For a lot of people, meat is a big staple of their meal, especially for men. So I think if a campaign was like don't eat meat twice a week, I think a lot of people would go, "So I starve for two days a week?" You have to give people an alternative."

Participants were on the whole unsure of how to adapt if the choice of foodstuffs available in the UK was limited to only seasonal or British products. This was partly down to confusion over what would actually be available. Consumers said that they currently purchase products with little understanding of whether they are in season or even where they come from, indeed a limited number of participants, conceived of 'seasonal' products as mince pies and Easter eggs as these products were only available at certain times of the year. The majority of participants through the groups reported they would need more information on what sort of food they would have access to and the sort of recipes they could cook with those particular products for them to feel happy with this change:

"I'm not 100% sure about what stuff I eat and where it really comes from. So I guess I'm not sure how it would impact on me."

Replacing meals with tablets was rejected by participants throughout the groups on the grounds that it would not fit in with current British culture. Eating was regarded by the vast majority of participants as a social activity. They enjoyed cooking, smelling and tasting food, and spending mealtimes with friends and family, and said that popping a tablet would be a poor substitute:

"You meet with friends, you go out for a meal, you cook a meal, you sit down and you talk about your day, don't you? You're not going to sit there over a tablet, saying, 'Oh, this is what I've done today, darling,' gulp, it's over"

Some participants suggested that the tablet could be used in situations during their working week when they were too busy to break for food or to aid in weight loss programmes. However, meal replacement tablets were deemed unsuitable for every meal. The participants could not see the British public embracing a food replacement tablet and felt the overall taste of food would be missed.

For some respondents in every group, laboratory grown meat was, on the whole, acceptable with the main advantage being a perceived welfare benefit of artificially producing meat rather than having to butcher an animal. This view was particularly prevalent for the vegetarian participants. The idea that a scientist could produce a product which was 'purer' that conventional meat and could even contain added vitamins and minerals was appealing for some participants. Some argued that conventional meat could contain growth hormones and preservatives and therefore lab meat could be of a higher quality and a healthier substitute. It was also suggested that if it was grown in a laboratory then it would be safer than coming from a live animal, with fewer problems due to the level of control involved.

"Well nothing's dead because of it and we still get to eat meat so I think it's the best of both worlds. I don't mind about the Frankenstein thing at all."

It has been over ten years since the Food Standards Agency (FSA) judged that GM foods are safe and pose no additional risks to the consumer [37]. Any products containing GM ingredients must be labelled as such in the UK. Despite this, there was confusion throughout the groups whether GM products are currently sold in Britain and as a result participants said that they would want more information about GM if it involved a greater number of products in the UK. Despite initial scepticism, participants highlighted benefits of using GM, particularly, given the preceding discussion of sustainability of future food systems, in terms of producing greater amounts of food and potentially lowering the price of certain products. A number of participants were worried about the long term health implications of GM products but there was a general sense of inevitability about the future expansion of GM products:

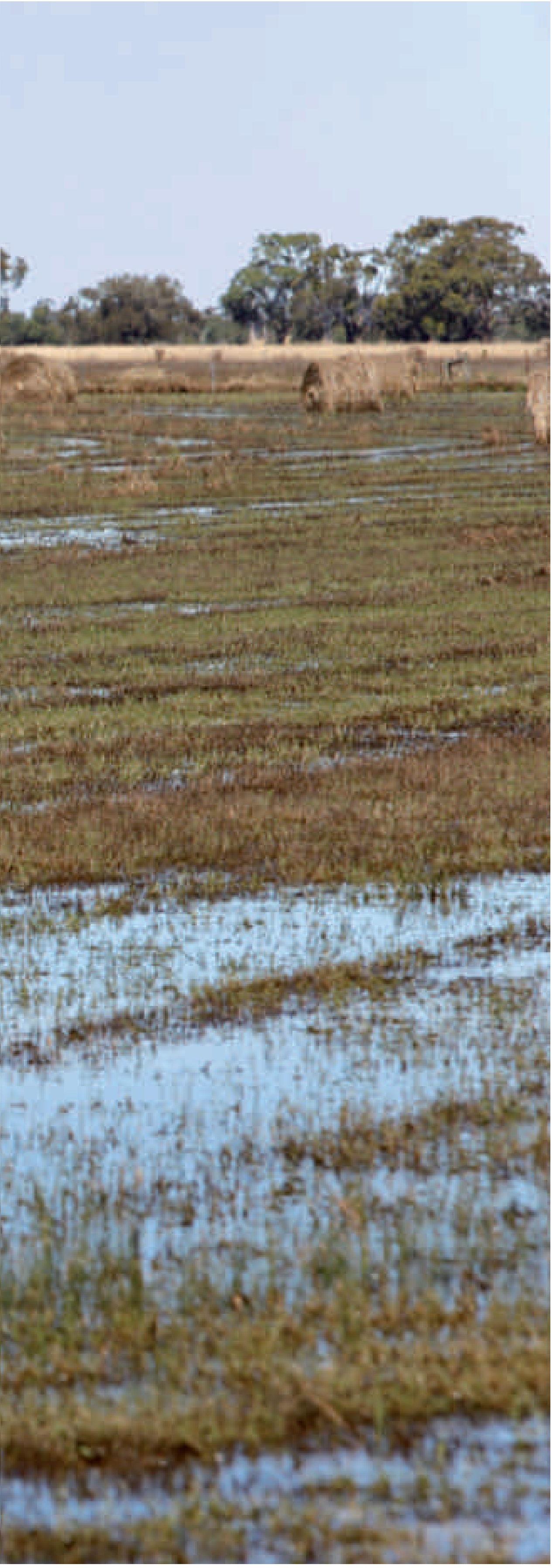
"I don't think we like the idea of GM food but it's the way it's going to be."

An eating house, attached, for example, to a block of flats, place of work, or school, where people would eat their meals instead of in their own home was extremely unpopular with all participants, the majority of whom conjured up ideas of large military-style canteens serving "slop". Participants said they were impractical and raised unprompted concerns about: restricted timings, queues, choice and the quality of food. Rather than conjuring an image of community cohesion, a number of participants, who did not have good relationships with their neighbours, said that eating houses may aggravate problems within their communities. Participants with families were also concerned about the food being offered, as cooking on such a scale might result in problems with food safety, the standard of food produced and the choice available to their family:

"It's limiting choice again innit like you've got a set menu I presume or it's like when you eat at school or at work or whatever it's just a limited choice some people may skip meals 'cause you don't like what they've got."

The focus groups provided a valuable insight into attitudes of consumers to food, both now and in relation to the types of changes illustrated in the scenarios. Whilst participants were not resistant to change per se, some ideas were better received than others. For example, while the idea of communal eating houses was rejected outright, the prospect of GM food and artificial meat were generally viewed more positively.

4. KEY INSIGHTS



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A 'no climate change' future does not exist. The climate is changing because of our influence, and it will continue to do so. While this could be taken to be a hopeless message, instead it should be seen as an empowering one. It means that people, through personal choices, collective movements, technological inventions, organisations and positions of authority have changed the past climate and will influence the extent of future change.

Taking the food system as an example, consumers, retailers, manufacturers, farmers, agrichemical industries, researchers and policymakers all influence the rate and level of cuts to greenhouse gases. But what does that mean for future farming conditions, availability of resources or the popularity of particular foods? By how much will global temperatures rise and what is required to bring about these futures? Where will the impacts of changing food demand manifest themselves? Finally, what will be the direct and indirect effects on the food system of mitigation, climate impacts and adaptation?

This research aimed to resolve some of these questions by exploring the potential for emission reductions at the same time as addressing future climate change impacts and rising levels of consumption.

4.1 An integrated view: adaptation, mitigation and rising demand

Mitigation affects adaptation – adaptation affects mitigation… The purpose of cutting greenhouse gas emissions is to reduce the extent of future climate impacts, but the converse is also important. Arguably more than any other sector, the food system will be impacted by a changing climate. With elevated temperatures and a shift in water resources, farmers will need to respond to more extreme weather events and different growing conditions. Areas that were once ideal for growing crops or rearing livestock may no longer be suitable.

These impacts will influence levels of greenhouse gases, as demonstrated in **Pasta & Pesto** (Figure 25) and **Lab Chops** (Figure 31). The less suited an environment for a particular crop or animal, the more inputs required to maintain yields. For instance, as global temperatures rise beyond 2°C, wheat yields will decline in mid-latitudes without additional fertilisers and N_2O production (e.g. **Pasta & Pesto** Figure 17). Similarly, to protect animals from high temperatures, air conditioned sheds require additional energy (e.g. **Chicken Tikka Masala**, Figure 29).

Understanding the trade-offs and complementarity between mitigation and adaptation is essential to paint a realistic picture of both future levels of emissions, and future climate change impacts. It isn't simply that levels of emissions cuts – mitigation – affects the amount of climate change, climate change in turn impacts on mitigation.

Rising food demand will elevate greenhouse gas emissions… The global demand for food will continue to rise in future decades. The more crops grown and livestock reared to meet this demand, the greater the amount of agricultural inputs and production effort required. Without efficiency or yield developments in low-input practices, careful land-use choices or radically new farming technologies, levels of greenhouse gas emissions will grow and certainly not fall in line with what is required to avoid severe climate impacts (**Pasta & Pesto**; **Chicken Tikka Masala**; **Lab Chops**).

There are strong parallels in this regard with the energy system. As nations industrialise, energy demand rises. Without low-carbon energy supplies, rising energy efficiency is needed to offset the rise in energy demand. But this is where the parallel ends. Energy has a suite of options to decarbonise supply to complement efforts to improve energy efficiency. The mitigation route is challenging but clear. For the food system, the options are not as apparent. Decarbonising the energy system contributes to emission cuts in the food system, but a much greater challenge is faced when seeking to cut non-energy related emissions of CH_4 and N_2O.

Solutions to mitigate these gases are diverse. If these emissions must grow to support global food security, particularly as temperatures rise, then nations with much higher per capita emissions need to find ways to reduce their contribution. This places pressure on both the need to exploit technical and practice-based solutions to avoid the emission of CH_4 and N_2O in a changing climate, as well as to reduce absolute levels of consumption in Annex B nations. Moreover, this analysis suggests that an efficient approach in terms of emissions would be to **maximise food production where inputs, and hence emissions, can be kept to a minimum**. Taking the bigger picture on land-use change will become increasingly important as the triad of challenges – meeting the global demand for food; cutting emissions; dealing with climate impacts grow in significance.

It is important to see the full picture...

Despite the convention in emissions accounting to include only greenhouse gases produced within a national territory, stakeholders involved in the food system, more naturally than in other sectors, consider emissions embedded in supply chains (Figure 10). This is because the emissions associated with the food system extend very visibly far beyond national borders.

The complementary consumption-based accounting approach – which includes the emissions embedded in imports but excludes those from exports – is particularly appropriate for the food system, because a high proportion of emissions are associated with the consumption of imported products[18] (29% compared with a national figure of 21%). As a consequence, adhering to emissions targets that aim to reduce production-based emissions will miss a very significant part of the problem. And, these emissions are being produced in nations where climate impacts will be different to those experienced in the UK. **Complementing a production-based accounting framework with a consumption-based one allows policymakers to consider the big picture**. Furthermore, nations with higher consumption-based than production-based emissions have scope for increasing their influence over global emissions and ensuing climate impacts.

Consumption-based accounting highlights the implications of only moderate improvements to carbon intensity in nations from which the UK imports [19], helps to avoid carbon leakage and opens doors to a wider portfolio of policy mechanisms that could be channelled through a broad range of supply chain actors. Whilst some aspects of the supply chain may be outside direct reach of policy, the link to consumption, offers one complementary mitigation lever.

Targets will be missed without integrating adaptation & mitigation...

UK policymakers generally place greater emphasis on mitigation than adaptation when debating climate change. Even amongst farming stakeholders, the term 'adaptation' is sometimes taken to mean adapting to changes needed to reduce greenhouse gas emissions. Yet there are three important reasons why as much emphasis must be given to climate impacts and adaptation as given to mitigation, above all when considering the food system:

Firstly, policymakers need to be realistic about the future being faced. This study is unusual in that it considers climate impacts beyond 2°C. The trajectory of global emissions is currently on track for at least 4°C of warming by the 2nd half of the century [5]. Whilst UK arable farming may be favoured for the coming couple of decades while temperatures elevate towards an increase of 2°C, above that level, more severe climate impacts will start to reduce productivity. Not to mention the impacts of extreme and disruptive weather events on the way towards even a 2°C rise.

Secondly, many of the impacts experienced at the higher end of the scale will affect levels of emissions. If a greater amount of fertiliser is required to maintain yields, or measures needed to protect livestock from the elements,

[18] Consumption here refers to goods and services consumed by UK households, government and purchased for capital investment.

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additional greenhouse gases will be released, further exacerbating the problem. Meeting the UK's agricultural emissions target of a 70% cut by 2050 will become increasingly difficult as temperatures rise, placing additional pressure on other sectors to decarbonise.

Thirdly, the UK's food system extends far beyond national borders. Climate change will impact on parts of that food system typically in advance of impacts experienced in the UK. This will affect food security, trade relationships, demand for UK exports, food prices, and the livelihoods of the producer communities. **An increase in demand for the UK's agricultural products will be a driver for rising UK greenhouse gas emissions under the current emission accounting framework**. Taking the consumption-based emissions totals into consideration provides a more systemic perspective on this issue.

Growth in consumption needs to be tackled to avoid 2°C... Taking the consumption-based approach to addressing mitigation in the UK means decarbonisation efforts need to include the emissions embedded within imports. Many of these exporting countries will not have greenhouse gas targets or be signed up to reduce their emissions to avoid particular levels of climate change.

Quantitatively, this becomes more important the greater the level of mitigation sought. The UK currently maintains its commitment to the 2°C threshold. For futures aiming to avoid a 2°C temperature rise, two things need to happen. **The emissions intensities associated with imports must be reduced over the coming decades far in excess of levels currently being considered by those nations and the demand for goods from those nations lowered**[19]. This is in addition to a low-carbon energy transition and low- to- zero growth in levels of consumption[20]. Without such far-reaching change, the UK's consumption-based emissions will exceed the UK's contribution towards a reasonable probability of avoiding the 2°C rise.

Reducing emissions in line with a 4°C temperature rise is very challenging...
Research on climate mitigation commonly uses the 2°C temperature rise as a backdrop. There is much less discussion on what it means to mitigate in line with 4°C. A common but misplaced assumption is that a 4°C rise is a 'business as usual' trajectory. This raises questions regarding what 'business as usual' can mean when facing uncertainties around climate impacts. And, what a worst case scenario would lead to. This research shows that even limiting greenhouse gas emissions in line with a 4°C global temperature rise is extremely challenging. For a nation such as the UK, cumulative emissions would need to be severely constrained, with reductions of at least 60% compared with 1990 levels by 2050 [2].

At present, the 2°C target is not complemented by adequate emission reduction commitments, even in nations with emissions targets [1]. Non-Annex B nations are generally without mitigation goals. If the target were 4°C, then these non-Annex B nations would continue to develop fossil-fuel reliant economies for decades to come. Thus emissions intensities of imports would remain unconstrained, and elevate the consumption-based emissions of nations reliant on imports.

Climate impacts accompanying a 4°C rise in temperatures are researched to a much lesser degree than impacts at 2°C. Nevertheless, research shows that they will likely be severe: 30% reduction in rice yields in China and India; the complete disappearance of glaciers from South America; up to 70% reduction in run-off around the Mediterranean; drought events occurring twice as frequently across southern Africa (Figure 1). **Avoiding 4°C is paramount but requires a step-change in action towards mitigation.**

4.2 Insights for agriculture

Agricultural emissions become more prominent in future... Mitigation effort is most commonly directed at CO_2 from fossil-fuel combustion. A transition to a decarbonised energy system by 2050 is considered feasible. But if this transition becomes a reality (2°C future), emissions from sectors more difficult to mitigate will start to increase in share. CH_4 and N_2O emissions from the food sector fall into this bracket (**Bubble & Squeak** and **Mash & Banger**, Figure 15).

Globally, ~13% of greenhouse gas emissions are from agriculture. Of this, less than 1% are CO_2, 53% CH_4 and 46% N_2O [17][21]. If the '2°C' scenarios are achieved (**Bubble & Squeak** and **Mash & Banger**), **the UK's emissions profile (Figure 4) will be increasingly**

[19] Reductions in imports from supplier nations, if replicated by other nations, would likely have negative economic implications for those nations.

[20] As measured in the model in terms of £ spent

[21] These figures alter significantly if land-use change is included, with estimated shares of 57% CO_2, 23% CH_4 and 20% N_2O [38].

[22] If land-use change is included, CO_2 emissions from agriculture will also be very important.

influenced by CH_4 and N_2O[22] associated with food – and this picture will likely be replicated elsewhere. Thus, to reduce emissions in line with '2°C', there need to be shifts in food consumption patterns and/or a step-change in the use of technology and practices in agriculture (e.g. **Bubble & Squeak** and **Mash & Banger** in Figure 15 & Figure 16).

For yields to benefit from climate change, 'national' emissions will rise... As temperatures rise, some places will likely be able to reap better yields. UK wheat production is in this category. However, to produce more wheat per hectare, more fertiliser will be needed in absolute terms, despite the fertiliser needed per unit of wheat produced remaining the same. If the UK is an efficient place to produce wheat, then this situation should be taken advantage of. But, allowance would need to be made for a rise in emissions from agriculture, while other sectors are decarbonising.

UK farmers express resilience... Farmers respond to weather on a daily basis. Their dominant perception of the climate change challenge is one of being able to draw on their flexibility to adapt to the changing environment over time. Farmers have always adapted and will continue to do so, although traditional use of indigenous knowledge is likely to be challenged by climate change. Of greater immediate concern to stakeholders is how to 'adapt' to new lower-emission agricultural systems. Nevertheless, an important issue recognised as a somewhat unknown quantity, is not how to respond to gradual climatic change, but how to respond to more frequent, recurring and extreme weather events or a greater level of uncertainty in weather forecasts.

4.3 Insights for food supply chains

The consumer vs retailer – a contested power relationship... The influence of key actors within the supply chain is of great importance for tackling food system emissions [39]. Yet where the power resides in the chain is perceived differently depending on who is asked. While supermarkets highlight the power of the consumer in driving and supporting change in the form of lower-carbon consumption, producers tend to lay the balance of power at the door of supermarkets. Potential policy interventions should be considered from these different perspectives to ensure that, particularly voluntary measures, are supported by those with the power to make them successful.

Information provision – necessary but not sufficient... A common response to addressing climate change through consumers is to provide information, in the form of marketing, leaflets, fact sheets, labels and so on. However, whilst the level of knowledge may be a necessary condition of low carbon behavioural change, it is not sufficient as even those that are both knowledgeable and motivated face structural and cultural barriers to change [40-42]. Given the deeply socially embedded and cultural nature of food and eating, **information provision alone will not necessarily lower the impact of food choices**.

Discussion across the high, medium and low carbon footprint categories supported the limitation of information provision as the sole tool for achieving emissions reductions as the most engaged and informed respondents tended to be in the highest footprint groups. The complexity of what 'sustainable consumption' actually means in practice and the many ethical, social and environmental factors it can encapsulate, led to calls from participants across the groups for more information to allow them make the 'right' choices. However, as noted above, such provision is likely to be necessary rather than sufficient condition of change.

Confusion over terms such as 'sustainable food' and a desire for more information provision was evidenced in relation to seasonality. Many participants discussed a sense of not knowing when products were 'in season' as they were constantly available on the supermarket shelf. Indeed a couple of respondents' frame of reference in discussing seasonality was related to products such as Easter eggs as these really could only be bought at certain times of year.

Livestock consumption may not be here to stay... Meat currently makes up around 14% of the daily UK calorie intake. The consumption-based greenhouse gases associated with unprocessed meat consumption are 15% of 'Food and Drink' emissions, excluding those associated with land-use change (Figure 11). However, meat is also consumed in combination with other ingredients in ready meals and other processed foods. Although a high proportion (55%) of 'Processed Foods' emissions are CO_2 emissions from the energy required for the processing, 29% of the emissions from 'Processed Foods' are also associated with meat. This elevates the percentage of 'Food and Drink' emissions linked to meat to 28%[23].

A shift towards a lower meat intake, or a vegetarian diet to mitigate emissions is an issue that has been raised by many other studies [21-23], and an obvious choice to reduce greenhouse gas emissions. The question is, what do consumers think about this – are they willing to alter?

Many of the female focus group participants were concerned that the men in their households would not support a reduction in meat consumption. However, both male and female groups tended to find a 20% reduction in meat consumption (**Bubble & Squeak**) potentially acceptable with participants talking about the reduction they were already making due to price rises. A 70% reduction (**Mash & Banger**) was not well supported across the groups with concerns over maintaining an interesting and varied diet.

Futuristic options such as laboratory grown meat or meals in the form of a pill (**Lab Chops**) raised interesting debate and discussion with stakeholders and consumers alike. Wider perceived benefits of unconventionally produced meat included improving animal welfare, standards and food safety. Meal pills did not receive such a warm welcome, with the lack of the social aspect to enjoying a meal cited as a reason to stick with more conventional fare. Their only glimmer of support was as a quick and convenient alternative when harried.

The future can be different... One of the biggest challenges faced in this project was facilitating new and creative thinking around food futures. Backcasting is a tool specifically aimed at supporting stakeholders in envisaging alternative futures. Although some struggled with concepts that were seemingly 'impossible' at the outset, the process successfully delivered a suite of coupled adaptation and mitigation scenarios for informing the

[23] Smaller additions to this figure would come from other sectoral spend on meat products, for instance in its transportation.

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policymaking process.

A 'no climate change' future does not exist. The climate has already begun to change because of our influence, and it will continue to do so. The logic of this should be considered empowering. As citizens, professionals, decision- and policymakers we have the power to change and influence the prospective climate. **We have a choice**. This could be a high mitigation, low adaptation future, with a 2°C target in mind. Alternatively, it could be a low mitigation, high adaptation future, leading to 4°C of warming in the latter half of the century. The consequences of these futures are very different, and will remain uncertain. But the mitigation choices we are making must be commensurate with the advice and the communication of risk to

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those that will need to adapt to climate change.

The importance of food system emissions in this debate cannot be overstated. A great deal of research and effort is directed at decarbonising energy systems. Yet food related emissions must also be constrained. Only by recognising the extent of food-related emissions can we fully recognise the energy challenge, because all these emissions are constrained by cumulative budgets of greenhouse gases.

One of the greatest difficulties in communicating the importance of significantly cutting emissions is the issue of timing. Different timeframes are frequently associated with mitigation and adaptation. For many, particularly those in Annex B nations, mitigation is characterised by short-term emission cuts, 2020 or 2050 targets. Climate impacts and adaptation, on the other hand, are often considered to be longer-term. Certainly the difference between high and low mitigation scenarios is less pronounced in 2050 than it will be by 2100 but **communicating the legacy of choices made in the short term to those in positions of influence needs much greater emphasis**.

Contrasting 2°C with 4°C futures goes some way towards achieving this goal. Currently we are implicitly mitigating for 4°C and adapting to 2°C; a complacent and precarious pathway. Instead, an explicit choice is needed given the implications of different climate futures for world regions. Moreover, if the international community considers 2°C to be a dangerous threshold, then new suites of policies and measures that can influence the full supply chain are required immediately.

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Project team(from the left): Ellie Dawkins, Ruth Wood, Laura Thom, Carly McLachlan, Alice Bows, Mirjam Röder, Clair Gough, Patricia Thornley, Sarah Mander (missing)

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