UK FOOD STRATEGY AND NET ZERO

Martin Livermore

The Global Warming Policy Foundation
Briefing 64

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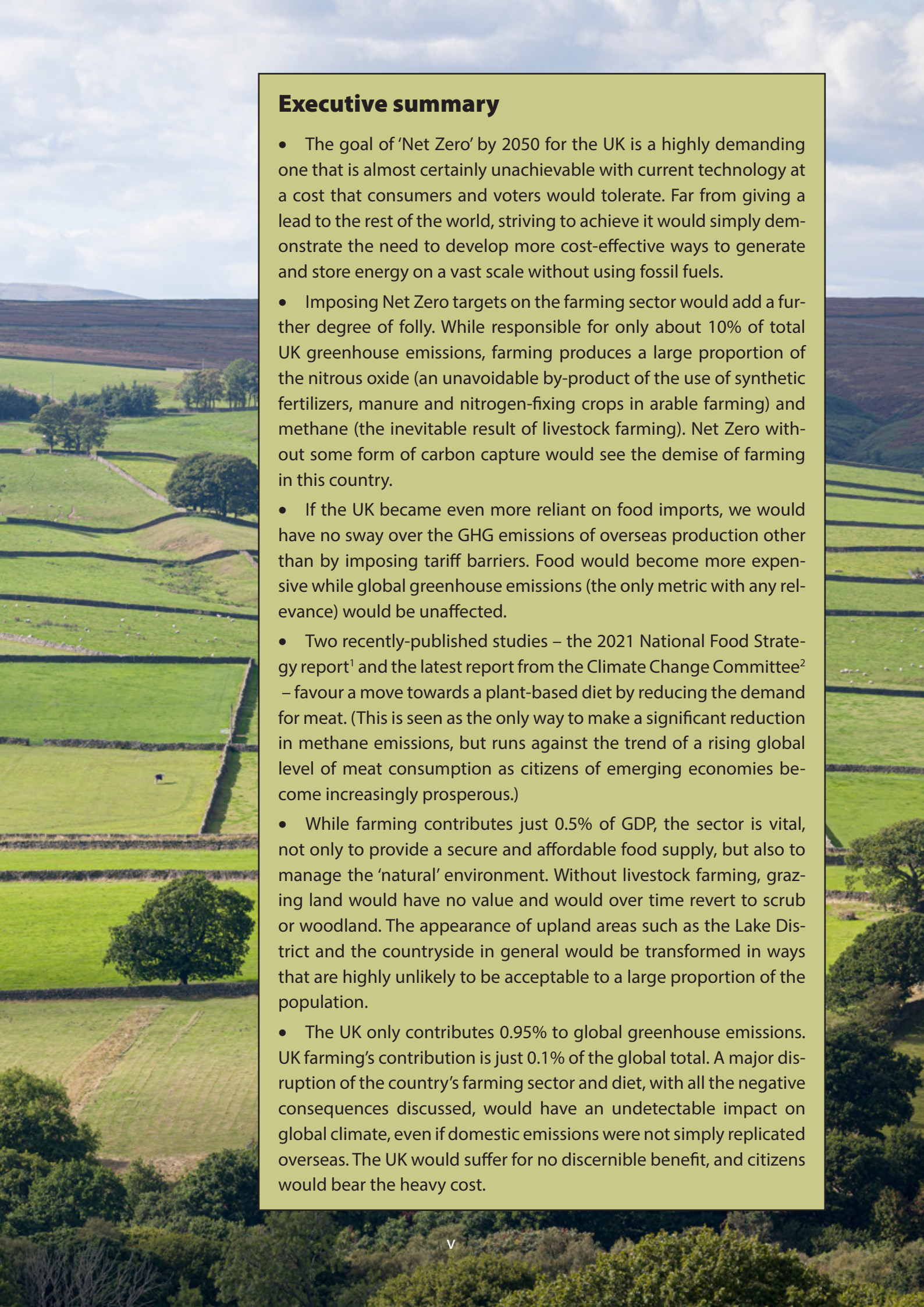
Contents

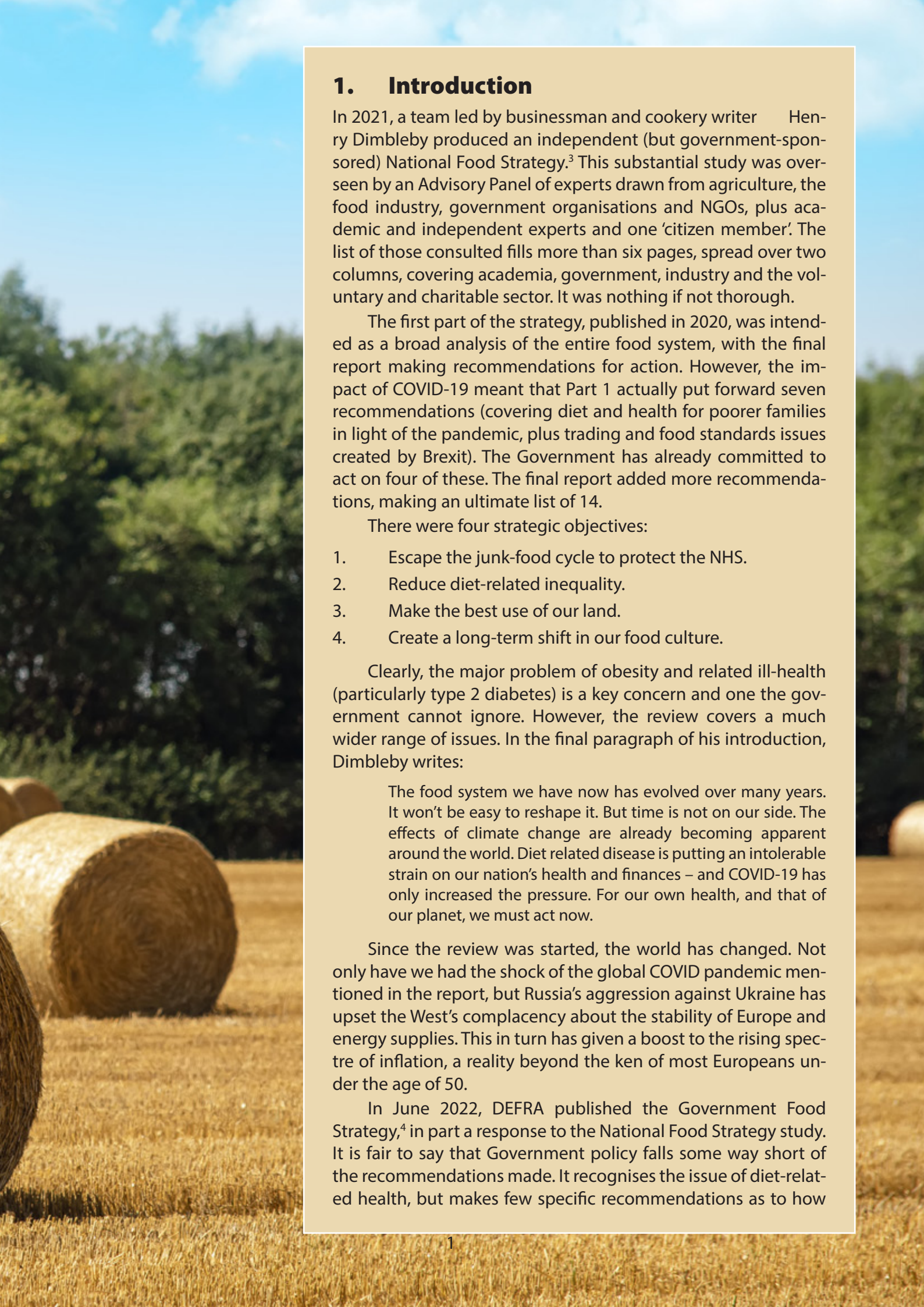
About the author

After graduating in chemistry, Martin Livermore worked for Unilever, Dalgety and DuPont for 27 years in a range of technical jobs in the food and agriculture sector, in the UK, South Africa and the Netherlands. He set up his own consultancy business in 2001, working with national and international trade associations and major companies on a range of science communications issues, while developing particular interests in the biotechnology and energy sectors. He was director of the Scientific Alliance from 2006 until 2018, working to encourage a rational, evidence-based approach to major policy issues.



Executive summary

- The goal of 'Net Zero' by 2050 for the UK is a highly demanding one that is almost certainly unachievable with current technology at a cost that consumers and voters would tolerate. Far from giving a lead to the rest of the world, striving to achieve it would simply demonstrate the need to develop more cost-effective ways to generate and store energy on a vast scale without using fossil fuels.
- Imposing Net Zero targets on the farming sector would add a further degree of folly. While responsible for only about 10% of total UK greenhouse emissions, farming produces a large proportion of the nitrous oxide (an unavoidable by-product of the use of synthetic fertilizers, manure and nitrogen-fixing crops in arable farming) and methane (the inevitable result of livestock farming). Net Zero without some form of carbon capture would see the demise of farming in this country.
- If the UK became even more reliant on food imports, we would have no sway over the GHG emissions of overseas production other than by imposing tariff barriers. Food would become more expensive while global greenhouse emissions (the only metric with any relevance) would be unaffected.
- Two recently-published studies – the 2021 National Food Strategy report[1] and the latest report from the Climate Change Committee[2] – favour a move towards a plant-based diet by reducing the demand for meat. (This is seen as the only way to make a significant reduction in methane emissions, but runs against the trend of a rising global level of meat consumption as citizens of emerging economies become increasingly prosperous.)
- While farming contributes just 0.5% of GDP, the sector is vital, not only to provide a secure and affordable food supply, but also to manage the 'natural' environment. Without livestock farming, grazing land would have no value and would over time revert to scrub or woodland. The appearance of upland areas such as the Lake District and the countryside in general would be transformed in ways that are highly unlikely to be acceptable to a large proportion of the population.
- The UK only contributes 0.95% to global greenhouse emissions. UK farming's contribution is just 0.1% of the global total. A major disruption of the country's farming sector and diet, with all the negative consequences discussed, would have an undetectable impact on global climate, even if domestic emissions were not simply replicated overseas. The UK would suffer for no discernible benefit, and citizens would bear the heavy cost.



1. Introduction

In 2021, a team led by businessman and cookery writer Henry Dimbleby produced an independent (but government-sponsored) National Food Strategy.[3] This substantial study was overseen by an Advisory Panel of experts drawn from agriculture, the food industry, government organisations and NGOs, plus academic and independent experts and one 'citizen member'. The list of those consulted fills more than six pages, spread over two columns, covering academia, government, industry and the voluntary and charitable sector. It was nothing if not thorough.

The first part of the strategy, published in 2020, was intended as a broad analysis of the entire food system, with the final report making recommendations for action. However, the impact of COVID-19 meant that Part 1 actually put forward seven recommendations (covering diet and health for poorer families in light of the pandemic, plus trading and food standards issues created by Brexit). The Government has already committed to act on four of these. The final report added more recommendations, making an ultimate list of 14.

There were four strategic objectives:

1. Escape the junk-food cycle to protect the NHS.
2. Reduce diet-related inequality.
3. Make the best use of our land.
4. Create a long-term shift in our food culture.

Clearly, the major problem of obesity and related ill-health (particularly type 2 diabetes) is a key concern and one the government cannot ignore. However, the review covers a much wider range of issues. In the final paragraph of his introduction, Dimbleby writes:

> The food system we have now has evolved over many years. It won't be easy to reshape it. But time is not on our side. The effects of climate change are already becoming apparent around the world. Diet related disease is putting an intolerable strain on our nation's health and finances – and COVID-19 has only increased the pressure. For our own health, and that of our planet, we must act now.

Since the review was started, the world has changed. Not only have we had the shock of the global COVID pandemic mentioned in the report, but Russia's aggression against Ukraine has upset the West's complacency about the stability of Europe and energy supplies. This in turn has given a boost to the rising spectre of inflation, a reality beyond the ken of most Europeans under the age of 50.

In June 2022, DEFRA published the Government Food Strategy,[4] in part a response to the National Food Strategy study. It is fair to say that Government policy falls some way short of the recommendations made. It recognises the issue of diet-related health, but makes few specific recommendations as to how

this might be tackled; in the foreword it merely says that 'there is more that must be done in future with government and industry working in partnership on a shared endeavour to promote healthier diets'.

Instead, the policy focus is on food security, although this is put into a broader context. It says that we must '…support a food system that offers access to healthy and sustainable food for all. It will complement the measures we have already taken to support those struggling to afford food and help them eat healthily'. The strategy also acknowledges the impact of farming on the environment, saying that agriculture policy 'will seek to financially reward sustainable farming practices, make space for nature within the farmed landscape, and help farmers reduce their costs'.

The environmental impact of food and farming is brought into sharper relief in the most recent report of the Climate Change Committee (CCC; 2022 Progress Report to Parliament[5]), published shortly after the Food Strategy White Paper. The CCC, driven as it is by the goal of achieving Net Zero by 2050, finds much to criticise in the current rate of progress across multiple sectors, with farming and land use being no exception. To meet this goal (which is both highly ambitious and of dubious benefit in terms of global emissions), recommendations are made for making farming more efficient and reducing both consumer demand for, and production of, milk and meat.

Against such a background, the current study considers the implications of climate mitigation policies for the food chain and the UK farming sector. Is Net Zero really to be a higher priority than securing an affordable, nutritious food supply?

2. Food policy in England and the UK

Food security has not been an issue in the UK for many years. As a rich country, with extensive international trade, a wide range of foods – both staples and luxuries – are available essentially all year round. As average incomes have risen, buying food has, for most people, become a smaller and smaller part of overall household expenditure (although this has to be qualified by the fact that a significant proportion of meals are now consumed outside the home). However, the country has never been self-sufficient in food, and the proportion of domestically-grown produce has declined in recent years. The country *is* largely self-sufficient in cereals, meat (though a net importer), milk and eggs, but is dependent on imports for nearly half of its vegetables and over 80% of fruit. Overall, in 2020, the UK imported 46% of the food consumed.[6] This reliance on imports has increased, while farmers are now seen as being as much landscape managers as food producers (see the next section for a discussion of environmental issues).

Until comparatively recently, the policy focus has tended to be on food affordability: on quantity rather than quality per se. In the eyes of some, this has contributed to the UK's unenviable

record of high levels of obesity and related illnesses. But farmers have also been rewarded for positive contributions towards the environmental impact of land management, such as creating wildlife habitats or, more recently, 'rewilding'. The addition of 'biofuels' (ethanol and biodiesel) to standard motor fuels has been part of this environmental thrust.

Farming plays a unique role in the UK and many other parts of the developed world. It is both utterly essential, since without a secure food supply society would rapidly collapse, while accounting for a less than 1% of GDP (in contrast to poor countries where farming is a major part of the total economy). Given the existing high levels of food imports, it is tempting to suggest that rich-world countries such as the UK could allow their agricultural sectors to wither unless they were globally competitive in the production of certain foods. It is a very tough industry in which to make a living, and without state support many farms would simply not be viable (at least as currently constituted and run). In common with other countries, the government has therefore protected farmers via a combination of subsidies and import tariffs (agricultural subsidies are often the most difficult to reform in trade liberalisation negotiations).

Table 1 summarises the extent of support for the agricultural sector in the UK (GFR is Gross Farming Revenue and the Nominal Protection Coefficient is an indication of the extent to which farmers receive higher prices than international market levels).

One clear fact that emerges is that farming receives total support equivalent to nearly half its contribution to the economy. Also, on average, farmers receive around a fifth of their total income via subsidies.

Farming is something that countries value for its own sake, perhaps at least in part because the demise of farmers would radically alter many of the 'natural' landscapes we take for granted. This innate need to sustain agriculture also explains the contrast between the sector's small economic contribution and its major political clout.

This is the background to the infamous EEC/EU Common Agricultural Policy[7] (CAP) which, in its earlier incarnations, paid

Table 1: Subsidies for UK agriculture

Indicator	2017	2018	2019	2020	2021
Total support estimate, % of GDP	0.28	0.28	0.27	0.27	0.30
Producer support estimate, % of GFR	18.8	19.7	19.2	18.9	23.4
Nominal protection coefficient, ratio	1.06	1.07	1.07	1.05	1.13
Agriculture in GDP, %	0.7	0.6	0.7	0.6	—
Agricultural employment, %	1.16	1.06	1.04	0.98	—

Source: Compareyourcountry.org

small-scale farmers to harvest unneeded produce (many of us will remember wine lakes and butter mountains). Its aims are to:

- support farmers and improve agricultural productivity, ensuring a stable supply of affordable food;
- safeguard EU farmers, so that they can make a reasonable living;
- help tackle climate change and the sustainable management of natural resources;
- maintain rural areas and landscapes across the EU;
- keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sectors.

The CAP is still the largest part of the overall EU budget (€57.9bn of €161bn total) and, of that, nearly three-quarters (€41bn) is direct income support. But, at the beginning of 2023, a revised 'greener and fairer' CAP came into force, covering the period till 2027. This places more emphasis on environmental issues: climate change, management of natural resources and biodiversity.

Governments have a particularly unenviable task when formulating food policy. Few voters are directly involved in farming, but people become acutely aware of rising food costs or shortages of certain items. In an ideal world, policymakers would like to achieve the following:

- guaranteed food security
- a balanced food supply affordable to everyone
- a healthy diet eaten by everyone, with much lower levels of obesity
- farmers who earn a decent living and are happy to continue farming
- an attractive farmed environment with high levels of biodiversity
- large reductions in GHG emissions from farming
- minimal public subsidy.

Of course, there is no perfect solution that meets all these criteria. For example, there are potential conflicts between maximising yields and fostering farmland biodiversity. Most problematic is the objective to slash emissions of methane and nitrous oxide. Methane, in particular, is largely generated by ruminant livestock (cattle, sheep, deer and goats). Significant cuts can only be made by reducing demand; that is, moving people away from consuming meat and dairy produce. Ultimately, this is a matter of priorities and public acceptance of change.

3. Food production and the environment

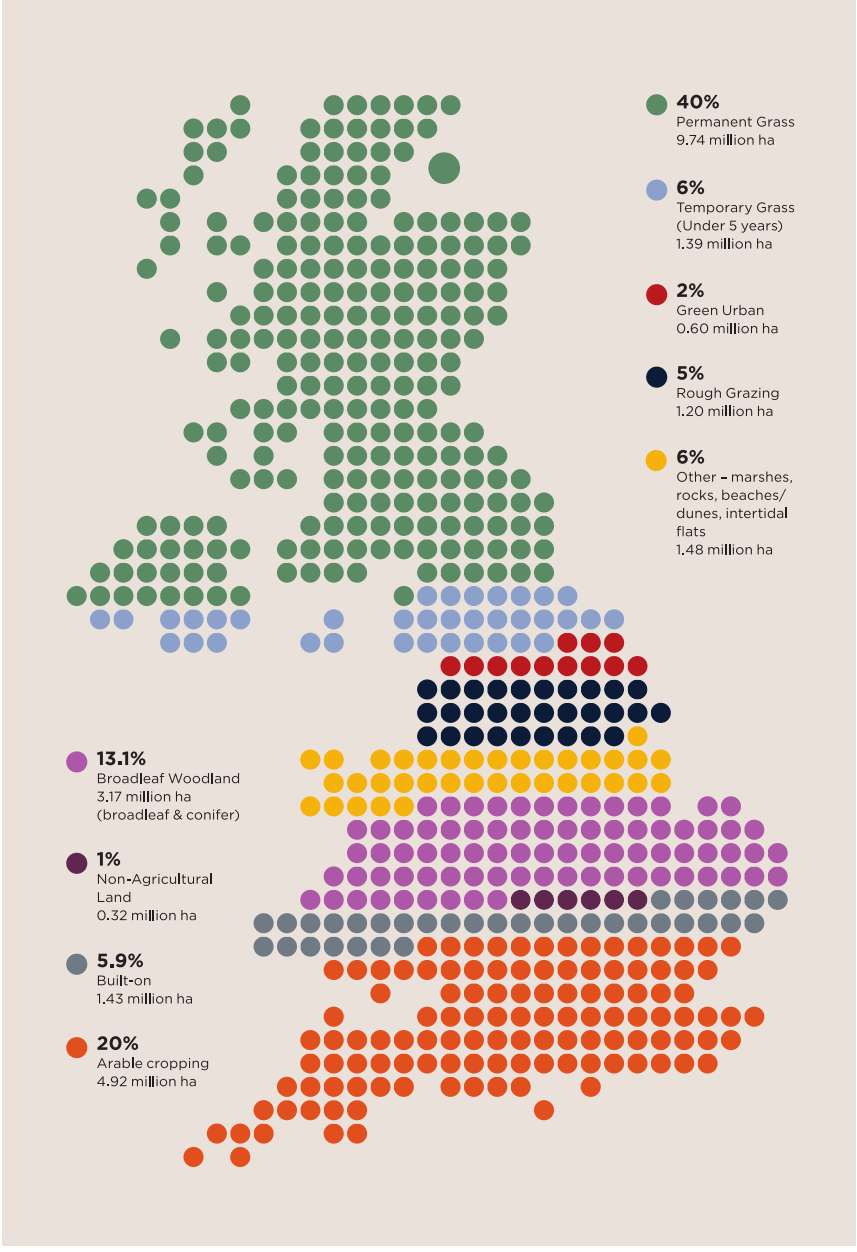
Our lack of concern about the level of food imports, and the increasing profile of issues such as biodiversity, soil health and so on, have resulted in farmers being paid for environmental

management rather than simply producing food (long gone are the days of farmers being encouraged to grub up hedges and maximise harvests). To an extent, this is quite compatible with high crop yields; by using field margins and areas of unproductive land as managed wildlife habitats (and/or sources of food for some species), farmers can concentrate on optimising yields on the fields themselves.

This, of course, only applies to arable farming. In fact, much farmland is only suitable for extensive grazing rather than growing crops, so allowing livestock to be raised, and making a major contribution to the meat and dairy sectors. In 2019, the total area of agricultural land in England was 9.06 million acres, of which 4.9 million acres was croppable area and 3.7 million acres was permanent grassland[8] (see Figure 1). In the same year, there were 5.3 million cows, 3.7 million pigs, 15.4 million sheep (plus 33.8 million chickens, managed separately from grazing animals).

Figure 1: Current UK land use.

Source: Savills.[17]



Leaving aside the issue of farmland biodiversity, the key concern of environmentalists regarding arable farming is the use of nitrogen fertilisers (mostly synthetic). Additional nitrogen is needed to improve yields, but not all of it applied to the soil is utilised by crop plants. Some finds its way into water courses and groundwater in the form of nitrate, but it is also a source of atmospheric nitrous oxide (N_2O), which is a greenhouse gas. In the case of livestock farming, the primary concern is methane (CH_4) – also a greenhouse gas – produced by ruminants (in a farming context, mainly cows and sheep). As a separate issue, ammonia is released from manure and slurry. The main concern with this is the gas's reaction with other chemical species to form particulates in the air (PM_{10} and $PM_{2.5}$), which can be breathed in and damage health.

But the demand side of the food chain is equally important. Livestock farming is a major source of methane, and grazing animals are kept on land unsuitable for arable farming, much of which could be used to grow trees to act as carbon sinks. For this reason, the National Food Strategy (and campaigning groups) proposed interventions to persuade people to consume less meat and dairy produce. A reduction in the numbers of grazing animals would reduce greenhouse gas emissions and potentially allow grazing land to be converted to woodland. To put this in perspective, according to a background report for parliamentarians:[9]

> The emissions reduction potential of population level dietary change has been estimated to be two to threefold greater than that of food waste reduction or changes to farming practice.

Undoubtedly, overconsumption of food relative to energy expended is an issue in the developed world; better lifestyles, including dietary changes, would help many people live healthier lives. However, much of the world still suffers from undernutrition and exists on a very restricted range of foods. As large numbers of people in developing countries are becoming more prosperous, global consumption of meat is increasing. In a free market, many people will choose to eat a more varied diet, which will include meat, and will drive increased emissions of methane.

As well as the supply and demand components of the food chain, we have to consider food waste. In poorer countries, this occurs primarily between harvest and the consumer, with inadequate storage and transport systems leading to losses from pests and diseases. In the rich world, on the other hand, it is consumers who generate most food waste. The relative affordability of food and widespread adherence to 'best before' dates as an indicator of edibility and safety means that plenty of perfectly decent food is thrown away. Changing consumer behaviour in this respect is challenging, but supermarkets are now stopping the use of 'best before' dates on a range of products (these were intended purely as a way of ensuring efficient stock rotation but gradually became seen as an indication of the safety or otherwise of foodstuffs).

4. Agriculture and climate change

Farmers grow crops and raise livestock suited to the land they farm, and the climate in which they operate. Plant breeders make incremental improvements to yield, disease resistance and so on, and in some cases develop varieties adapted to different weather conditions. Targeted breeding methods, including the latest gene-editing techniques, now also allow crops with improved tolerance to drought and/or flooding to be developed. Livestock also has a limited range of tolerance to climatic stress, but again breeders can help to produce strains that can thrive in more extreme conditions.

While certain crops are definitely suited to much warmer regions than the UK – olives, bananas, citrus fruit, for example – the cultivation pattern for some others varies with changing weather patterns. Grapes were widely grown across England during the Roman Warm Period, for instance, but it is only in recent years that domestic wine production has begun to grow significantly, because of the current warming trend. Similarly, in France, commercial sunflower growing was at one time restricted to Mediterranean areas, but has now spread to regions much further north.

Harvests vary annually in response to weather conditions and the impact of pests and diseases. In the era of globalisation, poor yields in one region are quite likely offset by good harvests elsewhere, and crops from both Northern and Southern hemispheres are traded round the world. As the world's population and pressures on existing farmland continue to grow, it is as important as ever to ensure that farmers across the globe can continue to raise their yields. There are some suggestions that a continued rise in average temperatures could reduce yields in some regions, particularly the tropics, and that it may no longer be possible to cultivate some crops in these parts of the world. In the UK, farmers may well have to change what they grow, in response to changing weather patterns.

To set against that, higher average temperatures at higher latitudes may lead to more productive use of arable land. Also, as atmospheric carbon dioxide levels increase, so, in general, do crop yields, since CO_2 level is a key limiting factor for the rate of photosynthesis. Nevertheless, the mainstream view is that global warming is a threat to agricultural productivity and hence to food security. One remedy prescribed to correct this is a reduction in livestock farming (and hence meat and dairy consumption) to enable larger areas of arable land to be cultivated.

However, there is no magic wand to enable this to happen and, even if there were, virtually all of the present area of grazing is likely at best to make relatively low-grade arable land. If not used for grazing, it will produce poor harvests.

Another factor reducing farmers' incentives to grow more food has been the move towards biofuels in the last couple of decades. Petrol now has 10% of added ethanol (E10) and diesel up to 20% of biodiesel. Most of the crops used to produce these

fuels (maize, wheat, sugar beet and palm oil) are grown abroad, although some biodiesel is made from waste cooking and lubricating oils. However, significant areas of UK farmland are still harvested to produce motor fuel: according to the most recent government statistics, 28,800 ha of wheat and 7,000 ha of sugar beet, equating to about 0.6% of the total UK arable land area.[10] All of this is turned into ethanol, which is 27% of the total bioethanol used for road transport. If we assume that UK wheat yields are representative of the average harvest across the mix of crops produced, both domestically and overseas, to produce UK bioethanol, then approximately 150,000 ha of arable land around the world is used to produce 3.4% of the UK's motor fuel needs instead of producing food. Assuming 8 tonnes/ha yield for wheat, this means that 1.2 million tonnes of wheat – equivalent to about 2.5 billion loaves of bread, or an equivalent quantity of animal feed – is being diverted to road transport, .

While this may seem a poor use of land, the push towards biofuels started at a time when harvests had been so plentiful that global commodity food prices had remained relatively stable for decades. However, this has not always been the case. The post-war era of price stability arose from the use of modern crop breeding and farming techniques, which enabled harvests to increase and enough food to be produced to feed a rapidly growing population and avoid a Malthusian disaster. The FAO Food Price Index was quite stable through from the 1980s to the early years of the 21st century,[11] but the global financial crisis of 2008 heralded a new wave of volatility. More recently, the COVID-19 pandemic pushed the index to new highs.

There are obviously a number of political and economic drivers behind this change, but taking land out of food production doesn't help; the greater the area used for biofuels, the more likely there is to be an impact on food commodity prices and food security, particularly for the world's poorest. Fortunately, it seems highly unlikely that use of this generation of biofuels for road transport will be expanded to any great extent. They are, after all, intended only as an element of the intended transition away from the internal combustion engine (unless fuelled by hydrogen). On the other hand, if the planned transition to all-electric vehicles does not come about as rapidly as planned, biofuels may be with us for longer than envisaged.

5. A new age of uncertainty for farmers

Until comparatively recently, farmers and policymakers had to focus solely on the need to produce good yields of nutritious crops as sustainably and cost-effectively as possible. Although agriculture remains the most protected sector of the economy, with tariffs set to protect farmers' livelihoods, the country is far from self-sufficient in food production. Globalisation means British consumers have come to expect not just New Zealand lamb, Danish bacon, French cheeses and Italian charcuterie, but also

grapes, apples and other fruit from both European and Southern hemisphere harvests and tomatoes and lettuces from Spain and Dutch greenhouses, so as to give continuity of supply all year round. Domestic self-sufficiency was really not seen as an issue when farmers in other countries could be relied upon to supply our needs. This meant that the focus of policy has shifted increasingly towards environmental factors; paying farmers to manage landscapes and biodiversity as much as to grow food is not seen as in any way problematic.

As this report is being written, people are learning to live with rates of inflation unknown to most people of working age. Global supply chains, disrupted during the Covid-19 pandemic, have been slow to respond to resurgent demand for both raw materials and finished products, Russia's invasion of Ukraine caused energy prices to spike, food prices are increasing rapidly, and rising interest rates are impacting mortgage repayments and providing a shock to the housing market. We are in the early stages of a significant shift in the economic circumstances, not only of this country, but also of the whole of Europe and the world.

The Russian invasion of Ukraine has been a major shock to the international system. After the collapse of Soviet satellite states of Eastern and Central Europe and the USSR itself in the two years following the fall of the Berlin wall in 1989, the Cold War was believed to have ended and, in Francis Fukuyama's famous phrase, we saw 'the end of history', with Western-style liberal democracy as the last stage of societal development. Well, maybe; but not yet, as both the growing assertiveness of Putin's Russia and Xi Jinping's China show only too well.

For Europe, coming to terms with a major war and learning to deal with an aggressive dictator aiming to restore parts of the continent to the Russian fold is traumatic. Providing Ukraine with modern weapons is a drag on already weakened economies. But the shock goes much further than that, with steep price rises for oil and gas contributing to escalating cost-of-living crises, and supply security becoming a looming problem, as sophisticated, energy-intensive modern economies struggle to break their dependence on Russian gas supplies. This of course has a knock-on effect on global commodity prices.

Food is also affected. Ukrainian supplies of wheat and sunflower oil (of which the country is a major exporter) can only leave the country with difficulty, and sanctions mean that Russian grain is no longer being imported by some countries. In a highly globalised economy, such disruptions reduce supply security and raise prices. To this, we have to add the inevitable price inflation because of higher fuel prices, affecting bulk shipment by sea as well as road transport. Russia and Ukraine are also major sources of synthetic fertiliser, needed for high crop yields. Supply disruption has compounded the impact of rising energy prices (fertiliser manufacture is a very energy-intensive process) to push up prices and thus also those of food. And, last but not

least, the growing realisation in recent years that China's status as workshop of the world does not make it any more likely to become a liberal democracy means that alternative suppliers are being sought, in most cases pushing up costs still further.

Amidst this perfect storm of structural problems for the global economy, we can set the highly ambitious plans of the UK and EU to 'decarbonise' their economies, in the belief that this will limit the projected harm that would result from continuing global warming. The UK, as usual, led the charge. Having previously committed to reducing net greenhouse gas emissions by 80% by 2050, under the short-lived government of Theresa May Parliament decided to achieve Net Zero by the same date. We have just 27 years to meet this 'binding, legal' obligation. The government also hosted the vast COP26 meeting in Glasgow in November 2021, at which more commitments were made by countries around the world and there was agreement on how the Paris Climate Agreement would be implemented. Effectively, countries agreed to do the best they could, but with few binding commitments for those outside Europe.

Figure 2 shows the changing contribution of different sectors to total UK greenhouse gas emissions in the two decades from 1990. The initial focus of emissions reduction work was on the energy sector. Despite the enormous expenditure on electricity generation from renewable sources, ongoing public subsidies and demand reduction, this effort only addresses the low-hanging fruit of decarbonisation. Radically cutting emissions from transport and domestic and business heating and lighting is a much more difficult (and expensive) task. Agriculture's emis-

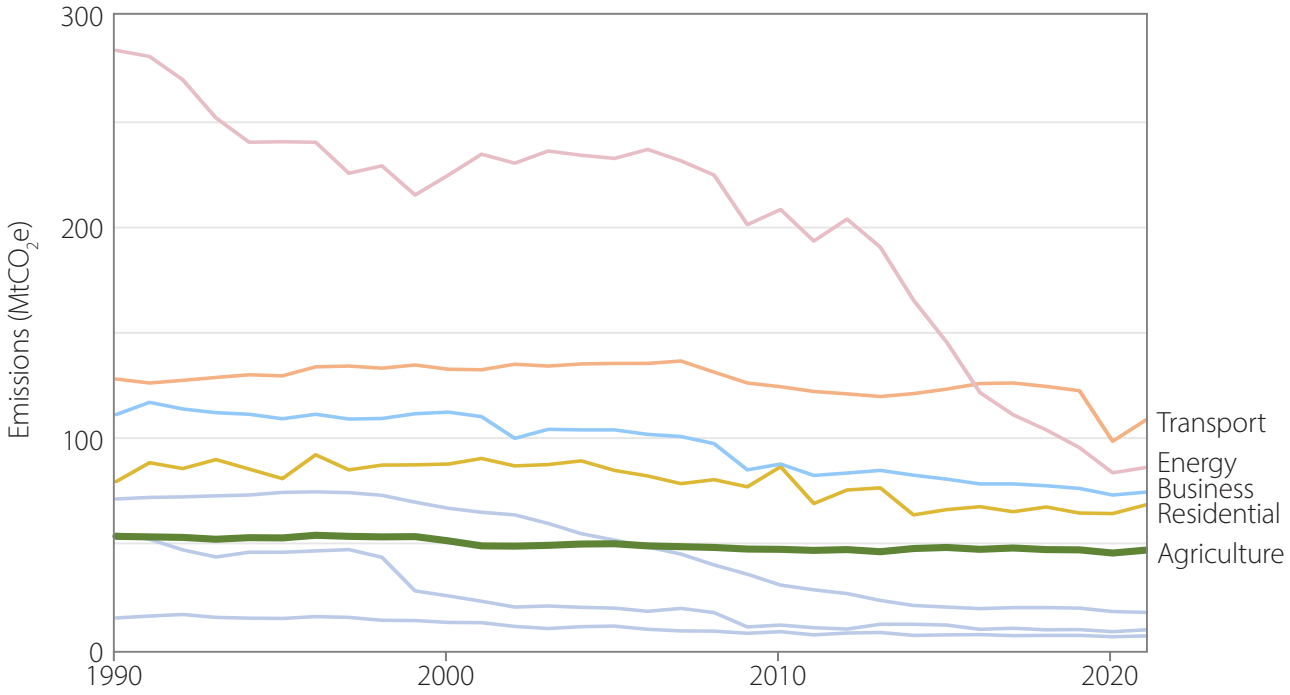


Figure 2: The small contribution of agriculture to total greenhouse emissions

Source: Final UK greenhouse gas emissions national statistics: 1990 to 2021.

sions have remained rather static over this period and, although relatively low in total, will receive increasing attention as the contributions due to transport and heating fall. However, large cuts in emissions from agriculture would require far-reaching changes to the very nature of farming. This would be very challenging, to put it mildly.

Global warming is, by definition, a global issue. It doesn't matter whether a tonne of CO_2 was emitted in Essex, Texas or Shanghai; it still gets mixed in the atmosphere and has the same modest impact on radiative forcing. Sacrifices made by citizens in European countries – and sacrifices there will be – mean nothing unless *global* emissions are being cut. The two largest emerging economies – China and India, together accounting for nearly 2.9 billion of the current world population of a shade under 8bn – will certainly not jeopardise their economic development to satisfy climate targets. Those committed to the IPCC agenda, however, will continue to compromise on many important issues with these countries to keep their nominal adherence to emissions reduction. This is akin to assuming that welcoming China and Russia into the integrated international trading system would influence their broader political development. The naïvety of senior politicians can sometimes seem breathtaking.

We are at a crucial juncture; decisions have to be made about priorities. The key one is to what extent emissions-reduction policy is allowed to trump everything else. If we consider the current UK situation, we find that the low-hanging fruit has mostly been picked and that things can only get more difficult and expensive from here on. And whatever commentators say about the need for government to subsidise consumers to make changes, the money required can only come from taxpayers, either directly or via taxes.

It is fanciful to believe that, during a major cost of living crisis, the average person would happily pay to convert from perfectly satisfactory forms of heating or transport to different ones. Such major changes cannot be carried out in a democracy without citizens' approval, which is one reason why some more extreme environmentalists would happily change to an authoritarian regime, which could act with impunity. Big Brother could get us to Net Zero. In practice, we have already seen the UK government (and governments across Europe) making compromises on fossil fuel use to help keep the lights on during the difficult winter of 2022/23. However, no country has yet dared to make a clear stand against current Net Zero plans, whatever politicians may think privately.

6. Farming's emissions

More specifically, what about farming and the food supply chain? The food we eat and the way we produce it may not be a major concern in terms of greenhouse gas emissions at present, but it will become so if and when the contribution of transport

and heating fall. So, are there cost-effective ways we can change the system to tackle this situation without compromising food security and affordability? There are many components of the roadmap to a Net Zero future, and all have an impact on our way of life, but none more so than the food chain. The global population is likely to peak later this century at something over 9 billion, from the present total of approximately 8 billion. Not only will the extra mouths need to be fed, but governments need to find ways to ensure the hundreds of millions of people who are presently food insecure and/or malnourished can access better diets in future. Those of us lucky enough to live in the rich world could see our sophisticated societies crumble if there are major disruptions to basic food supplies. Whatever action might be taken must not put global food security at risk.

The most recent government statistics show that, in 2019, agriculture gave rise to 68% of UK nitrous oxide (N_2O) and 47% of methane (CH_4) emissions (plus just 1.7% of carbon dioxide emissions). Overall, this comes to 10% of total UK greenhouse gas emissions. Both gases have much higher global warming potentials than CO_2; about 56 times for CH_4 and 280 times for N_2O over a twenty-year timescale.[12] Both are present at much lower levels than CO_2; in the case of N_2O only 330 ppb (parts per billion; a thousand-fold lower than carbon dioxide), and for CH_4 about 1900 ppb. However, the important thing is the likely contribution to global warming.

Carbon dioxide, the main greenhouse gas, produces a calculated radiative forcing (i.e. additional heating caused by the Sun) of 2.1 Wm^{-2} (watts per square metre). Nitrous oxide, despite its very high specific warming potential, leads to only a 0.2 Wm^{-2} forcing, although it does have a long residence time in the atmosphere (about 120 years). Methane, on the other hand, results in approximately 1 Wm^{-2}, a little less than half as much as CO_2. It also has an atmospheric residence time of only 12 years.[13] Methane is essentially a product of livestock farming, primarily cattle and sheep. These animals are ruminants. They exist by grazing (although in winter are fed a nutritious synthetic diet plus silage). Non-ruminants cannot digest the cell walls of grass and other greenery, but ruminants have several stomachs in which bacteria are able to digest this plant material by fermentation, so releasing the nutrients. A by-product of this fermentation is methane. Essentially, if we eat beef or lamb, drink milk or eat cheese, then inevitably there will be more methane emissions.

About two thirds of the N_2O emissions from farming come from the soil, mainly from use of synthetic nitrogen fertiliser, manure, and from nitrogen-fixing crops. Other sources are agricultural wastes and combustion. Those emissions have decreased since the 1990s, mainly through large reductions in use of fertilisers on grazing land and more efficient use on arable land. Further reductions could be made by even more efficient use of fertiliser, but a certain amount will always be released.

7. Agriculture and Net Zero – key issues

Land classification

In 2018, 17.4 million hectares of land in the UK – about 71% of the total – was used for agriculture. Of this, 6.1 million hectares (35% of the agricultural land area, virtually a quarter of the total land in the UK) was arable. However, this was a slight (0.8%) decline from the previous year. Cereals are the main crop of choice, accounting for about half of all arable land. The rest is grazing land of various sorts, or woodland.[14]

Land in England and Wales is categorised under the standard Agricultural Land Classification System into one of five grades,[15] with grade 3 being subdivided:

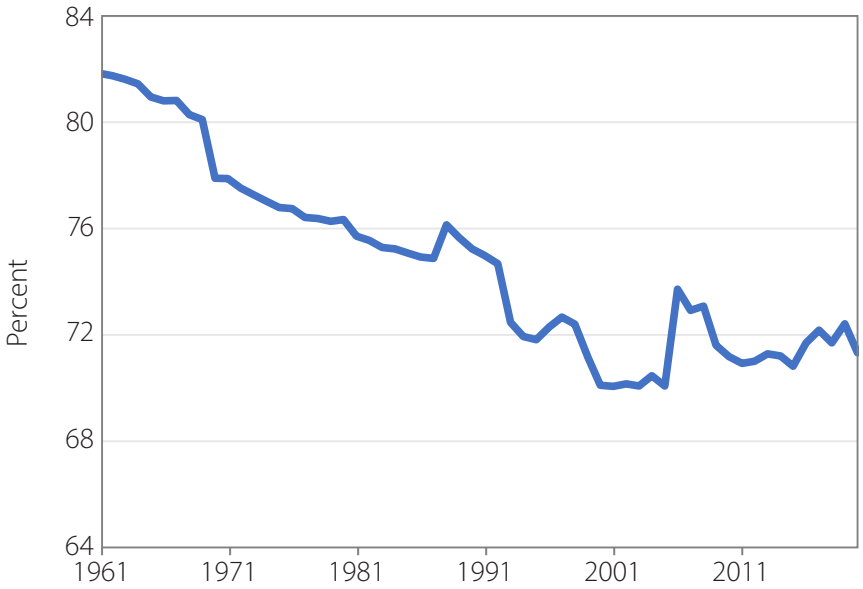
- Grade 1 – excellent quality land
- Grade 2 – very good quality land (with minor limitations)
- Subgrade 3a – good quality land with moderate limitations
- Subgrade 3b – moderate quality land with strong limitations
- Grade 4 – poor quality land (mainly suited to grass)
- Grade 5 – very poor quality land (mainly permanent pasture or rough grazing)

Most arable crops are grown on land classified as Grade 1, 2 or 3a. Much of the higher-grade land is found in the English Midlands and East Anglia. Scotland has its own similar system, but with an extended classification of lower grade land. Note, however, that land categorisation is not necessarily a fixed matter. Some areas will never be suitable for arable farming because of their poor soil quality, topography or elevation, but land that is prone to being waterlogged or over-dry can become more productive by drainage or irrigation. In addition, if any change of use is proposed – development, mineral extraction or waste disposal, for example – the classification of the land in question will almost certainly need to be reassessed.

Higher-grade farmland has a greater degree of protection from development than grazing land, but can still be used to grow biofuel crops, at the discretion of the farmer. Equally, farmers are being encouraged by some companies to lease some of their land for the installation of large-scale solar energy farms. While in some cases grazing can still take place between raised panels, in practice solar farms take agricultural land out of production. Nevertheless, a guaranteed income for 20 years or more, together with less land to manage, can prove tempting. Renewable energy projects are, of course, not the only threat to food production; major infrastructure projects such as HS2, or housing or commercial development near existing towns can also gradually reduce the area of arable farmland and grazing. Figure 3 shows a pattern of significant overall reduction since the 1960s, from approximately 82% of total land in 1961 to under 72% in 2020.

This is not just an issue in the UK. Urbanisation, transport and industrialisation can all take farmland out of production, and are big factors in many developing economies. And in the developed world, wildlife habitat management, 'rewilding' and other environmental projects also put pressure on agriculture. The net effect is to reduce the area available for food production in many countries. The global trend is for a continuing decline in the

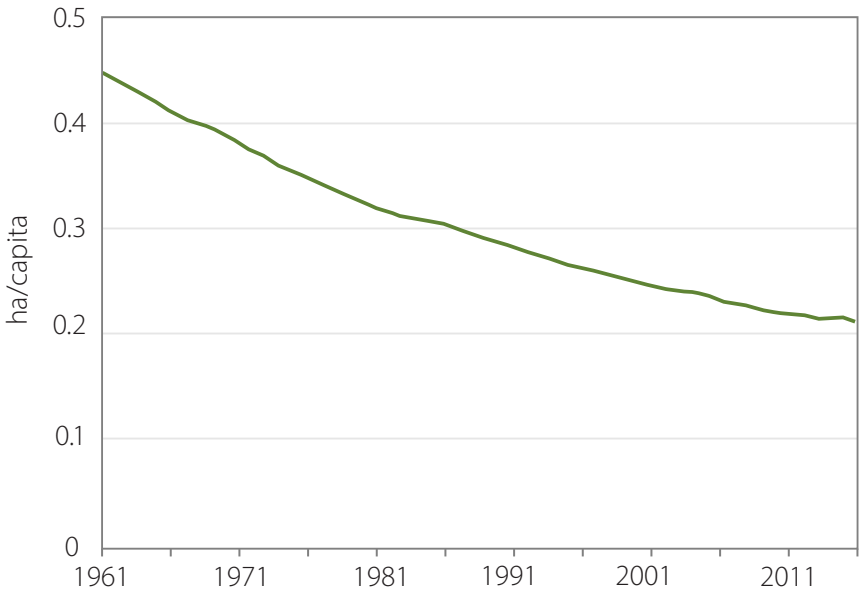
Figure 3: Percentage of UK land area used for agriculture. 1961–2020
Source: World Bank



farmland available per head of population (see Figure 4). Over the period shown, the world's population grew from 3 to 7.5 billion, illustrating the enormous productivity increases generated by modern plant breeding and farming methods.

With food production providing a relatively precarious living for many farmers, it is not surprising that some are keen to use their land in other ways. The drive towards Net Zero may not be a major factor in declining food self-sufficiency, but its prioritisation is indicative of a general complacency about food security.

Figure 4: : Global agricultural land per capita, 1961–2016
Source: FAO



Meat and dairy farming

The CCC and campaigners see a radical change of diet as the only way forward. Discouraging consumption of beef, lamb and dairy products would cut livestock farming and reduce methane emissions. Meat eaters would still have pork or chicken available, or turn to an array of plant-based meat products (or even lab-cultured meat, in the longer term). A range of vegan dairy alternatives are already available, with 'milk' made from oats, soya, coconut or rice widely sold.

However, eliminating cattle and sheep from the landscape has consequences, as does a radical change of diet. Humans are omnivores and, despite campaigners' claims, it can be difficult to achieve a good, long-term nutritional balance on vegan diets alone. Nor is there any real evidence to suggest that veganism is better for health than consumption of a well-balanced diet including meat and dairy products. There are a whole range of reasons for people choosing the foods they eat, including cultural preferences. By and large, people will eat more meat as they become more prosperous, although this is not always from ruminants (pork is the most popular meat worldwide) and some rich countries (e.g. Japan) consume more fish. Dairy products, although widely distributed, have not been part of the traditional diet in parts of south-east Asia.

In recent years, there has been a large increase in the availability and sales of vegetarian and vegan alternatives to meat and milk products. This has been driven by health concerns in some cases, and an ethical position in others. In practice, however, many people seem to be cutting down on meat and dairy rather than eliminating them; they are becoming 'flexitarians'. There is a certain element of fashion in the current trend, so it is likely that the demand for meat and dairy alternatives will plateau (if, indeed, it hasn't already done so). Moving to a plant-based diet for ethical or philosophical reasons is one thing, but not everyone will be happy to make compromises in terms of eating quality if they continue to include meat and dairy in their diets anyway. Another factor that will become increasingly important is the higher prices demanded for plant-based alternatives. As inflation begins to bite, many consumers will be looking for ways to reduce their grocery shopping bill.

Arable farming

Growing crops is not a major contributor to greenhouse gas emissions, but if the drive towards Net Zero is successful in other sectors, these emissions could form a much larger proportion of the total in a decade or two. CO_2 emissions are trivial in comparison to other sources, although minimising deep ploughing or even moving towards no-plough systems could reduce them further.

The only significant contribution arable farming makes to GHG emissions is in the form of nitrous oxide. Although present only at parts-per-billion levels, the gas's long lifetime in the atmosphere and high radiative forcing potential compared with

carbon dioxide gives some cause for concern. However, the high potential is to some extent a consequence of its very low level; each increment has a relatively larger effect than the equivalent amount of CO_2, simply because there is already enough of this gas in the atmosphere to saturate much of its infra-red absorption spectrum.

There is no viable way to reduce nitrous oxide emissions significantly, since the bound nitrogen essential for plant growth inevitably gives rise to some (plants cannot absorb nitrogen directly from the air; their roots absorb it in the form of soluble nitrogen compounds in the soil). Indeed, it is quite possible that N_2O emissions could increase in future if there is a move away from meat and dairy products in the average diet and a need to grow more crops. It is not easy to be sure about this, because large amounts of grain and beet are grown as animal feed, together with higher-protein crops, which are generally imported.

Food miles and embodied carbon

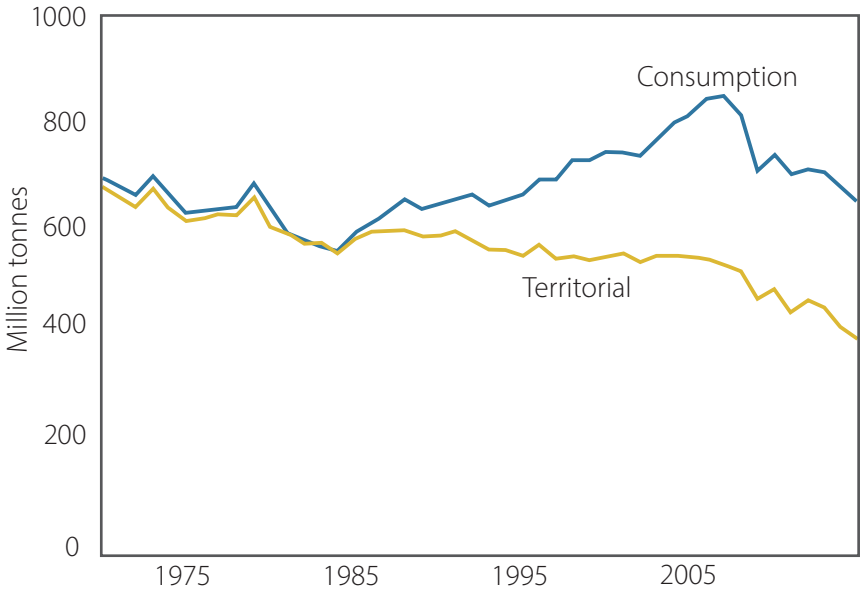
The UK already imports large quantities of food. Some things cannot be grown in our climate, and have to be imported; for example, bananas, oranges and avocados. Others are seasonal crops but are often made available year round by importing them from Mediterranean countries, Dutch greenhouses or California; for example, strawberries, lettuces and tomatoes. These are not essential; they could revert to being seasonal treats. Other imports are from countries that can produce certain foodstuffs at a lower cost; for example prawns from south-east Asia or Danish bacon.

Food products are imported because of consumer demand and, in some cases, importing is cheaper than domestic production. This is the normal basis for international trade, but climate-change policy introduces additional factors: food miles and embodied carbon. Rather than simply considering the financial cost of imports, we are now encouraged to look at the energy (and thus carbon dioxide emissions) required to transport them, plus the carbon intensity of their production in the first place. This is, of course, a logical position, since if global emissions reduction is the target there is no point in simply pushing part of domestic emissions offshore. What is relevant, however, is to ask what contribution a reduction in imported food would make to the UK's carbon budget.

ONS figures published in 2019 showed that imported goods added 250 million tonnes of carbon dioxide to the UK's total consumption-based emissions. Even though domestic emissions peaked in 1972, because of imported embodied carbon, total emissions only did so in 2007, 35 years later (see Figure 5).[16] While we know this, it is fiendishly difficult to separate the components of the imported embodied carbon. Food obviously makes a contribution, but is likely to be relatively minor. After all, we import things such as oil, steel and

Figure 5: Different measures of CO_2 emissions, 1971–2015

Consumption-based and territorial emissions. Source: ONS



manufactured goods in much larger quantities than most foods. The other important factor is the type of transport used. Bulk shipment by sea is not energy intensive, whereas air freight is. Road transport is towards the lower energy end of the range.

While it is difficult to be precise about the impact on UK emissions of reducing food imports, there are two conclusions we can reach. First, unless there is a reduction in consumer demand across a range of items, reducing food imports could only be achieved by erecting tariff barriers; for example by taxing foods based on their carbon footprint. It seems unlikely that consumers would be happy with food prices being artificially forced up. The knock-on effect, of course, is that food imports would have to be replaced by domestic production. Since we are far from self-sufficient in food, and most productive farmland is already efficiently used, it is difficult to see how this could be achieved. The second conclusion is that, despite the disruption and cost of trying to move to self-sufficiency in food production, the impact on global emissions would be at best a rounding error.

Synthetic fertilisers

The development of the Haber-Bosch process is arguably the primary reason why our planet can support a population of 8 billion. Invented by Fritz Haber, and developed into an industrial-scale process by Carl Bosch, it uses high pressure and temperature, together with a catalyst, to convert atmospheric nitrogen to ammonia, which is then used to make nitrogen fertilisers. The importance of this process was recognised by the award of the Nobel Prize for chemistry to both Haber and Bosch. While undoubtedly being a major boon to humanity, synthesis of ammonia is not only an energy-intensive process in its own right, but requires hydrogen. This is currently largely obtained from natural gas and thus is a major source of carbon dioxide emissions.

Plants need nitrogen from the soil to achieve their growth potential, but nitrogen compounds are soluble, and wash away

from season to season. Legumes – peas, beans, clover and so on – have root nodules containing the symbiotic nitrogen-fixing bacteria that provide the necessary fertilisation directly, but all other plants are dependent on what they can get from the soil. Nitrogen fixation in crop plants more generally is a goal for plant biotechnologists, but achieving this end is very difficult. All other crop plants essentially rely on synthetic fixed nitrogen from the Haber-Bosch process.

The exception, of course, is for crops managed organically (a fairly meaningless term, but one which we all understand to avoid the use of synthetic inputs). Organic farmers do not use synthetic fertilisers, but instead rely on animal manure and 'green manure' (nitrogen-fixing crops such as clover that are cultivated and then ploughed in to fertilise the following crop). This system relies on keeping livestock and is inherently less productive than more conventional agriculture.

Productive modern agriculture is made possible by a number of factors, but the most important is surely the use of synthetic fertiliser. In 1968, Paul Ehrlich's book *The Population Bomb* predicted that a modern-day Malthusian disaster was now unavoidable because a rapidly growing population simply could not be fed. However, at the same time, what has become known as the Green Revolution was underway. Plant breeders, in particular Norman Borlaug (later winner of the Nobel Peace Prize), developed dwarf varieties of wheat and rice, allowing more of the plant's photosynthetic capacity to be used to produce grain rather than straw. Coupled with improved agricultural practice and, in particular, appropriate use of nitrogen fertiliser, this greatly increased cereal yields. Periodic famines in India, for example, became a thing of the past, and the country turned into a net exporter of wheat.

Because there are large energy barriers to overcome to make ammonia from nitrogen and hydrogen, the Haber-Bosch process is inevitably very energy intensive and thus a significant source of carbon dioxide emissions. Additionally, the more nitrogen there is in the soil, the greater the emissions of nitrous oxide. And yet there is no alternative at present if the growing world population is to be fed. There is a case for reducing meat and milk consumption, since growing crops for animal feed is an inefficient way to produce protein. In principle, plant-based diets should lead to lower agricultural emissions of greenhouse gases, particularly in the case of methane (although we have to take account of the additional emissions resulting from extracting and processing plant proteins into final products).

But, even if people were happy to stop eating meat and dairy products, the reality is not so simple. Most good-quality arable land is already in use, and most grazing land would not produce good yields. Also, much of the manure from farm livestock is put back onto fields as slurry to provide a source of nitrogen. If this was no longer available, more synthetic fertiliser would be

needed. Essentially, synthetic fertilisers are vital if people are to be fed.

8. UK contribution to global emissions

In 2019, the total CO_2 emissions from the UK (i.e. production, not consumption figures) amounted to 369 million tonnes (Figure 6). In 2020, emissions dropped to 329 million tonnes. These figures ignore land use. In 2020, this represented just 0.95% of global emissions, down from 2.64% in 1990 (world CO_2 emissions totalled 36.7 billion tonnes in 2019). Consumption-based emissions for the UK in 2019 (the most recent year for which data is available) were 520 million tonnes, bringing the country's contribution to 1.4% of global emissions (Figure 7).

Achieving Net Zero for the UK would be effectively a rounding error in global emissions, which continue to increase. China, far and away the world's largest CO_2 emitter for over a decade, will not compromise its economic growth in the cause of climate change mitigation; to do so could bring the legitimacy of

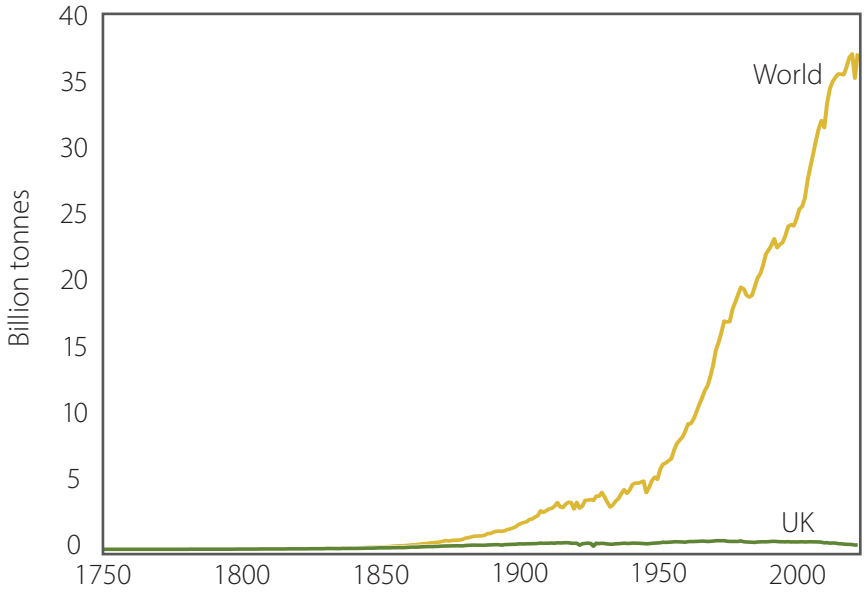


Figure 6: UK and global CO_2 emissions. 1750–2021.
Source: Our World In Data.

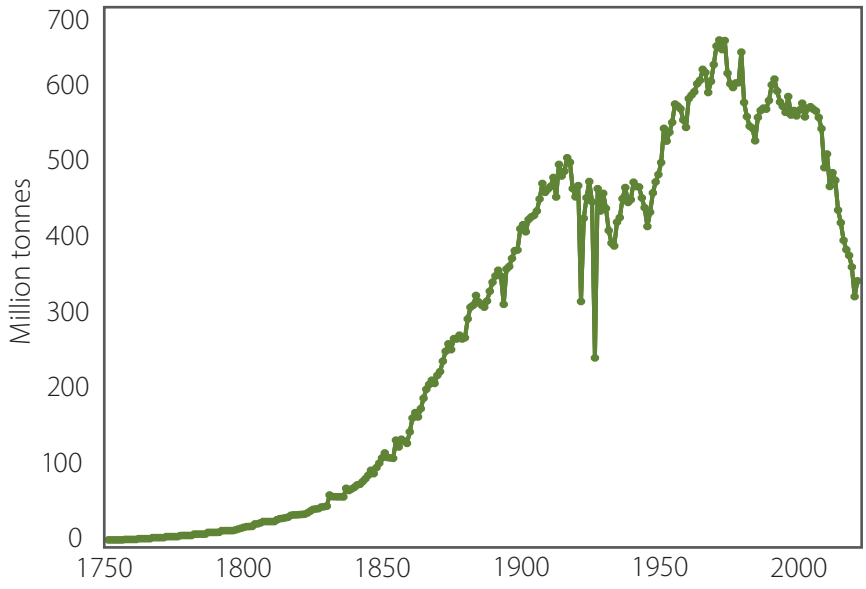


Figure 7: UK CO_2 emissions. 1750–2021.
Source: Our World In Data.

the CCP's rule into question, something President Xi could never allow. Instead, China can make vague statements of intent and receive praise from the international climate change establishment, while in practice doing little other than profiting from the export of solar panels, rare earth metals and other components necessary for the radical switch away from fossil fuels.

In this context, it is instructive to look at what the UK has achieved in recent decades. Total emissions have fallen very significantly, now standing at about the same level as in late Victorian times. This is for a country of 67 million, compared to about 31 million in 1870. This has only been achieved with significant effort and cost, which could perhaps be considered to have been misspent given the impact it has had not just on global emissions but the progress of much larger economies towards reducing their own.

9. Farming contribution to UK emissions

As we have seen, although farming contributes very little CO_2 to the total, it is a major source of nitrous oxide and methane emissions. So, overall, agriculture contributes 10% of the UK's total GHG emissions. Given that farming as a sector is only about 0.5% of GDP, this gives it a very large carbon footprint per unit of economic activity. Nevertheless, eliminating UK farming completely would reduce global emissions by a trivial amount, while transforming the countryside and food supply chain, and devastating the rural economy.

The farming sector is unique, comprising an insignificant part of the economy of most developed countries, and yet hugely important for a number of other reasons, not least of which is the vital need to feed people. Just as it is not helpful to consider farming primarily as an economic activity, neither is it productive to focus on the sector's contribution to GHG emissions. Radical reduction of emissions from almost any source has a major impact on how we live, now that the low-hanging fruit of partial electricity grid decarbonisation has been harvested. Trying to convert hundreds of thousands of houses from gas-fired to heat pump-driven heating is, to say the least, daunting, with major cost and lifestyle implications, but at least it targets a large percentage of CO_2 emissions. Making a significant cut to agricultural emissions, on the other hand, would severely compromise food security as well as forcing people to make major dietary changes, and all for an imperceptible impact on global emissions.

The other factor that politicians may not have taken fully into account is that the proposed changes represent an existential threat to the livelihoods of many farmers, who are already making only a modest living. Many would not take this lying down. We are already familiar with the sight of French farmers protesting at threats to their livelihoods, but this is something of a French cultural trait. In the Netherlands, though, farmers have become equally militant recently. In 2019, a legal ruling forced

the government to bring in legislation to reduce livestock numbers and fertiliser use to comply with targets under the 1991 EU Nitrates Directive. New limits were introduced in each of the country's 12 provinces, but angry farmers who drove their tractors to provincial assembly buildings quickly caused several local authorities to backtrack.

In 2022, the Dutch government announced a further initiative to cut emissions of ammonia and nitrous oxide by half by 2030, sparking more protests by farmers and even leading to police firing shots at one demonstration in Friesland. This is a particularly sensitive issue for the Dutch, the world's second largest exporters of agricultural produce, but the Europe-wide nature of the nitrogen reduction targets means that opposition is not confined to one country. This year, farmers from Germany, Italy, Spain and Poland have also demonstrated, partly to show their support, but also because they think that their own farms will be targeted next.

The EU Nitrates Directive, now in force for 30 years, was originally put into place to reduce nitrate pollution and threats to biodiversity, but the drive to reduce nitrous oxide as part of climate mitigation measures has given it new impetus. Farmers fear that environmental and climate targets will take precedence over their own livelihoods. The situation is different in the UK, where the push to reduce farming's carbon footprint is driven primarily by climate policy. The effect, though, would be the same; to threaten the future of many farmers. And the almost certain outcome would be widespread opposition, demonstrations and disruption to food supplies. Meanwhile, China will continue to expand its use of coal-fired power stations.

10. Prioritising food security

Life is about priorities. Individuals must decide what is important and what is urgent. Businesses must do the same, but also have to make firm plans for the longer term. The same applies to governments, but in this case their prioritisation affects everyone. At a basic level, most politicians see the need to provide security and prosperity to their country's citizens, but there are many important policy areas where decisions contributing to these objectives have to be made. Tax rates, welfare payments, the transport network; decisions made in these and other areas affect all of us, but more recently climate change policy has been added to the mix.

Climate campaigners believe that nothing is more important than taking a lead in slashing emissions of greenhouse gases. Our elected politicians have gone along with this, first passing the Climate Change Act in 2008, so making it in principle a legal obligation to meet emissions reduction targets, then setting a goal of an 80% reduction in emissions (against a 1990 baseline) by 2050. The icing on the cake was the further tightening of this target, in 2019, just before the Covid pandemic hit, to Net Zero by

2050. We now labour under a legal obligation (enforceable how?) to decarbonise one of the world's largest economies within 30 years, while global emissions seem set to grow for some years yet.

Imposing economic costs is one thing. Maybe renewable energy and alternatives to gas heating and the internal combustion energy will turn out to be creators of domestic jobs, energy security and economic growth (but there again, maybe they won't). But re-engineering the UK's agricultural sector and food supply chain will inevitably have a massive impact on farmers, the countryside and diets, whether or not people conform to policymakers' expectations and move to plant-based diets or whether they simply eat more imported meat and dairy produce. Decreeing the effective end of much livestock farming would be devastating.

Compromising food security by restructuring farming in this way – most grazing land is unsuitable for growing reasonable harvests of most crops and so domestic food production would inevitably fall – would make it much more difficult for the government of the day to fulfil its primary functions of enabling citizens to live secure and prosperous lives. Doing this for the sake of 10% of the country's overall emissions of GHG would be pure folly.

11. Conclusions

If people think that Brexit was an act of self-harm, achieving Net Zero by 2050 would make this seem trivial in comparison. There is a good case to be made that the UK could contribute significantly to global emissions reduction by developing new technology to enable this to be done cost-effectively. This would, of course, also benefit the economy directly by creating jobs and export opportunities. Use of existing technologies – essentially using wind and solar energy with no large-scale storage to power everything including heat pumps to replace gas boilers – is eye-wateringly expensive, inefficient and leaves the country at the mercy of variable weather patterns. At the same time, it currently increases our dependence on China for solar panels and rare earth metals. But arguably it is the drive to slash emissions from farming that would be the biggest problem.

While farming is a tiny part of total GDP, it is absolutely vital for both our food security and the appearance of our 'natural' landscape, so much of which is actually shaped and managed by farmers. And while it is quite probable that, given time, more cost-effective and efficient ways to generate low carbon energy and store it will be developed, it is difficult to foresee developments that would enable significant decarbonisation of livestock farming. This leaves us with the sole option of drastically cutting back on meat and dairy consumption in the country, so driving livestock farmers out of business (no doubt with compensation from taxpayers, adding further to the cost).

And all this for what? To shave a further fraction off the already trivial contribution of the UK to global GHG emissions? Enthusiasts for emissions-cutting would say that this is a moral obligation, since our country was the birthplace of the Industrial Revolution and hence set the world on track for global warming. Moreover, they would say, if we take the lead, others will follow. This is wishful thinking of the highest order. In democracies, such far-reaching policies ultimately need the consent of citizens, and at some stage this has to be sought via the ballot box. There are already clear signs that people are beginning to baulk at the costs of the revolution they will have to fund; most people are also unlikely to move away from meat and dairy simply to save the climate. In autocracies such as China, ruling parties are equally unlikely to jeopardise their position by making their populations unnecessarily poorer.

In conclusion, we can say that while trying to slash greenhouse gas emissions from UK farming might appear to be one of the easier parts of climate change policy, it is actually one of the most difficult. In a rational world, farming should essentially be left alone to continue to evolve and improve, while policy should focus on technology breakthroughs in other sectors.

References

1. https://www.nationalfoodstrategy.org/.
2. https://www.theccc.org.uk/publication/2022-progress-report-to-parliament/.
3. https://www.nationalfoodstrategy.org/.
4. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1082026/government-food-strategy.pdf.
5. https://www.theccc.org.uk/publication/2022-progress-report-to-parliament/.
6. United Kingdom Food Security Report 2021: Theme 2: UK Food Supply Sources.
7. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en.
8. Farming Statistics Land Use, Livestock Populations and Agricultural Workforce At 1 June 2019 – England.
9. Climate Change and Agriculture; POSTNOTE number 600; May 2019.
10. https://www.gov.uk/government/statistics/area-of-crops-grown-for-bioenergy-in-england-and-the-uk-2008-2020/section-1-biofuels.
11. https://www.fao.org/worldfoodsituation/foodpricesindex/en/.
12. IPCC Second Assessment Report; 1995.
13. Atmospheric methane and nitrous oxide: challenges along the path to Net Zero; Nisbet et al; *Phil Trans R Soc A* 2021, 379, 20200457.
14. Agriculture in the United Kingdom 2018; DEFRA et al; 2019.
15. http://www.lra.co.uk/services/agricultural-land-classification.
16. https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/compendium/economicreview/october2019/thedecouplingofeconomicgrowthfromcarbonemissionsukevidence.
17. https://pdf.euro.savills.co.uk/uk/rural---other/spotlight--the-farmland-market---january-2019.pdf.

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