SCENARIOS SUB REPORT

The Role of the UK Food System in Meeting Global Agreements:

Supporting Evidence

Global Food Security

Sustainable, healthy food for all

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This sub-report was prepared by Maia Elliott on behalf of the Global Food Security (GFS) programme. It provides an overview of the evidence supporting the scenarios in the GFS report *The Role of the UK Food System in Meeting Global Agreements: Potential Scenarios* (2021).

The scenarios sub-report should be cited as:
The Role of the UK Food System in Meeting Global Agreements: Supporting Evidence (2021). The Global Food Security programme, UK Research and Innovation.

The electronic version of this sub-report can be found at:
www.foodsecurity.ac.uk/publications/UK-food-system-scenarios-evidence.pdf

Introduction

In 2017, the Global Food Security (GFS) programme launched a scenarios exercise to explore what the UK food system could look like in 2050 if it were transformed to meet the UK's global agreements on climate mitigation (i.e. the Paris Agreement) or sustainable development (i.e. the Sustainable Development Goals), in a more localised or a more globalised context.

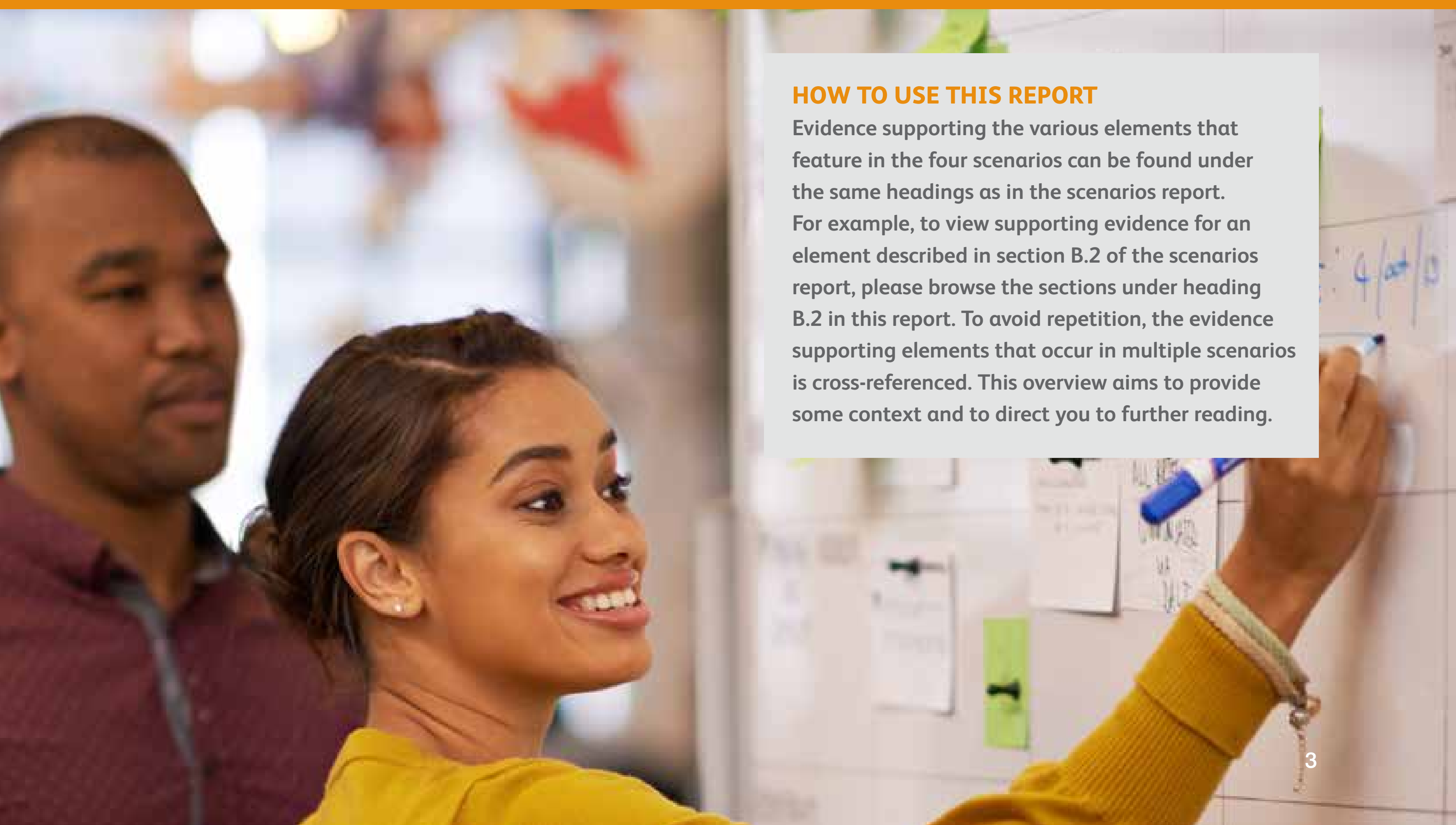
A team of experts developed four distinct food system scenarios, each with its own benefits and challenges. The four scenarios were analysed and discussed by a multidisciplinary taskforce of academics and stakeholders with expertise spanning the UK food system. Feedback from the taskforce was incorporated to produce the final four scenarios, which were then analysed to reveal potential opportunities and challenges that should be considered in real-world decision-making. These scenarios can be found in the GFS report *The Role of the UK Food System in Meeting Global Agreements: Potential Scenarios.*

This scenarios exercise is an example of grounded speculation, a highly valuable policy tool for preparing for uncertain futures. The scenarios do not attempt to predict the future of the UK food system, nor do they suggest what the preferred future might be.

The scenarios simply had to be plausible under the stipulated conditions (i.e. in a more localised or a more globalised setting, with a primary focus on mitigating climate change or striving to meet wider metrics of sustainability alongside bold climate action). This sub-report outlines the evidence supporting the plausibility of the four food system futures.

Considering a system from different perspectives is vital when preparing for an uncertain future, and this is reflected in the variety of sources that informed the scenarios exercise. Although much of the evidence originates from academic publications, the scenarios were also informed by news articles, industry- and NGO reports, websites, surveys, and blogs. These non-academic communications are particularly useful for identifying emerging trends, as well as documenting current events and public opinions.

Given the wealth of information that was drawn on to build the four scenarios, this report does not aim to provide an extensive or critical analysis of the the supporting evidence. Its aim is to provide a succinct demonstration that the events in the scenarios are informed by current events, case studies, pre-existing ideas, and academic research.



HOW TO USE THIS REPORT

Evidence supporting the various elements that feature in the four scenarios can be found under the same headings as in the scenarios report. For example, to view supporting evidence for an element described in section B.2 of the scenarios report, please browse the sections under heading B.2 in this report. To avoid repetition, the evidence supporting elements that occur in multiple scenarios is cross-referenced. This overview aims to provide some context and to direct you to further reading.

Year 2050: the climate has changed significantly

Locked-in climate change

In each of the four scenarios, locked-in climate change directly or indirectly impacted UK food production and key growing regions that supply the UK. Although climate mitigation has the potential to lower the incidence and severity of extreme weather events such as heatwaves in the future, today's mitigation efforts are not projected to impact climate extremes until the latter half of the 21st century[1]. However, it should be noted that there are large uncertainties over when the effects of climate mitigation will be felt, since climate change signals are expected to be relatively small compared to natural climate variability.

Temperature rise and extreme weather

Across the four scenarios, the average global surface temperature rose by 1.5˚C, the frequency and intensity of extreme temperatures and precipitation increased, and the UK generally experienced milder, wetter winters and hotter, drier summers. The incidence of very hot summers could approach 50 % by 2050[2], and the area of land projected to experience simultaneous heat waves could increase 16 % with each additional degree of global heating[3]. However, climate variations mean that occasional cold winters, dry winters, cool summers and wet summers will still occur[2]. Between 2020 and 2050, average annual temperatures over the UK are projected to increase by 1.3˚C if stringent climate mitigation is introduced in the near future, and 1.7˚C if global greenhouse gas emissions continue to rise unmitigated[4]. Over the same period, precipitation is projected to change +5 % in the winter and -11 % in the summer if climate change is stringently mitigated, while precipitation changes are projected at +7 % in the winter and -15 % in the summer if climate change is not mitigated.

Impacts of climate change on UK food production

Although warmer temperatures did boost the UK's winter wheat yields some years, the overall impact of climate change on the UK food system remained negative across all four of the scenarios. By the 2050s, UK winter wheat yields are generally projected to increase in the absence of heat and drought stress[5]. However, extreme temperatures could be occurring every other year by the middle of the century, so the overall net effect of future climate change on agricultural production in the UK is still expected to be negative. The 2018 heatwave reduced grazing land productivity, forced the use of winter feed, increased cattle heat stress, reduced the growth of many staple crops (notably cereals, potatoes, salad, fruit and vegetables) and increased crop damage from pests[6].

Besides the threats posed by extreme temperatures, changing rainfall patterns, and the increasing spread of pests and diseases on livestock and crop systems, sea level rise is also likely to increase soil salinity, compaction and inundation in the future[7]. A strong regional shift in suitability for carrots and potatoes (without irrigation) is anticipated, and by the 2050's a 7-fold increase in irrigation water would be needed to maintain current production levels[8]. However, there may be the potential to grow a wider range of crops on the UK's arable land than at present, such as sunflowers, grain maize, soya, fruits and vines[6].

A The carbon-neutral food system

The carbon-neutral scenario describes a future in which the UK food system is more localised in 2050 than it was in 2020, and where climate mitigation has been the major driving force in transforming the food system. This section provides an overview of the supporting evidence for this scenario.

A.1 The carbon-neutral food system scenario

A.1.1 The rise of mega farms and vertical farms

In the carbon-neutral scenario, food production was dominated by ultra-efficient large-scale conventional farms, as well as aero- and hydroponic vertical farms. The dominance of large-scale conventional farms is supported by the emergence of US-style intensive mega farms in the UK, which have grown by over a quarter in the past six years[9]. The increased use of vertical farms in this future is supported by the cutting-edge research being conducted at Rothamsted Research and the John Innes Centre, which is producing four to five crops a year instead of the conventional one or two outdoors[6]. This is possible due to the LED indoor system that mimics the sun but provides the plants with 22 hours of light per day.

The scenario also highlighted the high cost of vertical farming, preventing those on lower incomes from accessing these fresh foods. This effect is supported by the high electricity costs associated with growing food vertically, which make it uneconomical to grow lower value crops this way[6]. The energy-intensity of vertical farming means that growing food vertically can emit more greenhouse gases than it would to ship those foods in. Furthermore, building vertical farms is very expensive, and (unlike well-managed agricultural land) these farms decrease in value over time[10].

A.1.2 Climate-resilient food production systems

The megafarms adopted climate-resilient food production systems to protect against extreme weather in the UK in the carbon-neutral scenario. Climate-resilient food production systems include indoor farming, as well as the investment in irrigation systems, rainwater storage, crop rotations, the provision of shade and shelter for livestock, the use of drought-resistant varieties of crop, and improving field drainage[11]. Agroforestry (the planting of trees, shrubs and hedges on cropland and pastureland) was not adopted as a climate resilience strategy in this scenario, which prioritised modern climate-smart technologies over conventional practices. This approach is supported by the long-standing disconnect between the agricultural and forestry sectors[12].

A.1.3 Increasing mechanisation

Although the agricultural sector expanded in the carbon-neutral scenario, ever-increasing mechanisation steadily shrunk its workforce. The UK's agricultural sector has been experiencing a declining workforce over the past decade, with less than 1 % of the UK's working population now working in food production[13]. The increasing mechanisation of agriculture is likely to continue, as economic pressures are driving farmers to replace labour with technology.

A.1.4 Carbon pricing and the cost of food

In this carbon-neutral scenario, carbon pricing was introduced to reduce emissions. This approach has been widely suggested as a means of levelling the playing field for UK heavy industry whilst affirming the UK's position as a global leader on climate action[14].

Carbon-pricing increased the cost of food in the carbon-neutral scenario, limiting food choice for those on lower incomes. This outcome is supported by a 2016 study, which measured the impact of an emissions-based food tax across different income groups in the UK[15]. Although the tax was effective at lowering household greenhouse gas emissions, it also found that the burden fell disproportionately on the poorest households, who spend more of their disposable income on food.

A.1.5 Carbon pricing and food waste

Carbon pricing reduced household food waste in the carbon-neutral scenario, an effect that is supported by historical evidence that the decreased affordability of food during economic recessions is generally accompanied by a reduction in household food waste[16]. Citizens found ways to make food go further (e.g. saving leftovers and freezing perishable produce) which meant they did not need to buy as much food when it became less affordable[17].

A.1.6 Carbon pricing and home-cooking

Carbon pricing increased the popularity of pre-cooked foods in the carbon-neutral scenario. Approximately 21 % of total household energy is used in the kitchen, and nearly two thirds of that energy is used to store and prepare food[18]. Therefore, an economy-wide carbon tax would increase the cost of home cooking, increasing the appeal of pre-cooked foods.

A.1.7 Increasing UK self-sufficiency whilst achieving carbon-neutrality

In the carbon-neutral scenario, UK food policy focused almost solely on increasing self-sufficiency whilst achieving carbon-neutrality in the food system. According to a 2018 report by the Committee on Climate Change (CCC), the UK could meet its climate mitigation targets whilst protecting its natural capital by reducing the area of grasslands by a third (including some lowland and peatland)[6]. This approach would release land to grow energy crops, which could be used to offset agricultural emissions and achieve a Net Zero food system. However, the CCC's recommendation does not assume the UK will need to be more self-sufficient in the future. Achieving greater self-sufficiency alongside bold climate action would require greater land use efficiency and agricultural diversification.

A.1.7.1 Greater land use efficiency

Greater land use efficiency could be achieved by shifting towards a more plant-based diet. Today, 85 % of the UK food system's land footprint (home and abroad) is associated with the production of meat and dairy, despite the UK population deriving only a third of its calories and half of its protein from livestock[19]. A study investigating the micronutrient content of UK diets and land use, identified that root, tubers and vegetables require the least amount of land to produce 23 key nutrients for human health, while red meat, oil crops and sugar require the most land[20]. Vegetables, roots and tubers can produce enough nutrients to feed approximately 42 people per hectare per year, cereals can feed approximately 21 people per hectare per year, and eggs (the most land-efficient animal product) can only feed four people per hectare per year. Therefore, increasing food production whilst ensuring enough available land for carbon-offsetting could be achieved by shifting towards a more plant-based diet.

A.1.7.2 Agricultural diversification using crop rotations

The diversification of agriculture is another key strategy to increase the UK's self-sufficiency, as the UK currently imports 77 % of its fruits and vegetables[21]. Cereals take up 60 % of the UK's arable land, of which 54 % is wheat[22]. In the carbon-neutral scenario, crop rotations were adopted to diversify food production systems. This alternative cropping system has proven capable of increasing crop yields both in favourable and unfavourable growing conditions[23], as well as reducing the amount of agrochemicals needed[24]. This approach would reduce the UK's reliance on imported fertilisers and pesticides, simultaneously increasing the UK's self-sufficiency and lowering its agricultural emissions. Lower emissions would reduce the amount of land required to offset these emissions, reducing the land footprint associated with the UK food system.

A.1.8 Methane-free livestock

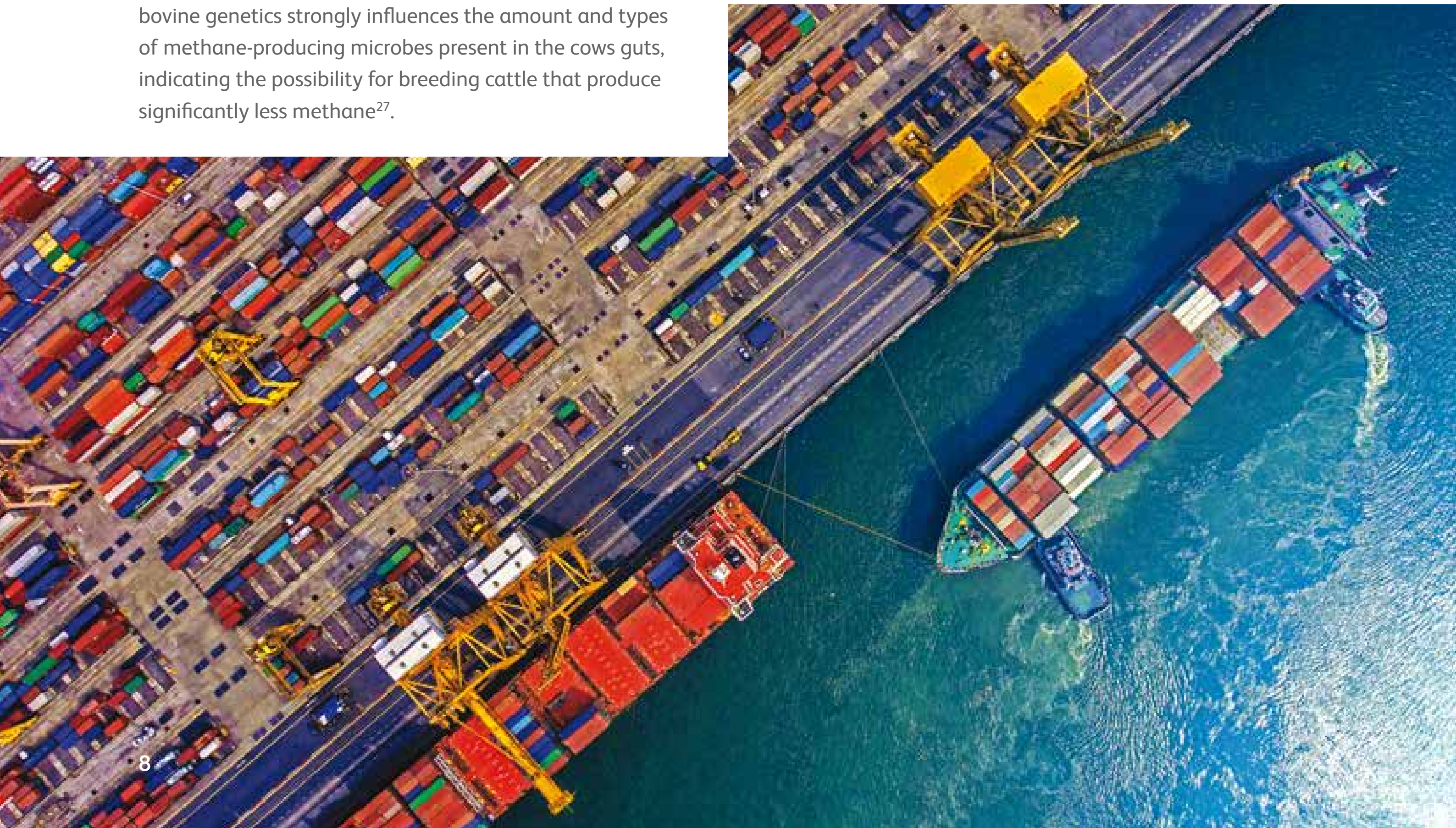
Methane-free cattle were engineered in the carbon-neutral scenario, an outcome that is supported by the growing research on low-emissions livestock systems. A 2015 study demonstrated that the methane emissions of cows can be reduced by 30 % using a methane-inhibiting feed additive[25], and more recently it was found that incorporating seaweed into the diets of cattle can reduce their methane emissions by over 50 % [26]. Another strategy to lower methane emissions from livestock involves genetic selection. An international study of 1,000 cows in 2019 showed that bovine genetics strongly influences the amount and types of methane-producing microbes present in the cows guts, indicating the possibility for breeding cattle that produce significantly less methane[27].

A.1.9 Zero-emission machinery

In the carbon-neutral scenario, the large state-owned farms processed their produce using ultra-efficient, zero-emission machinery. According to a 2020 report by the Manufacturing Technologies Association, this outcome could be achieved by investing in the development of smart grid and battery technologies that support the use of renewable energy in the manufacturing sector[28]. A completely zero emissions system in the food industry has already been designed using pineapple processing as a case study[29].

A.1.10 Zero-emission food transport

The zero-emission food transport fleet in the carbon-neutral scenario is supported by the growing public, media and industry attention towards food miles, spurred by the increasing globalisation of the UK food system. Although many foods are thought to be flown into the UK (e.g. avocados and almonds), flights only account for 0.16 % of global food miles[30], while shipping accounts for nearly 60 % of food miles, and vehicles 31 % . Hydrogen-powered ships that produce water and electricity without emissions, are already being tested in Europe and are expected to be operational within a decade[31]. New regulations have sparked a growth in the sales of electric trucks, which is estimated to increase from 31,000 in 2016 to 332,000 by 2026[32].



A.1.11 Higher import costs

Food prices are higher in the carbon-neutral scenario compared to 2020, partly due to the implementation of the carbon tax (see section A.1.4), but also due to higher import costs. This outcome is supported by a 2021 analysis from the global consultancy OC&C Strategy Consultant, which states that the costs of imported foods could increase by 8 % over the coming years[33]. The experts estimate that the added paperwork that traders must go through and new checks at the UK-EU border could drive up the cost of imported foods by $4.1 billion for the UK food industry. With the profit-margins of suppliers' already being paper-thin, the price hike will likely be passed onto citizens unless major efficiencies can be found elsewhere in the food system.

A.2 Impacts of the carbon-neutral food system

A.2.1 Lack of dietary diversity associated with poorer health outcomes

In the carbon-neutral scenario, high income households continued to enjoy varied, high-quality diets, while low-income households faced a reduction in dietary diversity, widening the health gap between socioeconomic groups. Dietary diversity is considered a key indicator of diet quality and nutritional adequacy, and has been associated with reducing the risk of various health conditions such as Type 2 diabetes, metabolic syndrome, depression, food allergies, and osteoporosis, as well as reducing the risk of mortality[34]. Consuming a greater diversity of vegetables reduces the risk of diet-related disease the most, which supports the outcome that poorer citizens who had limited access to vertically-grown vegetables in this scenario, experienced poorer health outcomes.

A.2.2 Access to nature and wellbeing

Megafarms dominated the rural landscape in the carbon-neutral scenario, which removed affordable and easy access to nature-based recreation and reduced the wellbeing of citizens on lower incomes. This effect was supported by evidence that urbanisation is likely to increase in the future, and that increasing urbanisation is associated with less time spent in nature[35]. A UK study of 3,000 survey respondents found that those living in nature-deprived urban areas tend to have worse health outcomes across multiple domains, including depression and isolation[36].

However, people who had access to allotments in the carbon-neutral scenario experienced positive mental health effects, an outcome that is supported by the beneficial effects of 'green therapy', a wellbeing movement that is receiving increasing support from UK health professionals[37]. Patients who score low in the wellbeing category are referred to spend time gardening and growing food as part of their recovery and rehabilitation programmes. Green therapy has been found to not only improve mental health, but also have physical and social benefits. Over 1,500 organisations have signed up to Growing Health, a national community food growing scheme that aims to promote health and wellbeing[38].

A.2.3 Reducing agrochemicals and impacts on yield

In the carbon-neutral scenario, deep emissions cuts across the food system required a significant reduction in the use of agrochemicals. A study in Spain comparing conventional and organic cropping systems found that the emissions from organic management systems (which do not use agrochemicals) were 36-65 % lower than those of

conventional management systems, depending on the crop type[39]. These results show that a large proportion of the emissions associated with crop production are attributable to the use of agrochemicals.

The reduction[40] in greenhouse gas emissions from reducing agrochemicals was also accompanied by overall lower productivity per land unit area in the carbon-neutral scenario. This outcome is supported by an analysis of 362 publications comparing organic and conventional crop yields[40]. On average, organic yields are 80 % of conventional yield, depending on the crop type. Under these conditions, growing the UK's food supply without agrochemicals could require 25 % more land (or more). This outcome could exacerbate the land-use tensions arising from the need to produce more food domestically and the need to mitigate climate change (see section A.1.7).

A.2.4 Neglect for wider sustainability

The carbon-neutral food system was primarily focussed on climate mitigation, which led to the neglect of other issues such as biodiversity loss. The effect of biodiversity loss being eclipsed by the issue of climate change is supported by a study investigating the relative distribution of funding for biodiversity loss and climate change, as well as the scientific and newspaper coverage these issues received[41]. The study found that greater attention for climate change was associated with less coverage and funding for biodiversity loss.

A.2.5 Crop rotations boost soil health

In the carbon-neutral scenario, the widespread use of crop rotations improved soil health. The positive impacts of crop rotations on soil health include increasing nitrogen fixation (reducing the need for fertilisers) and increasing opportunities for microorganisms to grow that protect against soil-borne crop pathogens (reducing the need for pesticides)[42]. However, the benefits depend greatly on the types of crops rotated, the order in which the crops are rotated, how frequently rotations occur, the history of the farmland, and the characteristics of the soil.

A.2.6 Reducing emissions improves air and water quality

The drive to lower greenhouse gas emissions improved air and water quality in the carbon-neutral scenario. The considerable evidence demonstrating that high-emission agricultural practices (e.g. harvest fires, agrochemical use, and increased livestock stocking rates) are detrimental to air and water quality supports this effect[43].

Besides improving the quality of the UK's air and water, it is possible that reducing agricultural emissions could improve the health of the citizens who breath the air and drink the water. Fertiliser use and livestock production (the two highest emitters in the UK food system) are strongly associated with higher ammonia emissions. 90 % of ammonia in the atmosphere originates from farms, and it is the only pollutant in the UK that is on the rise[44]. When inhaled, ammonia pollution can lead to higher death rates, respiratory problems, cardiovascular diseases, cognitive decline and low birth weights. It is estimated that at least 3,000 deaths could be avoided per year if the UK halved its ammonia emissions.

A.2.7 Aquaculture allows marine biodiversity to recover

In the carbon-neutral scenario, the growth of aquaculture reduced large-scale marine fishing, allowing national marine biodiversity to recover. This effect is supported by evidence that aquaculture has been meeting the increasing global demand for fish since the late 1980's, thereby reducing the pressure on overexploited wild stocks and boosting natural species diversity[45]. However, aquaculture must be carefully managed to avoid unintended negative impacts on marine biodiversity. Conservation Evidence has gathered over 25 interventions that could minimise the impacts of aquaculture on marine biodiversity, such as swapping fish meal for plant-based alternatives in the diets of farmed fish, the use of probiotics and immunostimulants instead of antibiotics, and the construction of artificial reefs to reduce the dispersal of effluents[46].

A.2.8 The emerging market for low-emissions technologies

In the carbon-neutral scenario, the UK's commitment to net zero emissions by 2050 and its transformative agricultural policy catalysed emerging markets for low carbon technologies and mechanisation across the food system. Climate-smart agriculture (i.e. measures and technologies that improve food security, enhance resilience to climate change and pests, reduce greenhouse gas emissions and increase productivity) is considered a growing private sector opportunity, with the sector expecting major business opportunities of $2.3 trillion annually by 2030[47]. Section A.1.9 touches on the investments needed to develop net zero machinery for the food system.

A.2.9 Increasing food system transparency

Advanced tools for food traceability were implemented in the carbon-neutral scenario, leading to greater transparency across the food system. This outcome is supported by the development of distributed ledger technologies (DLT), which are capable of enhancing security and data integrity in the food system, without the need for a third-party organisation[48]. Blockchain is an example of a DLT that can be used to reduce the risks of food contaminations by allowing citizens to trace a food product throughout the supply chain. This DLT also benefits smallholders in lower-middle income countries, by recognising their ownership over the food they produce, removing barriers to trade, reducing the fees paid in each transaction, and freeing up financial systems.

Personalised carbon footprint tracking also led to greater transparency in this scenario, a development that is supported by the emergence of fitness apps that allow citizens to track their nutritional intake by scanning the barcodes of their food products. Using a similar strategy, Hugh Weldon (the Young Champion of the Earth for Europe 2018) is currently developing a new app called Evocco, which, alongside nutritional information, also aims to estimate the climate impact of its users' food choices[49].

A.2.10 Overcoming barriers to land use transitions

In the carbon-neutral scenario, new land management skills were required to overcome the initial barriers to achieving the marked land use transitions. This is supported by the 2018 Committee on Climate Change report on land use and climate change[6], which highlighted the following barriers to changing UK land use:

In 2020, the Committee released a detailed assessment of recommendations to develop policy that can address these barriers[50]. These policy recommendations centre around promoting transformational land uses, rewarding landowners for public goods that deliver climate mitigation and adaptation objectives, reflecting the value of the goods and services that land provides, and providing support to help land managers transition to alternative land uses.

> *"[Barriers] include inertia in moving away from the status quo and lack of experience and skills in alternative land uses; long-term under-investment in research and development and bringing new innovation to market; lack of information about new low-carbon farming techniques; high up-front costs of new farming methods and alternative land uses; uncertainty over future markets for new products; and little or no financial support for public goods and services provided by land that do not have a market value."*

A.2.11 The rural-urban divide

The divide between rural and urban areas was exacerbated by the changing face of agricultural production in the carbon-neutral scenario, which undermined traditional rural communities and reduced the agricultural workforce. Evidence supporting the future reduction in agricultural workforce is outlined in section A.1.3, and the divide between rural and urban areas is supported by the growing political divide observed during the Brexit referendum and the US elections in 2016[51]. The narrative of "metropolitan elites vs rural folk" has been adopted across the globe, spanning places with very different cultures and levels of development, such as Turkey, Thailand, Brazil, Egypt and Israel.

A.2.12 Loss of small, traditional farms

Small, traditional farms were replaced by large-scale modern farms in the carbon-neutral scenario. This outcome is supported by the observation that the number of small farms in the UK has almost halved in the past 30 years due to powerful economic forces driving changes in farm size structures[52]. 25 % of UK farming families now live below the poverty line, with many traditional farms having to

provide other services alongside food production in order to survive[53]. 17 % of farms make more money from their additional enterprises than they do from producing food. Furthermore, the number of County Farms (owned by local authorities to allow young people and newcomers start small farming businesses) has also been halved in the past 40 years, contributing to the greying of the traditional farming sector and the loss of smallholders[54].

A.2.13 The livestock sector goes under

In the carbon-neutral scenario, the livestock sector went under before the year 2050. This event is supported by a recent report by the independent think tank RethinkX, which analyses and forecasts technology-driven disruption and its implications across society[55]. According to the report, non-animal-derived food products could cost less than half the price of animal-derived food products in the US by 2030, leading to the collapse of the US livestock industry. Although this paradigm shift could result in the loss of 50 % of the 1.2 million US jobs in beef and dairy production by 2030, it could also create at least 700,000 new jobs in the US 'modern foods' industry.

A.2.14 Polarisation in diet and health between rich and poor

The carbon-neutral scenario saw a growing polarisation in the diets and wellbeing of high income and low income households. This effect is supported by the mounting evidence that there are vast differences between the prevalence of diet-related diseases, general health, and life expectancy between different societal groups in the UK[56]. People living in the most deprived areas of England have been found to live an average of eight years shorter than people living in areas with the lowest deprivation[57]. People living in the least deprived areas of England experience on average 20 more years of good health than people living in the most deprived areas. Healthy life expectancy falls below the state pension age of 65 for the poorest 45 % of the English population. There is also a higher prevalence of ill mental health in more deprived areas, an effect that is underpinned by inequalities in the social and economic circumstances.

A.2.15 Social tension between rich and poor

The growing polarisation in diet and wellbeing also increased social tension and resentment between low- and high income groups in the carbon-neutral scenario. This effect is supported by the historical evidence that the perception of unfair inequality leads to civic unrest[58]. During the Great Recession in 2007-2008, the people of Ireland were initially tolerant of the universal economic hardship that ensued. However, when the Irish economy began to recover in 2014-2015, the Irish people took to the streets to mass protest a new tax on water, which disproportionately penalised those on lower incomes. The increasingly unfair economic inequality was not tolerated in this case study, suggesting that increasingly unfair health inequality between the income groups would also not be tolerable in this scenario.

A.2.16 The injustice of carbon rationing

In the carbon-neutral scenario, carbon rationing was implemented via personal carbon trading in the form of individual per-capita emissions credits, alongside parallel schemes for industry. This scheme led to a growing sense of unfairness, which fuelled civil unrest (see section A.2.15). This effect is supported by a study exploring the existing ethical objections to carbon trading, ranging from concerns that it puts a price on the natural environment, and that would not encourage the wealthy to reduce their emissions, to concerns that carbon trading would hit poorer households harder than richer households, and that it wouldn't be effective at reducing overall emissions[59]. The study found that only the objection that can be sustained is the concern that it would hit the poorest households the hardest. However, given that the other ethical concerns about carbon trading are not supported, the authors emphasise that this finding calls for the design of carbon-trading schemes that provide adequate compensation for poorer households, not the elimination of carbon-trading as a strategy to reduce greenhouse gas emissions.

A.3 Key events that shaped the carbon-neutral food system

A.3.1 Higher import costs & rising tensions

Higher import costs and rising tensions between global trading partners fuelled the drive to produce more food domestically in the carbon-neutral scenario. The evidence supporting higher import costs is outlined in section A.1.11, and the rising tensions between global trading partners is supported by the increasing challenges to multilateralism and free trade recognised in the *World Economic Forum's Global Risks Report* and the *Marsh JLT Specialty's Political Risk Map 2020*[60]. For example, Hong Kong's relationship with mainland China is increasingly strained following months of protests, and the UK's changing relationship with the EU is expected to dominate Europe's political risk landscape for the foreseeable future. Furthermore, the short-term political risk index scores of several Latin American countries have deteriorated as their governments struggle to balance social stability with economic reforms, and although the political risk scores of several African nations remains unchanged, upcoming elections have the potential to create political instability. The UK currently imports food from all over the world, so rising tensions within and between global trading partners has the potential to disrupt the UK food system.

A.3.2 Extreme weather leads to food price spikes

The disruption of domestic and global food production due to extreme weather led to food price spikes in the carbon-neutral scenario, sparking the nationalisation of the UK food system and a societal call for bold climate action. This key driver of food system transformation is supported by the Committee on Climate Change's UK Climate Change Risk Assessment 2017 Synthesis report, which states that the risks posed by cliamte change to domestic and international food production is currently at medium magnitude[61]. The impacts of climate change on the UK food system are discussed on pages 4 and 5 of this report, but this driver will also affect international food production, food trade and food supply chains, increasing the volatility of food prices and leading to occassional food price spikes.

A.3.3 Net Zero agricultural policy

The government's Net Zero agricultural policy was another key driver in the carbon-neutral scenario, which prioritised national production and the rapid decarbonisation of the food system (notably through strong reductions in livestock numbers). Evidence that reducing UK livestock numbers by shifting towards a plant-based diet could release land for offsetting emissions in the food system (e.g. BECCS and reforestation) while increasing national production, is outlined in section A.1.7.

However, the strong reduction in livestock numbers has also been identified as a key strategy to achieving Net Zero emissions in UK agriculture due to the large quantities of methane produced by ruminant livestock[62]. This greenhouse gas traps heat 84 times more effectively than carbon dioxide (CO_2) over 20 years, and 28 times more effectively over the course of 100 years[63]. Although CO_2 can remain in the atmosphere for thousands of years, methane only remains in the atmosphere for 12 years, so reducing methane emissions in the food system (e.g. through minimising livestock numbers and food waste) presents an important quick-win climate mitigation opportunity[62].

The possibility of engineering livestock that produce less methane is discussed in section A.1.8, however, this climate mitigation strategy is less systemic than reducing meat consumption, as it does not reduce other negative impacts of livestock production such as lower land use efficiency (see section A.1.7.1), ammonia emissions (see section A.2.6) and the poorer health outcomes associated with high levels of red and processed meat consumption[64].

A.3.4 EU meat scandal

In this scenario, citizen preferences for locally-grown food and greater food traceability were driven by an EU meat scandal and a series of damning UN reports on aspects of the food industry. This event is supported by previous events such as the 2018 Spanish meat scandal, which involved hundreds of tons of expired meat products that were destined to be destroyed being resealed and relabelled to go back on sale[65].

B The communal food system

The communal scenario describes a future in which the UK food system is more localised in 2050 than it was in 2020, and where wider sustainability has been the major driving force in building this food system. This section provides an overview of the supporting evidence for this scenario.

B.1 The communal food system scenario

B.1.1 Political instability drives localism

In the communal scenario, the UK reduced its reliance on international trade due to political instability and climate disruption in the twenties. Evidence supporting current and future political instability between the UK's trading partners is outlined in section A.3.1, while the evidence supporting climate-related disruption to the UK's food system is outlined in section A.3.2.

B.1.2 Global market cannot solve climate change alone

The former faith that the global market could solve complex challenges such as climate change without state intervention was abandoned in this scenario. This effect is supported by growing evidence that the market's current approach to addressing environmental issues (predominantly relying on consumers and shareholders to make ethical choices) is not delivering systemic change at the required pace and scale[66]. Appropriate models of environmental intervention would likely require a close collaboration between state and market actors, as industry has the depth and quality of information that is required for effective government decision-making.

B.1.3 Redistribution of wealth and land

In the communal scenario, measures were adopted to reduce wealth accumulation by the highest earners, redistributing land and wealth amongst the UK population, as well as supporting livelihoods and improving citizens' quality of life. Several practical approaches to the redistribution of wealth amongst the UK population have already been proposed[67], ranging from taxing wealth as well as income[68] to introducing a £10,000 'citizen's inheritance' for young adults[69].

Potential strategies to redistribute agricultural land amongst the population include reclaiming and protecting council-owned County Farms to give young people a way into farming, and establishing a Community Land Fund to help communities buy privately-owned land for communal use[70].

B.1.4 Agricultural diversification increases self-sufficiency

In the communal scenario, local production systems diversified with more complex rotations and smarter land use, which allowed more food to be grown locally and reduced the UK's reliance on exports and imports. The potential of diverse crop rotations and smarter land use to increase self-sufficiency is discussed in section A.1.7.

B.1.5 Less food choice and quantity
The drive to grow more of the nation's food supply domestically decreased the availability of many of the population's favourite fruits and vegetables in the communal scenario. Currently, 77 % of the UK's fruit and vegetables are imported[21], and the remainder are grown on just 1 % of the UK's land surface[71]. The dependence on imports is partially due to the lack of seasonal diets, but also because many of the nation's favourite foods do not grow well in the UK, such as bananas, melons, citrus fruits and pineapples[72]. Therefore, shifting to more localised food systems would likely result in the reduced availability, or strictly seasonal availability, of fruits and vegetables that are currently consumed year-round in the UK.

Despite being more self-sufficient for food, the amount of food produced per capita decreased in this scenario. This effect is underpinned by the argument that future food security would not require ever-greater quantities of food production, but could instead be achieved by reducing food waste, changing diets, and reorganizing the political and economic landscape to decrease inefficiencies in the food system[73].

B.1.6 Increased public understanding of food system
Greater understanding of the value of food production and natural resources increased in the communal scenario, stimulating the drive towards a low-waste, communal economy. Currently, the most commonly used strategies to increase the public understanding of the food system are information and education campaigns. Campaigns to prevent and reduce food waste have been particularly successful, ranging from school campaigns[74] and information platforms[75], to community cooking classes[76] and face-to-face door-stepping campaigns[77]. However, in order to be effective, food system information campaigns must accurately target the specific knowledge gaps that drive unsustainable practices[78].

B.1.7 Greater self-sufficiency has increased food prices
In the communal scenario, food prices were higher than in 2020 due to the loss of productivity from comparative-advantage and trade, coupled with the need to diversify production and reduce the scale of farming. This effect is supported by the historical evidence that the investments in international trade and productivity growth, which gave rise to the global food system after the Second World War, have increased food yields and driven down food prices[79]. Reducing reliance on a global food system that is geared towards cost-effectiveness, in favour of growing more of the nation's food domestically (often in less favourable growing conditions), would therefore increase the cost of food production and thus food prices.

Smaller-scale, diversified food production systems are often associated with higher food prices because they tend to be less orientated towards maximising food productivity than large-scale homogenous food production systems. The external costs of large-scale, homogenous food systems are immense however, costing the UK an estimated £120.25 billion per year (most of which is paid for through citizen taxes)[80]. Therefore, the rise in food prices associated with smaller-scale, diversified food production systems could be offset by the reduction in external costs.

B.1.8 Higher food prices reduce household waste
Higher food prices reduced household food waste in the communal scenario, an effect that is supported by the historical evidence outlined in section A.1.5.

B.1.9 Diversification supports biodiversity and climate resilience
In the communal scenario, agricultural diversification fostered a resurgence of biodiversity and made UK food production increasingly resilient to the changing patterns of weather associated with climate change (see *Temperature rise and extreme weather*, page 4). Researchers have identified land simplification as a key driver in the loss of biodiversity[81], and suggested that biodiversity on farms could be boosted by implementing cross-cutting policy frameworks and land management strategies that specifically aim to diversify farmlands and restore habitat heterogeneity[82].

Agroecological farming includes a wide range of high diversity, low input approaches to producing food whilst simultaneously boosting ecosystem services. Agroforestry (i.e. planting trees in crop- and pasture lands) is an example of agroecological farming. Although there is limited evidence that agroforestry increases yields in intensive European agricultural systems, it has the potential to increase the UK's resilience to climate change by improving carbon sequestration in soils and trees, as well as supporting nutrient and water cycling[83].

B.1.10 UK food system more vulnerable to climate change at home
Mild food shocks still occurred when extreme weather hit the UK in the 'more localised' communal scenario. This effect is supported by the observation that the global food system can provide a safety net to countries experiencing crop failure[84]. Globalisation enables countries to share their grain reserves, provides access to international food assistance programmes, and incentivises countries to intensify their domestic production when other nations are severely impacted.

B.1.11 Joined-up UK food system policy
The food system in the communal scenario was shaped by a food policy framework that supported the sustainable production of climate-friendly, nutritious foods, as well as using financial incentives to encourage citizens to adopt healthy, sustainable diets. This joined-up food systems approach to policy ensures that challenges are tackled from multiple perspectives and in a holistic way[85], and has been proposed as a means to simultaneously protect the environment, ensure animal welfare, improve public health and guarantee the availability of nutritious food for current and future generations[86].

B.1.12 Ultra-processed foods have lost their market value
The internalisation of external health costs eliminated the market value of ultra-processed food in the communal scenario. The focus on ultra-processed food stems from research linking its intake with increased incidence of obesity and cardiometabolic disease[87]. Following the success of the UK's sugar tax[88], a tax on ultra-processed foods has been proposed as a strategy to internalise the burgeoning external health costs of ultra-processed food consumption[89].

B.2 Impacts of the communal food system

B.2.1 Government schemes to reduce health inequality
In the communal scenario, government schemes aimed to make healthy, sustainable food available to the poorest in society, significantly reducing the incidence of diet-related diseases and reducing health inequalities between socioeconomic groups. Several government food assistance programmes already support low income households in the UK, including food vouchers or cash transfers,

supplementation programmes, and free school meals. There is a need to ensure that the foods provided are healthy, sustainable and capable of meeting the complex needs of food-insecure families[90]. This may require systems-based approaches (i.e. the alignment of food programmes with health programmes) as well as opportunities for beneficiaries to influence the design of these interventions[91].

B.2.2 De-intensification of agriculture

The de-intensification of agriculture at scale produced cleaner air and water in the communal scenario, which boosted public health and encouraged people to enjoy the outdoors more actively. The impacts of practices associated with intensive agriculture on air and water quality (and public health by extension) are discussed in section 2.2.6. De-intensification has also been shown to improve the quality of intensively farmed soils[92].

B.2.3 Greater equality linked to better mental health

Greater equality in society improved the population's mental health in the communal scenario, which gradually led to greater social solidarity. This effect is supported by research linking higher levels of income inequality to poorer mental health outcomes[93]. Socioeconomic inequality can impact on physical health, mental health, and wellbeing by undermining the quality of social relations, increasing status competition, and increasing stress. This relationship suggests that a sharper focus on reducing socioeconomic inequality could reduce mental illness[94].

B.2.4 Sustainable, local production

Prioritising sustainable, local production enabled growers in the communal scenario to adopt farming practices that protected their soil and local water sources. These sustainable, local food production systems were smaller-scale and follow established agroecological principles. The positive impacts of de-intensification of agriculture on soil and water quality are discussed in section B.2.2, and the principles of agroecological farming are outlined in section B.1.9.

B.2.5 Ecosystem services

In the communal scenario, sustainable, local production systems produced a healthier environment, supporting essential ecosystem services that improved quality of life (i.e. through improving air and water quality, see section A.2.6) as well as the UK's climate resilience. Food system-related strategies to bolster climate resilience through ecosystems include the adoption of agroecological practices (see section B.1.9) and reducing the utilization of peatlands for food production.

Peatlands are a type of wetland that covers 3 % of the surface area of all land on earth, but stores twice as much carbon as all of the world's forest biomass combined[95]. Besides being a key target for climate change mitigation, healthy wetlands also act as a natural buffer against climate change-induced extreme weather, capable of soaking up heavy rainfall and preventing flooding, as well as releasing stored water during periods of drought. UK agriculture is particularly vulnerable to droughts and flooding, so restoring peatlands is key to making the UK food system more climate resilient. Nearly 80 % of the UK's peatlands have been impacted by human activity[95], with peat soils (particularly lowland 'fen' peat) being widely used for arable and horticultural crop production, livestock grazing, conifer forestry, and gardening. The East Anglian fens alone produce a third of England's fresh vegetables and a large proportion of the UK's salad crops.

B.2.6 Market support for sustainable economy

Market actors in the communal scenario responded positively to the wholescale structural changes that disrupted incumbent technologies and markets, actively generating new ideas and approaches to support the shift towards a circular and sustainable economy. This outcome is supported by the growing trend for private companies to adopt their own climate mitigation- and sustainability targets, as well as a letter signed by over 120 leading UK businesses calling on the government to introduce bold, long-term policies that will support the transition to a low-carbon economy[96].

B.2.7 Preventing value extraction

The disconnect from the global market prevented multinational corporations from taking profits out of the country in the communal scenario, which provided some unexpected boosts to the UK's economy. This effect is supported by the finding that in 2020, multinational companies were able to shift $1.38 trillion of profits out of the countries where the profits were generated[97].

B.2.8 Lighter-touch globalisation

The UK's shift towards a more localised food system initially frustrated long-term trading partners in the communal scenario, but the frustration diminished when it became apparent that lighter-touch globalisation enabled more effective approaches to collective problems like climate change. The evidence supporting this effect is outlined in section B.1.12.

B.2.9 Intergenerational divide

The communal scenario saw an intergenerational divide over food ethics, with parts of the older generation resenting the changes that shifted them away from the cheap, unsustainable foods that they were raised with, while food ethics intensified amongst younger generations. This effect is supported by a Populus poll commissioned by the Food Ethics Council, which found that 16-24 year olds consider the food system to be significantly more 'unfair' to farm animals (55 %) and the natural environment (46 %), compared to adults over the age of 65 (32 % and 28 % , respectively)[98].

B.2.10 Alternative measures of growth

The greater focus on sustainability, wellbeing and fairness as part of an alternative economic model, led to a more positive society in the communal scenario. This approach is supported by the various paradigms that have been developed in an attempt to shift the focus from economic wealth as a sole metric of success, to also incorporate social and environmental metrics[99]. One example of such a paradigm is 'doughnut economics', which sets out nine ecological boundaries and 12 social boundaries that aim to serve as a compass to ensure a safe and just space for humanity in the 21st century[100].

B.2.11 Building community through food

In the communal scenario, reconnecting with local food production fostered a greater sense of local community and reduced the burden of loneliness and mental illness, particularly in the elderly. Section A.2.2 outlines the evidence supporting this effect.

B.3 Key drivers that shaped communal food system

B.3.1 Nationalism driving localism

In the communal scenario, the rise of inward-looking nationalism and the growing volatility of international trade supported the move towards a more localised food system. Evidence for the growing volatility of international trade is outlined in section A.3.1. Nationalism-driven political instability contributes to this volatility, as it can rapidly change trading relationships[101]. The food system is particularly vulnerable to rapid changes in the political landscape due to the extended time between food producers investing in labour and inputs, and the time of harvest and trading.

B.3.2 Rise in diet-related diseases

An ambitious healthcare plan was announced to manage the rise in diet-related diseases in the communal scenario, shifting the focus from curative to preventative healthcare. This approach is supported by evidence that poor diets led to 22 % of global adult deaths in 2017[102]. Nearly two thirds of UK adults are living with overweight or obesity, with one in five of children in the UK affected by overweight or obesity by the time they start school. Poor diet has been estimated to cost the NHS around £6 billion per year, a figure that is expected to rise to £9.7 billion per year by 2050 (with societal costs of £49.9 billion) unless urgent action is taken[103].

B.3.3 Higher cost of imported medical supplies

The higher cost of medical supplies also drove the shift from curative to preventative healthcare in the communal scenario. This effect is underpinned by the potential impacts of the UK's changing trade relationships on the pharmaceutical sector[104]. For example, the additional costs and requirements associated with border checks could increase the price of imported medicines in the future. Any delays at the border could also result in the loss of time- or temperature-sensitive medical supplies, driving up prices.

B.3.4 Growing awareness of global impacts

Growing awareness of the global impacts of the UK food system on health, indigenous people, and the environment led to a push for the UK to take back control of its food system in the communal scenario. A GFS study exploring public views of the food system revealed that there is low public awareness of some of the challenges facing the food system[105]. However, research exploring what drives changes to buying and consumption habits has found that once citizens are informed of challenges in the food system, they are more willing to change their habits[106]. Therefore, increasing transparency and revealing the connections between people's values and their food habits (e.g. by providing carbon footprint information on food packaging) could facilitate the transition to a more just and sustainable food system[107].

B.3.5 Whole government food policy

The communal scenario saw the launch of a bold initiative to disrupt business-as-usual in the food system in the form of a whole government food policy. This approach is already reflected in initiatives such as the National Food Strategy[108] and Scotland's Good Food Nation policy framework[109]. The rationale for a whole government food policy is laid out in section B.1.11.

C The commercial food system

The commercial scenario describes a future in which the UK food system is more globalised in 2050 than it was in 2020, and where climate mitigation has been the major driving force in transforming the food system. This section provides an overview of the supporting evidence for this scenario.

C.1 The commercial food system scenario

C.1.1 Green energy dominates the countryside

In the commercial scenario, most of the UK's agricultural land was given over to low carbon energy production, with bioenergy feedstock, plantation forests, and renewable energy farms dominating the countryside. This approach is supported by the fact that many leading climate mitigation strategies (i.e. the generation of renewable energy, bioenergy with carbon capture and storage, and re-/afforestation) require significant land area when brought to scale. Approximately 70 % of the UK's land surface is currently used to produce food[110], so ambitious strategies to mitigate climate change in the UK would likely require reducing the land footprint of the UK diet (see section A.1.7) or a greater reliance on food imports.

C.1.2 Large-scale regenerative agriculture

Farms were large-scale and commercially run in the commercial scenario, employing circular and regenerative agriculture to minimise the inputs of organic and inorganic fertilisers. Regenerative and circular agriculture both follow the principle that soil health is the foundation of the food system, promoting agricultural practices that support soil quality and biodiversity (e.g. cover crops, no-till). Circular systems also aim to use residual products from one chain as feedback for another[111]. Some British farms have already managed to increase levels of food production alongside enhancing the quality of the environment, while reducing their inputs, wastes and pollution[112].

C.1.3 Loss of family farms

Family farms are virtually non-existent in the commercial scenario, with the exception of a handful of small cattle, sheep and goat herding communities in the uplands of Wales and Scotland. The loss of family farms is supported by evidence outlined in section A.2.12.

C.1.4 Low-methane livestock

In the commercial scenario, livestock systems were designed to produce minimal volumes of methane. The evidence supporting this development is outlined in section A.1.8.

C.1.5 Abandonment of just-in-time supply chains
Although climate-driven shocks to harvests and trade flows increased the price of food in this scenario, supermarkets were able to keep food prices relatively stable by switching from just-in-time supply chains to maintaining considerable stocks. Currently, the just-in-time supply chain model of UK supermarkets provides 5-10 days of groceries in the country (less for fresh produce)[86], making the food system particularly vulnerable to sudden food shocks such as those caused by extreme weather. The COVID-19 pandemic highlighted its vulnerability to food shocks, amplifying the call to re-evaluate just-in-time models[113].

C.1.6 Shelf-stable foods
In the commercial scenario, the shift away from just-in-time supply chains was made possible by the high share of basic foods that were processed to maximise shelf-life. Innovative technologies to extend the shelf life of food and drinks are currently being developed and implemented, ranging from novel packaging solutions and next generation plant-derived food additives, to food treatment methods such as smart spray drying and cold plasma treatment[114].

C.1.7 Decarbonisation of food transport
The global ground and marine transport fleets were fully decarbonised in the commercial scenario, and air freight was rarely used, transporting only the highest-value, most perishable, exotic foods. Evidence supporting this development is outlined in section A.1.10.

C.1.8 Economy-wide carbon pricing
Economy-wide carbon pricing had a significant impact on the range of foods that were accessible to the average UK consumer in the commercial scenario. Evidence supporting the impacts of carbon-pricing on food accessibility is discussed in section A.1.4.

Although there is significant variation within food types depending on production methods, beef, lamb and dairy products tend to be the most carbon-intensive UK food products. Approximately 58 % of the UK's agricultural greenhouse gas emissions are attributable to the production of these foods, not including the soil emissions that are associated with growing the cereals to feed the animals[6]. For comparison, the production of 1kg of beef is estimated to produce 60kg of GHGs (CO_2e), while producing one kilogram of peas emits just 1kg of GHGs[115]. The carbon footprint of lamb and cheese is more than 20kg of GHGs for each kilogram, while chicken and pork have the lowest footprints out of the UK's staple animal products, emitting six and seven CO_2e per kilogram, respectively. Therefore, the cost of these foods would be most affected by the introduction of economy-wide carbon pricing.

C.1.9 Rise of alternative proteins
In the commercial scenario, insect-based and algal protein products were commonplace. Algae are highly nutritious, with some species having all the essential amino acids and a dry mass consisting of 70 % protein. However, the low level of technological readiness and the green colour of the algae have been identified as major barriers to integrating algal protein into meat substitutes[116].

Edible insects can also be highly nutritious, as well as having the potential to greatly increase the efficiency of the food system by eating food waste before becoming food or livestock feed themselves. Although edible insects are already a popular protein source in other parts of the world, a major challenge to sustainably upscaling this sector in Europe is the EU's requirement that edible insects are raised on high-quality feed that is fit for human consumption.

Following the announcement of a new EU policy to promote the domestic production and consumption of plant-based proteins in 2018, the algae and insect production sectors implored the EU to form a plan to boost the development of their sectors too[117].

C.1.10 Cultured meat technologies

The commercial scenario saw a large upswell in the investment in cultured meat technologies, as well as growing pressure from investors in food companies to phase out animal-derived products. Cultured meat, which is produced by taking tissue from an animal and growing the cells in a laboratory, was shown to be technically feasible in 2013 when the Dutch company Mosa Meats produced the world's first lab-grown burger[6]. Investment has flooded into the sector since then, bringing production costs down from £215,000 per burger in 2013, to just £8 per burger five years later[118]. There is a high level of public acceptance for lab-grown meat, with 40 % of UK adults believing that they will be eating lab-grown meat and fish by 2028[119]. The growing popularity of cultured meat and meat alternatives has led the $20 trillion investor network FAIRR to predict that some major meat suppliers could be losing as much as 45 % of their earnings by 2050[120].

C.1.11 AI in the food chain

Artificial intelligence (AI) was ubiquitous in food chain logistics in the commercial scenario, which greatly reduced food loss and waste from farm to plate. AI has already been identified as a promising tool to 'design out' food waste, capable of generating an estimated $127 billion per year by 2030 if incorporated at every stage of the food supply chain[121]. For example, AI can use image recognition to identify the ideal picking time for fruit, or match food supply and demand more accurately. A start-up called Wasteless is currently using machine learning to optimise the price of each food item on the shelf (the dynamic prices are depicted on small screens), reducing waste by incentivising citizens to buy products that are closer to their sell-by date[122].

C.1.12 Waste-to-energy bioreactors

In the commercial scenario, many food outlets and households had waste-to-energy bioreactors that linked to the national grid and offered subsidies to users. UK anaerobic digestion plants are currently producing enough biogas to power over one million UK homes using these types of bioreactors[123], and some companies have started offering home biogas systems[124].

C.1.13 Restoring soil fertility with waste

In this scenario, the yields from food waste collection programmes were used for domestic biomaterial production or to produce digestate that could be used to restore soil fertility in countries that had suffered greatly from climate change. The latter use is supported by evidence that the 10 million tonnes of food waste that is sent to landfill every year could be turned into nutrient-rich biofertiliser and energy using anaerobic digestion technology[125]. Besides reducing the UK's dependency on fossil fuels, the biofertiliser could also be used to restore soils in global regions most affected by climate change. Roughly three-quarters of African farmland has been degraded of nutrients, severely affecting sub-Saharan Africa's production of cereals and contributing to the malnourishment of 200 million people in the continent[126].

C.2 Impacts of the commercial food system

C.2.1 Impact of socioeconomic status on diet

In the commercial scenario, the health impacts of radical shifts in the food system were positive for people with higher-than-average incomes and education, but this was

not the case for people with less income, time and options. This effect is supported by research demonstrating that the nutritional quality of food purchases differs significantly between higher income households and lower income households[127]. The National Food Strategy also highlights the trade-off between health and wealth, identifying poverty and exhaustion as key drivers of unhealthy diets that are rich in cheap, processed foods[108]. A study exploring the effect of healthy eating interventions found that some interventions, such as dietary counselling and personalised nutritional education, have greater benefits for individuals with higher socioeconomic positions than those with lower socioeconomic positions, which could increase these pre-existing inequalities[128]. The authors suggest that a combination of taxes and subsidies could preferentially improve the diets of lower income households.

C.2.2 Health benefits of less red meat and ultra-processed food

The reduction in red meat and calorie-rich, ultra-processed food consumption eased the burden of diet-related diseases among people with higher socioeconomic status in the commercial scenario. It is well-established that the higher consumption of red meat and processed red meat increases the risk of cardiometabolic diseases, certain types of cancer, and death. For example, an eight-year study exploring the impact of changes in red meat consumption on mortality in 27,916 men and 53,553 women (all without cardiovascular disease of cancer to start with) confirmed that increases in red meat consumption (particularly processed red meat) are associated with higher mortality[129]. Another study showed that even in young, healthy individuals, small reductions in red and processed meat consumption reduced levels of LDL cholesterol, a risk factor for heart disease[130]. However, the researchers also observed a reduction in red and white blood cells after individuals reduced their meat intake, indicating that efforts to reduce meat consumption need to be combined with efforts to increase the consumption of a wide variety of fruits, vegetables, pulses and whole grains. The link between ultra-processed food consumption and increased incidence of disease is outlined in section B.1.12.

C.2.3 Personalised health and carbon efficiency products

In the commercial scenario, private insurance companies offered personalised products to optimise the healthiness and carbon efficiency of citizens' diets. A similar approach has already been adopted by the private insurance company Vitality, which encourages customers to earn points and rewards for doing exercise (verified by tracking device or an app)[131]. The use of personalised carbon footprint tracking products is based on the evidence outlined in section A.2.9.

C.2.4 Low dietary diversity and mental health

Dietary diversity fell when supermarkets began mass-stockpiling cheap tinned and preserved foods in the commercial scenario, which had negative impacts on mental health. The link between dietary diversity and mental health is supported by a large-scale population study of community-based elderly individuals[132]. The researchers found a significant positive association between dietary diversity and psychological resilience in this population, with the strongest association in the young elderly subsample.

The consumption of vegetables, fruits and nuts contributed most positively to resilience scores, possibly due to the presence of polyphenols and favourable fatty acid profiles, which can reduce oxidation and inflammation (two key factors in depressive symptoms). However, the study did not rule out reverse causality, i.e. that more resilient individuals are more capable of preparing more diverse diets, or that low resilience influences an individual's food choices.

C.2.5 Food fortification to combat malnutrition
In the commercial scenario, long-life foods were increasingly fortified to combat rising malnutrition in vulnerable segments of society. Although a healthy, balanced diet is the best way to prevent malnutrition, fortification has been identified as a cost-effective tool to improve the nutritional quality of processed foods and prevent micronutrient deficiencies in vulnerable populations[133]. Manufacturers fortify foods by adding essential trace elements and micronutrients to them during processing.

C.2.6 Locked-in climate change
Locked-in climate change yielded increasingly frequent and severe climate events in the commercial scenario, damaging infrastructure and degrading vulnerable habitats such as wetlands. The climatic changes described on page 4 of this report will affect most (if not all) of the UK's ecosystems, but wetland habitats are particularly at risk[95]. These ecosystems are shaped by rainfall patterns and the presence of groundwater, two factors that global heating will disrupt. Even a small temperature increase could accelerate evaporation, resulting in the loss of seasonal wetlands and many of the native species that depend on them. Section B.2.5 outlines why the loss of UK wetlands would be a detrimental to the UK's climate resilience as well as to wildlife.

C.2.7 Access to countryside and wellbeing
The radical transformation of the UK countryside to maximise carbon storage led to a sense of collective loss amongst the population in the commercial scenario. Evidence supporting the impact of reduced access to natural landscapes on citizen wellbeing is outlined in section A.2.2[36].

C.2.8 Climate mitigation impacts on biodiversity
The expansion of bioenergy crops and plantation forests in the commercial scenario created landscapes that were optimal for carbon capture, but detrimental to biodiversity. This outcome is supported by the research outlined in section B.1.9, which identifies land simplification as a key driver of biodiversity loss[81]. A study investigating how

the expansion of bioenergy cropland to meet the Paris Agreement would impact on global vertebrate diversity also supports this outcome[134]. The authors acknowledged that although bioenergy crops have an important role to play in climate mitigation, the expansion of high-intensity land use that is required to meet current energy needs would severely impact biodiversity, outweighing the positive impacts of climate mitigation on wildlife. According to this study, achieving the Paris Agreement while protecting biodiversity requires an immediate and significant reduction in energy consumption.

Another strategy to protect biodiversity whilst achieving climate mitigation goals involves the careful consideration of the original land cover before establishing new tree plantations. Studies have shown that afforesting a non-forest ecosystem (e.g. a natural grassland) will not support natural forest biodiversity, even after two centuries[135]. Afforestation will bring the greatest biodiversity gains in areas that have experienced significant deforestation, as well as intensively-used lands that have been degraded[136]. Plantation forests with a mix of naturally-occurring native woodland species, structures and stand ages will support biodiversity more than plantation forests lacking this diversity.

C.2.9 Biodiversity of green urban spaces

In the commercial scenario, biodiversity also suffered in and around urban areas, as society prioritised high-tech home and community environments over green spaces and gardens. Urban green spaces (e.g. gardens, parks, verges, playing fields, allotments, street trees, wetlands, brownfield land, and ‘encapsulated countryside’) not only protect urban areas from flooding and heat risks, but can also be rich in biodiversity. However, as urban green spaces have continued to shrink in the UK[137], the abundance and occupancy of urban species has fallen by 11 % since 1970[138]. This decline has been attributed to increasing housing density leading to smaller gardens and the loss of allotments, as well as the development of biodiversity-rich post-industrial land (i.e. quarries, railways, spoil heaps and previously developed land). A study investigating simple vegetation interventions to increase urban biodiversity found that sparse understorey vegetation and exotic vegetation reduces the occupancy of urban wildlife, and argues that increasing the percentage of native vegetation in urban areas and providing more understorey vegetation would benefit a broad array of species[139].

C.2.10 Large-scale investment in low-carbon tech

The commercial scenario saw large-scale investment in novel technologies to support ambitious climate action. The role of investors in achieving the EU’s net-zero emission target (as well as the significant profitability of low-carbon investments) has been outlined in a report by the Carbon Disclosure Project[140]. The report estimates that annual low-carbon capital investments will need to grow about €122 billion a year in order to hit the net-zero target by 2050.

C.2.11 Impacts of carbon taxes and sharing economy

The manufacturing and retail industries were hit particularly hard by carbon taxes and the sharing economy in the commercial scenario, which suppressed the demand for many consumer goods. Section A.1.4 outlines evidence that a carbon tax would change the food purchasing habits of low-income households.

The rise of the sharing economy in this scenario is supported by rising popularity of peer-to-peer markets such as Gumtree, Airbnb and the food sharing app Olio. Research has shown that this new economic model could support the transition towards more sustainable consumption and production models by reducing waste and promoting the more efficient use of resources in the food system[141]. However, the authors note that the sharing economy does not necessarily improve sustainability if, for example, the savings that are made reducing food waste are then used to buy more expensive, resource-intensive foods.

C.2.12 Food producers could not adapt in time

In the commercial scenario, the shift in consumer demand and private-sector disinvestment from carbon-intensive food supply chains unfolded more rapidly than the UK agriculture sector had anticipated. Section A.2.13 outlines how the shift in consumer demand towards plant-based diets could impact the meat industry, and there is evidence that investors are starting to take note of how the climate emergency will affect the food market. Following an assessment of the impact of carbon pricing, a major investor in emerging markets recently divested from dairy companies in Vietnam and Mexico, and several big global lenders have acknowledged that the credit risk for the agricultural sector is likely to increase if the climate crisis worsens[142]. Without sufficient support, many livestock producers and farmers in the commercial scenario were unable to transition in time to climate-mitigating food production systems. The barriers that are currently preventing UK food producers from making the low-carbon transition are outlined in section A.2.10.

C.2.13 European climate refugees
The inflow of climate refugees from southern Europe and neighbouring regions caused social unrest in the commercial scenario. This event is supported by evidence that the number of climate events in Europe causing citizen displacement have more than doubled in the last four years[143]. Furthermore, extreme weather events are lasting longer than they did in the past, with Spanish heatwaves lasting an average of 15 days between 2015 and 2020, but only lasting an average of five days between 1975 and 2014. Southern European citizens are increasingly leaving their habitual homes as the impacts of adverse environmental changes continue to affect their lives and living conditions, moving within their own country or emigrating abroad.

C.3 Key drivers that shaped the commercial food system

C.3.1 Upswell in public support for climate action
The commercial scenario saw an upswell in public support for climate action following frequent and disruptive high-profile protests. This driver is supported by the emergence of global environmental movements such as Fridays for the Future[144] and Extinction Rebellion[145], which have brought the demand for ambitious climate action into the mainstream. The success of these movements is reflected in a 2019 poll, which revealed that nearly 70 % of British citizens now support urgent political action to protect the environment and tackle climate change[146]. Greener UK and the Climate Coalition found that two thirds of the people their researchers questioned believe that the UK needs to cut its carbon emissions much faster than currently planned.

C.3.2 Catastrophic climate disasters
Catastrophic climate disasters led the UK to prioritise climate mitigation and adaptation over sustainable development in the commercial scenario. According to a recent report by the UN Office for Disaster Risk Reduction, the incidence of climate-related catastrophes has dramatically increased, with 7,348 disaster events recorded over the last two decades, while 1980-1999 saw 4,212 events[147]. Researchers insist that although improved recording and reporting of disasters accounts for some of the increase over the last 20 years, climate change has increased the severity and frequency of climate-related catastrophes. Section A.2.4 outlines evidence that the societal focus on climate change can detract from the other metrics of sustainability.

C.3.3 Breakdown of international rules-based politics
The breakdown of international rules-based politics was another driver of climate action being prioritised over sustainable development in the commercial scenario. Evidence supporting the future breakdown of international rules-based politics is outlined in a 2018 paper by the Select Committee on International Relations, which concluded that "trends including populism, identity politics, nationalism, isolationism, protectionism and mass movements of people are putting considerable pressure on states and traditional structures of government"[148].

Despite the breakdown of international rules-based politics, the rising incidence and severity of domestic climate incidents described in section C.3.2 led to global action on climate change. However, the loss of multilateral cooperation and rise of nationalism meant that any sustainability targets that were felt less acutely in the UK were deprioritised[149].

C.3.4 Investor pressure to tackle climate emissions
The commercial scenario saw investor pressure to tackle food-sector emissions when the reputational risk of supporting high-emissions food value chains became too great. The evidence supporting this outcome is outlined in section C.2.12.

C.3.5 G20 countries implement economy-wide carbon pricing
Although international rules-based politics broke down in the commercial scenario, domestic climate events drove G20 countries to implement economy-wide carbon pricing and subsidies for low-carbon supply chains and innovation. This driver is supported by UNEP's Emissions Gap report, which calls for G20 nations to at least triple the level of ambition of current nationally determined contributions (NDCs) to keep global heating below 2°C[150]. The report identified the lack of economy-wide climate action (e.g. introducing ambitious and comprehensive carbon pricing) as a serious action gap with high potential for emission reductions. The impacts of economy-wide carbon pricing are outlined in sections A.1.4 – A.1.6 and section C.1.8.

D The collaborative food system

The collaborative scenario describes a future in which the UK food system is more globalised in 2050 than it was in 2020, and where wider sustainability has been the major driving force in building this food system. This section provides an overview of the supporting evidence for this scenario.

D.1 The collaborative food system scenario

D.1.1 Wildlife-friendly landscapes and urban spaces

In the collaborative scenario, the UK was considerably greener by the year 2050, with rural areas seeing a richer variety in landscapes and urban spaces covered with green walls. Evidence supporting the diversification of agricultural landscapes is discussed in section B.1.9, while the greening of urban areas is outlined in section C.2.9.

D.1.2 Carbon- and food literacy

Greater carbon- and food literacy made the UK diet considerably greener in the collaborative scenario, reducing meat consumption and creating healthier food environments. The UK-based Carbon Literacy Project has been working to increase the carbon literacy of individuals, communities and organisations since 2013, providing online and classroom-based training on climate change, carbon footprints, and how everyone can do their bit[151]. Their training also covers food system sustainability, and has been shown to generate consensus and conversation around climate change and its impacts. Strategies to increase food literacy across the population are outlined in section B.1.6.

D.1.3 Benefits of nutritious plant-based diets

In the collaborative scenario, the shift towards nutritious plant-based diets reduced the levels of obesity, diabetes, and heart-related conditions, as well as improving mental health, and reducing the climate impacts of the UK diet on the tropics. Section C.2.2 outlines the health benefits of reducing red and processed meat consumption, and the link between increased dietary diversity and mental health is outlined in section C.2.4. The UK food products that produce the most greenhouse gas emissions are outlined in section C.1.8. Although tropical countries have contributed the least to climate change and are most vulnerable to climate events, they are projected to experience the strongest increase in climate variability in the future[152].

D.1.4 Global governance arrangements

The collaborative scenario saw the efficiency of food production increase due to global governance arrangements that guided which foods were best grown in which parts of the world. A framework for global institutional arrangements has already been proposed to build a well-functioning world food system based on a set of essential

international public goods[153]. These public goods include trade and transboundary competition policy, international resource management, the handling of large-scale food emergencies, research and innovation, and transboundary food safety. The paper proposing this framework suggests establishing an international platform to redesign global food governance with the support of an International Panel on Food, Nutrition and Agriculture (based on the design of the International Panel on Climate Change).

D.1.5 World-class, low-carbon livestock system

The UK developed a world-class, low-carbon livestock system capable of promoting biodiversity and supporting reforestation in the collaborative scenario, producing high quality, grass and insect-fed beef for the global market. This outcome is supported by the National Farmers Union's ambitious commitment to go Net Zero by 2040[154], as well as evidence that Britain's denuded landscapes are well-suited to extensive beef production, making the UK's predominantly grass-fed beef less emission-intensive than beef produced through intensive beef-production systems or grass-fed beef produced in more forested nations[155].

The plausibility of this scenario's livestock system is supported by evidence demonstrating the regenerative potential of silvopastoral systems, a type of agroforestry that introduces trees, hedges, shrubs and fodder plants to pastureland to improve animal nutrition and enable the production non-food products (e.g. fuel and fibre) alongside livestock[156]. Silvopastoral systems can also bolster ecosystem services such as climate change mitigation, biodiversity, water management and erosion control[157]. A six-year study of a silvopastoral system in Wales found that the presence of trees did not affect livestock productivity[158], and a Canadian study has estimated that 6.4 million hectares of silvopastoral pastureland with fast-growing tree species would be enough to sequester the total emissions of the Canadian agriculture sector[159]. For comparison, Canada's agricultural sector produces approximately 59 megatons of emissions each year[160], whereas the equivalent value is 46.3 megatons in the UK[161]. The UK currently has 9.74 million hectares of permanent pasture[162], implying that the large-scale adoption of silvopastoral systems in the UK has the potential to produce carbon-neutral British beef.

D.1.6 Eliminating soya for animal feed

The use of soya for animal feed was abandoned in the collaborative scenario, with livestock being raised on grass and insects instead. The UK imports roughly 2.26 million tons of protein-rich soya meal each year, 1.1 million tons (48.7 %) of which is currently fed to British livestock[163]. According to WWF's Risky Business report (using data from 2015), 77 % of the UK's imported soya products (beans, meal and oil) originate from locations with a high deforestation risk, making this type of animal feed particularly unsustainable in terms of climate mitigation and biodiversity[164].

However, feeding insects to livestock has the potential to reduce these environmental burdens. Insects can be highly nutritious, capable of producing the same amount of edible protein as soya and animal products with similar amounts of energy, but using less land and emitting less greenhouse gases[165]. Studies have indicated that enriching piglets' diets with insect protein improves their gut health, that insect meal can safely replace up to half of farmed fish feed, and that chickens consuming insect feed perform just as well as those consuming commercial feeds. Section C.1.9 discusses the potential for insect protein to address food waste, as well as some of the challenges to upscaling this sector.

D.1.7 Co-operatives give citizens stronger voice

In the collaborative scenario, food production and supply chains were managed through co-operative structures, giving a much stronger voice to citizens through part-ownership of the food system. Co-operatives are "autonomous associations of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically-controlled enterprise"[166]. This model can sustainably support smallholder farmers to achieve economies of scale, improving their access to financing, markets, information and other resources. Consumers' cooperatives are also contributing to greater food security and sustainable agriculture by promoting the purchase of foods produced in ways that align with their members' values. The cooperative movement is present in all sectors of the economy and most countries across the globe, counting more than a billion members worldwide.

D.1.8 Technology enables transparency in the food system

Advanced communications and tracking technologies were common throughout the food system in the collaborative scenario, with ubiquitous apps and data portals in shops that allowed the UK public to see exactly where, and under what conditions, their food was being produced. Section A.2.9 discusses technologies with the potential to increase transparency in the global food system.

D.1.9 Greater transparency supports farmers in developing countries

The increased transparency in the collaborative scenario gave farmers in developing countries a stronger negotiating position, reducing the global inequality between countries. This outcome is supported by a proposal tabled by the European Commission in 2019, which aims to increase the transparency of food price information to increase fairness and empower smaller actors in the food supply chain, such as smallholder farmers in low income countries[167].

D.1.10 Global food investment bank

In the collaborative scenario, a global food investment bank was established to proactively support sustainable practices across the food supply chain and provide insurance for any global food shocks. This investment bank was partnered with a physical food bank, which included 80 days of key food supplies. A similar approach has already been adopted by the World Food Bank, an asset-backed investment platform that partners with governments, smallholder farmers, processors and every part of the food supply chain to improve the efficiency of food production and finance[168]. Its core asset is extended shelf-life foods, which are held in reserve in a network of strategic locations around the world. These shelf-stable foods are available for purchase when local food markets are volatile due to humanitarian crises, environmental issues, or market inefficiencies. Besides stabilizing markets, filling gaps and improving efficiencies, the World Food Bank also gives farmers access to affordable financing and high-quality inputs (e.g. seeds), as well as providing education on sustainable agricultural practices.

D.1.11 Climate resilience through built-in redundancy
In the collaborative scenario, extreme weather events gave rise to agricultural management practices with built-in redundancy, resulting in a significant food surplus in years with less climatic shocks. Stringent measures are being introduced across Europe to prevent agricultural surplus, so the concept of strategic obsolescence to protect against climate-induced extreme weather remains understudied. However, there is increasing evidence that agricultural waste could create twice as much economic added value if used to create bio-based products, compared to generating electricity, animal feed and fuel[169]. This implies that strategic agricultural redundancy could be economically viable within a circular economy where bio-refinery and cascading technologies have been adapted to agricultural residues.

D.1.12 Food preservation technologies
Advancements in food preservation technologies ensured that the surplus discussed in section D.1.11 could be used to restock the physical food bank. Section C.1.6 outlines the innovative technologies currently being developed to extend the shelf-life of foods.

D.1.13 Turning food surplus into bio-products
In the collaborative scenario, any food surplus that was not used to restock the physical food bank served as the main input to the biofuel, bioplastic, and biopharmaceutical industries. The creation of bio-based products from food surplus or waste (alluded to in section D.1.11) is a growing area of research. Researchers are currently exploring the feasibility of turning food waste into 100 % recyclable or biodegradable bioplastic[170], and working to develop food waste-based biofuels that are more economical to use than petroleum-based fuels[171]. Researchers in Manchester are using novel experimental and computational methodologies to explore the sustainable biological production of biopharmaceuticals from agricultural and food waste[172].

D.1.14 Locked-in climate change could lead to public backlash
Locked-in climate change led to some public backlash against the shift in society in the collaborative scenario, prompting a subset of the population to question the legitimacy of the UK's ambitious climate strategy and the wider Sustainable Development Goals agenda.

There is general consensus that the heavy reduction of CO_2, methane or black carbon (soot) emissions would have the quickest climate mitigating effects, however these effects would likely not be detectable until mid-century[173]. The impacts of heavy reductions in nitrogen oxide emissions would not be detectable until the second half the century, and any reductions in sulphate aerosols (particles produced by the combustion of coal and fuel oil that cause respiratory difficulties, damage green plants, and create acid rain) could rapidly increase temperatures, as these atmospheric particles have a cooling effect. Combined, these factors suggest that climate mitigation efforts today will not be reflected in the global temperature before 2050, regardless of how ambitious and disruptive these strategies are. Unless this is clearly communicated to policymakers and the public, there is a risk that these climate mitigation strategies could be perceived as ineffective and cause societal backlash. Therefore, keeping the focus on the concentrations of greenhouse gases and the carbon intensity of the global economy will be key to maintaining public and policy support for climate mitigation in the coming decades.

D.1.15 Slow uptake of participatory democracy

In the collaborative scenario, participatory democracy models were initially captured by special interest groups, as it took a long time to increase participation in democratic processes across society. The lag in the uptake of participatory democracy models is supported by the observation that although the call for more effective public participation in planning, policy development and public service delivery has been made for decades, these appeals have not been heeded[174]. A study exploring the role of public participation in influencing public attitudes towards governance identified the lack of trust between governments and citizens as the key barrier to successful participatory democracy. The authors argue that this barrier could be overcome by governments trusting that citizens with resources and the right conditions will competently act for the common good. This trust would increase citizens' engagement in the process and potentially reduce their distrust in government.

D.1.16 Public-private form of government

A new public-private form of government was in power in the collaborative scenario, consisting of elected officials and cooperative structures. A similar governance structure has been proposed to tackle the climate challenge, known as Globalization 4.0[175]. Through promoting practical, public-private arrangements to help governments find agile, collaborative solutions to the climate emergency, this global platform for action enables and encourages a wide range of different partners to engage in actions to mitigate climate change within a meaningful timeframe.

D.2 Impacts of the collaborative food system

D.2.1 Shift towards plant-based diets

Although the UK primarily produced high quality red meat in the collaborative scenario, the embedded costs of its production made it prohibitively expensive for regular consumption. This outcome is supported by a report exploring a sustainability charge on meat in Europe, which estimates that the social costs associated with the production of beef is currently €5.70 per kg[176]. Land-use impacts on biodiversity, greenhouse gas (and other pollutant) emissions, and livestock diseases were the main factors. A study conducted in the Netherlands calculated that if the external costs of conventional pork production were incorporated into the consumer price, the price of pork would increase by 31 %[177]. Section C.1.8 outlines the carbon footprints of different animal-based foods.

D.2.2 Health benefits of greener diets

Coupled with the reduction in sugar and saturated fat consumption, the shift towards plant-based made the UK diet healthier and more balanced in the collaborative scenario. The link between ultra-processed food consumption and increased incidence of disease is outlined in section B.1.12, and the health benefits of reduced red and processed meat consumption is outlined in section C.2.2.

D.2.3 Biofortification

In the collaborative scenario, biofortification is commonplace in food production. Like standard fortification (outlined in section C.2.5), biofortification is a cost-effective tool to reduce malnutrition on a population scale. However, instead of adding essential trace elements and micronutrients during processing, biofortified foods consist of crop varieties that have been nutritionally enhanced using conventional plant breeding or genetic technology[178]. Biofortification is proving an effective strategy to combat malnutrition in food insecure countries, with over 7.6 million households around the globe growing and consuming biofortified crops in 2018. Examples of biofortification include the development of vitamin A-rich maize and cassava, iron-rich beans and millet, and zinc-rich wheat and rice.

D.2.4 Creative food processing increases food choice

Although the range of available ingredients decreased in the collaborative scenario, creative food processing provided a wide range of food choices. According to the European Food Information Council, food processing is defined as "any action that changes or converts raw plant or animal material into safe, edible and more enjoyable, palatable foodstuffs"[179]. Food processing goes back millennia (turning grain into bread, for example) but today processing typically refers to food manufacturers applying modern scientific and technological principles to change the properties of raw foods. Section C.1.6 outlines how food processing is increasing the shelf-life of foods, but processing is also being harnessed to create an ever-increasing variety of tasty, attractive food choices from the same basic raw materials. This is evident from the dominance of five staple crops in the Western diet (rice, wheat, maize, oats and potatoes), despite the rich diversity of foodstuffs available to us.

D.2.5 Lower incidence of diet-related disease reduces healthcare costs

In the collaborative scenario, the decreased incidence of diet-related diseases lowered healthcare costs and reduced the health gap between socioeconomic groups. Evidence supporting the financial burden of diet-related diseases on the NHS is outlined in section B.3.2, while section A.2.14 outlines evidence of the existing the health gap between socioeconomic groups.

D.2.6 Stigmatisation of diet-related diseases

The sense of personal responsibility for health management led to the widespread stigmatisation of diet-related diseases in the collaborative scenario. The framing of obesity as a matter of personal responsibility has been identified as a key factor in the lack of progress on tackling the obesity epidemic[180]. This framing does not reflect the complex systems-level action that is required to address the underlying genetic, environmental, physiological and psychosocial drivers of the condition. It is also driving the stigmatisation of obesity, with more than 80 % of UK adults believing that people with obesity are viewed negatively, and 62 % believing that people with obesity are discriminated against[181]. Nearly half of adults living with obesity in the UK have felt judged because of their weight, including in healthcare settings (42 %) and gyms (32 %).

D.2.7 Reduced environmental footprint of UK food
In the collaborative scenario, the shift towards plant-based diets and the reduction of food waste significantly lowered the environmental footprint of the UK's food system. The impact of shifting towards more plant-based diets on the UK's land footprint is discussed in section A.1.7.1, while the carbon footprints of plant-based and animal-based foods are discussed in section C.1.8. The shift towards plant-based diets would also affect the environmental footprint of the UK's food waste, as animal-based food waste tends to emit more greenhouse gases than plant-based food waste[182]. For example, meat and fish only make up 8 % of the food wasted by UK households but produce 19 % of the UK's food waste-related emissions, while fresh salads and vegetables account for a quarter of all edible food wasted in the home but only produce 12 % of the emissions associated with UK food waste.

D.2.8 Technology has minimised food waste
Food waste was minimised through the integration of technology along the global supply chain in the collaborative scenario, such as advancements in refrigeration, packaging and access at the retail end. The potential for artificial intelligence to reduce food waste is discussed in section C.1.11, and the technological advancements increasing the shelf-life of foods is discussed in section C.1.6. Other technologies include the use of fridge cameras that send a photo to your phone when the fridge door closes, so you can see what is in the fridge on-the-go and avoid buying things you already have[122]. Another example is Bluapple, a gadget that sits on top of the fridge and absorbs ethylene gas to keep perishable foods fresh for longer.

D.2.9 Lowering the UK diet's global land footprint
The shift in UK diets towards plant-based released vast areas of land abroad for the global regeneration of climate-mitigating forests and biodiversity in the collaborative scenario. This outcome is based on a study published in 2016, which found that 70 % of the cropland associated with UK food and feed supply is located abroad, and that the global land footprint of the UK diet increased by 23 % between 1986 and 2009[183]. Plant-based foods typically have a much smaller land footprint than animal-based foods (see section A.1.7.1), so shifting towards a more plant-based diet could release vast areas of land abroad.

D.2.10 Agroecological livestock system
In the collaborative scenario, the UK's world-class livestock system applied agroforestry principles to support biodiversity and climate mitigation at home. The potential for agroecological livestock systems to support biodiversity and climate mitigation is discussed in section D.1.5.

D.2.11 Sustainable intensification of food production
UK soil health and water management were prioritised in the collaborative scenario, and emission-lowering techniques that sustainably intensified agriculture became the norm globally, reducing the use of fertilisers, pesticides and other chemicals. Some British farms have already adopted this approach, increasing their levels of food production and enhancing the quality of the environment, while reducing their inputs, wastes and pollution[112]. Emission-lowering strategies that have sustainably intensified agriculture on UK farms include investing in technology to improve input efficiency, minimising tillage, reducing livestock numbers to increase crop area and generate renewable energy, and switching over to more productive livestock breeds[184].

D.2.12 Concentration of global economic power
In the collaborative scenario, global economic power was concentrated within four large blocs: the European Union, China, India and the USA. This outcome is supported by a long-term economic forecast conducted by the Japan Centre for Economic Research, which projects that India and China's share of global gross domestic product (GDP) will be on par with the United States and European nations' combined share by the year 2060[185]. This forecast also projected that by 2060, Europe's GDP share could be half

of what it was in 1990, but that EU will be able to retain its position as an economic power if European nations remain firmly united.

D.2.13 Alternative governance structures
Economic power moved to participatory democratic processes and cooperatives in the collaborative scenario, and more transparent, citizen-driven governance structures. Cooperatives are considered democratic organisations, often using participatory mechanisms of governance to share risk, power and reward[186]. According to the Economics Foundation, shifting away from extractive, disconnected, and short-termist forms of ownership could "re-orientate enterprise towards the common good, shape production toward democratic needs, stem financial leakage and build a future of shared economic plenty by sharing the rewards of our collective economic endeavours".

A report published in 2018 discussing the societal benefits of introducing Social Wealth Funds (collectively-owned investment vehicles aimed at social goals) argued that this citizen-driven approach to enterprise could foster inclusive growth and counter the power of private capital[187].

D.2.14 Boom of biofuel, bioplastic and biopharmaceutical sectors
Integrating the production of biofuels, bioplastics, and biopharmaceuticals with the food system allowed these sectors to boom in the collaborative scenario. The evidence supporting this outcome is outlined in section D.1.13.

D.2.15 Data transparency increases trust
In the collaborative scenario, data transparency across the food system led to a significant decrease in unethical practices and a consequent increase in societal trust. The potential of increased food system transparency to decrease unethical practices is supported by a study examining the impacts of introducing transparency into China's food governance framework[188]. The paper concluded that although food chain transparency is still in its infancy in China, there was already evidence that greater transparency put some pressure on food chain actors supplying global food exports, driving them to improve their food quality and sustainability performance.

The potential for food system transparency to increase societal trust is reflected in a new regulation concerning the transparency and sustainability of the EU risk assessment in the food chain[189]. This regulation stipulates that from March 2021 onwards, citizens will have access to and be consulted on the studies and information submitted by the food industry in the risk assessment process. Section D.1.15 outlines how such participatory approaches could increase citizen trust.

D.2.16 Reduction in inequality empowers citizens
The significant and visible reduction in national and global inequality resulted in citizens feeling more in control of their lives in the collaborative scenario. This effect is supported by a cross-national study examining the connection between economic inequality and political power[190]. The study found that in both developed and developing nations, as well as in democratic and non-democratic nations, greater income inequality is associated with greater political and civil inequality, reducing the power of citizens to influence their society.

D.3 Key events that shaped the collaborative food system

D.3.1 Global social movements merge

In the collaborative scenario, global social movements merged to hold governments to account, fight growing inequality, and improve democratic processes. This effect is supported by a study of social movements in the United States, which showed that individuals who had previously been involved in other (non-anti-war) movements were more likely to join the post-9/11 anti-war movement through organisations that had hybrid identities (i.e. organisational identities that span two or more social movements)[191]. The authors concluded that hybridization is key to ensuring that social movements achieve critical mass. This conclusion is also supported by a study of the 2017 Women's March in the US, which found that the large turnout was the direct result of the effective mobilization of various individuals and organisations that were motivated by intersectional issues, including race, class, gender, sexual orientation, and legal status[192].

D.3.2 Transformation of UK health system

The UK health care system was transformed to tackle rise in diet-related diseases in the collaborative scenario, through progressive taxes and financial incentives to encourage healthy eating. Evidence supporting the transformation of UK healthcare is discussed in section B.3.2, and section B.1.12 outlines how the introduction of health-motivated taxes could support healthy eating. Section C.2.1 outlines the importance of combining progressive food system taxes with food system subsidies to support low income households.

D.3.3 Untraceable food contamination events

In the collaborative scenario, a series of untraceable food contamination events fostered public distrust in supply chains, pushing innovation that led to complete data transparency across the food system. This outcome is supported by a letter signed by nine leading food safety groups following the widespread and untraceable outbreak of E.coli originating from romaine lettuce in 2018[193]. This letter argues for the need to introduce rules and support to ensure enhanced record-keeping for designated high-risk foods. Innovations that are capable of supporting enhanced record-keeping across the global food system are discussed in section A.2.9.

D.3.4 Public demand nationalisation of critical infrastructure

Years of increasing food prices, combined with a greater awareness of other countries' nationally-owned assets, led the UK public to demand the nationalisation of critical infrastructure such as food and energy systems in the collaborative scenario. Evidence supporting rising food prices is discussed in sections A.3.2 and B.1.12. The drive to nationalise critical infrastructure is supported by a recent survey exploring public attitudes towards nationalising the energy system[194]. According to the 2020 YouGov survey, 54 % of UK respondents support bringing energy companies back into public ownership, while 18 % oppose and 28 % are unsure. An existing example of a nationalised energy asset is the French state-owned multinational electric utility company Électricité de France S.A (EDF), which owns one of the UK's Big Six energy providers, EDF Energy[195]. An existing example of a state-backed food asset is China's second-largest food processor, Bright Food, which has activities spanning agriculture, dairy, canned foods, sugar and cereals[196].

Conclusion

The scenarios described in the GFS report *The Role of the UK Food System in Meeting Global Agreements: Potential Scenarios* do not aim to predict what the UK food system will look like in 2050, nor do they suggest what the preferred future might be. However, the evidence outlined in this report demonstrates the plausibility of the events in the four scenarios.

The supporting evidence was drawn from a wide array of sources, ranging from academic publications and business reports, to NGO blogs and newspaper articles. Given the high degree of uncertainty facing the global food system, it is natural that some of the current events, case studies, pre-existing ideas, and academic research that have informed the scenarios will be challenged or disproven in the future. Advancements in our understanding of our food system do not detract from the value of this scenarios exercise however, as its value lies in stimulating thought and discussion about the potential opportunities and challenges that could arise from transforming the food system to meet our global agreements.

These scenarios are not only a valuable resource for policymakers, but also for the citizens who will play a vital role in reshaping the food system (evident from the wealth of citizen-driven initiatives outlined in this report). Focussing the conversation on evidence-based scenarios instead of the evidence itself means that stakeholders do not need a deeper understanding of the wide array of supporting evidence in order to join in the conversation. This approach creates a more level playing field between different stakeholders in the food system, facilitating cross-stakeholder discussion and collaboration.

In conclusion, in combining academic research, industry reports, NGO knowledge, and the lived-experiences of everyday citizens to explore the role of the UK food system to meeting global agreements, the Global Food Security programme is providing thought leadership on the future challenges surrounding the UK's food security, as well as highlighting the value of greater cross-stakeholder collaboration.

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