The Bioeconomy Consultants

NNFCC

An introduction to UK policies and bioeconomy innovation

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NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels, and biobased products.

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1 Executive Summary

The bioeconomy represents the economic potential of harnessing the power of bioscience and the use of renewable biological resources to replace fossil raw materials in innovative products, processes, and services. While the bioeconomy covers the production of food, feed, fibres, biobased products, and bioenergy, this policy review focusses on the most relevant driving policies and actions which affect the development of bioenergy and biobased products.

The UK is recognised as a world leader in the biosciences field. The potential to use biotechnology in the production of biofuels and biobased products has stimulated several important research programmes. However, research is just one element of successful innovation whereby new products and process are commercialised. Government policy plays a critical role in driving and shaping innovation systems, particularly where this delivers in areas addressing social needs, public good, and areas of market failure where private finance is difficult or expensive to secure.

A clear example of failure is the inability of the market to address issues such as climate change, primarily due to the externality of greenhouse emissions to commercial activity. The UK Government recognises the need for intervention and has introduced a range of policies to both drive changes in operational practice and establish new market opportunities. The bioeconomy has at its heart the use of renewable sustainable raw materials, which when coupled with low carbon processes (i.e. those with low energy requirements such as biotechnology, or utilising renewable energy), provides a route to low carbon fuels and products, offering valuable climate change mitigation opportunities.

This report introduces the various UK legislation and Government policies which influence the direction and growth of the UK bioeconomy. A brief introduction to industrial biotechnology and bioeconomy evolution is provided, followed by an overview of key current legislation, policies, and strategies.

The approach to climate change mitigation, how the environment is protected and how markets are supported or regulated all influence how the bioeconomy develops. The direction of travel is not always clear with conflicting policy aspirations and differing viewpoints on the impact of possible interventions. These issues have arguably caused inertia in bioeconomy policy development and therefore have slowed market growth. This is particularly evident in relation to support for biobased products.

Throughout the bioeconomy there is the need to balance the environmental benefits of switching from fossil carbon to renewable carbon, with the need to sustainably source biomass. The demand for biomass can be significant when viewed from the perspective of power, heat, and transport fuel. However, the drive towards ‘Net Zero’ greenhouse gas emissions and the required move away from combustion technologies, means biomass resources can be increasingly focussed on applications where alternative approaches are limited e.g. chemicals, plastics, and aviation fuel.

The UK has the research base to be an influential player in the global bioeconomy. How the UK focusses and capitalises on this potential will depend, in part, on how its policy landscape evolves.

2 Introduction

2.1 Innovation Systems – more than research

2.1.1 Innovation systems

Innovation drives economic growth and business resilience, however too often innovation is considered solely in the context of technical development. A far more complicated series of actions is required to transform an invention or scientific discovery into a product or process which provides value, in other words an innovation.

For manufacturing industries, including biorefining and industrial biotechnology, this means implementing a process which produces a product for sale, therefore generating value from commercial revenue.

Innovation requires an ecosystem, with multiple stakeholders performing a range of actions, all of which play an important role in supporting the innovation process. Identifying and addressing flaws and bottlenecks within innovation systems can lead to increased levels of innovation, both within businesses and also at a regional or national levels.

An innovation ecosystem is built from components which include actors, institutions and technoeconomic factors. The systems actors; are the organisations contributing to a technology, as a developer or adopter; and system facilitators that act indirectly as a regulator or financier including the institutions which lie at the core of the ecosystem, providing the rules and boundaries in which the system operates. Formal institutions include national and local policy makers but also informal institutions reflecting societal morals, values and ethics that influence policymaking. The third component of the system is technoeconomic factors which define and constrain the system such as cost, compatibility, safety, or reliability.

Innovation relies on the effective interaction of all the systems actors to provide a vibrant and supportive innovation culture that successfully delivers. Without this interaction, knowledge development and transfer will be limited; legal and regulatory frameworks could be misguided or inappropriate; entrepreneurs will be poorly informed on business opportunities and risks, and industry, academia and Government will struggle to find a consensus around the legitimate direction of technology development, and therefore where support and actions should be focussed.

Knowledge development relies on a range of disciplines and expertise, and effective knowledge exchange is critical. Knowledge exchange and knowledge diffusion can be facilitated through the effective organisation and support of formal networks, through meetings, workshops, and conferences, and through project collaborations. The UK has invested in a comprehensive system of networks across the bioeconomy, including Networks in Industrial Biotechnology and Bioenergy, Knowledge Transfer Network and numerous special interest and local cluster organisations.

Learning activities drive not only technological development but also the understanding of markets, social dynamics, and sustainability considerations. Knowledge development considers academic research as well as the work of consultants and the benefits of ‘learning by doing’. In the UK, we have

a world leading bioscience knowledge base, providing a strong foundation for industrial biotechnology innovation.

2.1.2 The role of policy in the innovation system

Government policy plays a critical role in the shaping and dynamism of the innovation system, particularly in areas addressing social needs, public good and areas of market failure.

Policy plays a key role in setting the focus and vision for the innovation system. The so-called 'direction of search'. Reaching consensus on the direction of the search means efforts can be focussed and typically limited resources deployed effectively. Care should be taken to ensure the search is not too narrow and stifling. A clear direction of search creates the necessary conditions for knowledge development.

Any innovation will face a degree of resistance to change. The extent to which advocacy coalitions are formed is dependent on the nature of the change, barriers to change and the implications for market incumbents or society in general. Recent debates around food versus fuel and the use of genetically modified organisms demonstrate the impact that advocacy coalitions can have in influencing innovation, in terms of how policymakers, companies and investors react when balancing risk assessments.

Like any activity, innovation requires resources. Policy plays a critical role in resource mobilisation, either directly determining (e.g. through mandates), or through influencing, the deployment of public finance which directs the allocation of material and human capital within the system. Resource requirements vary depending on the nature of the innovation and its point of development but include technical skills, finance and subsidies, infrastructure such as educational systems and technology scale up facilities and raw materials for manufacturing. For example, the scale up facilities offered by BioPilotsUK[1] form an essential part of the UK's bioeconomy innovation system.

Without an innovation sponsor, emerging technologies will struggle to compete against incumbent technologies. In areas of market failure, the Government, must take on the role of the innovation sponsor and create demand for the emerging technology. Market formation may involve financial support for the emerging technology or taxing the use of competing technologies. It may also involve guiding the development of public systems and infrastructure, the direction of public procurement, the development of standards and labels, or mandating the supply of a product, as seen in the renewable energy market. The creation of markets stimulates the final aspect of the innovation system, the requirement for entrepreneurial activity.

2.2 The Bioeconomy

The nature of the bioeconomy causes significant issues for coherent policy development. It is broad in its market coverage with competing uses for its resources; it falls across the remits of multiple Government departments with different perspectives on positives and negatives, and many of its

[1] BioPilotsUK is a collaboration created by four established biorefining open-access centres who recognise the importance of partnerships to develop UK bio-based value chains. https://biopilotsuk.com/

drivers such as climate change mitigation and environmental protection are hard to quantify in economic terms.

2.2.1 Definition perspectives

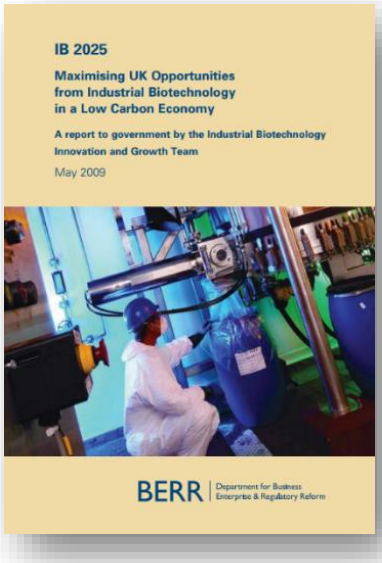
The European Commission considers the bioeconomy to encompass the production of renewable biological resources and their conversion into food, feed, bio-based products, and bioenergy. It includes agriculture, forestry, fisheries, food, and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. From a UK perspective the bioeconomy represents the economic potential of harnessing the power of bioscience, using renewable biological resources to replace fossil raw materials in innovative products, processes, and services.

While the European definition places the emphasis on the production and processing of renewable biological resources, the UK puts a special focus on the use of bioscience.

How the bioeconomy is defined or framed is important. It sets the direction for policy development, it influences the formation of stakeholder groups, it provides a direction of travel but also determines the nature of change resistance. The heart of the bioeconomy is sustainability, however the complexity of the bioeconomy results in the need for balance and compromise between a bioeconomy for the provision of food, feed, fuel and products, a social bioeconomy for health and leisure and a bioeconomy for the protection and restoration of the environment.

Bioeconomy policies typically have three focus areas, the use of renewable biological resources e.g. biomass, the adoption of biotechnology across the economy, and the protection of the natural environment. However, as demonstrated in the definitions developed by UK and EU institutions, one focus area will take an influencing position.

2.2.2 A recent history of UK IB and Bioeconomy Policy development



A timeline of recent policy publications related to IB and bioeconomy in the UK are shown in Figure 1.

In the foreword to the UK's 2009 Innovation and Growth Team (IGT) report on Industrial Biotechnology (IB),[2] BERR's then Secretary of State, Lord Mandelson stated, 'IB will be one of the strongest driving forces behind the world's low-carbon revolution. Offering businesses, the capability to develop and use less carbon intensive products and processes, whilst also reducing costs and opening-up new, emerging, and established markets.' The Government's response to this report included the implementation of several key actions for the UK bioeconomy including the creation of the IB Leadership Forum (which drew together industry and funder interest to better inform Government policy making and

[2] BERR: IB 2025: Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy. https://webarchive.nationalarchives.gov.uk/20090609032547/http://www.berr.gov.uk/files/file51144.pdf

funding priorities), the development of an open access demonstrator facility, and specific funding for IB research, technology development and scale up.

Although the IB-IGT report heralded an increase in investment and research activity, in parallel concerns were being voiced about the use of land and particularly agricultural products as feedstock for biotechnology processes. This is most prominently evidenced in 'the Gallagher Review of the indirect effects of biofuels production'.[3]

Alongside issues of land use, questions were voiced around the impact of biofuel on food prices.[4] Although refuted,[5] these concerns refocused the bioeconomy's direction of travel toward the use of waste feedstock for commodity products. The House of Lords Science and Technology Select Committee's review of the bioeconomy specifically questioned the opportunities of using waste as a resource to stimulate the bioeconomy.[6] The review concluded that there is an enormous opportunity for growing the bioeconomy using a range of feedstocks, including waste. The House of Lords report provided the stimulus for Government action towards the delivery of a long-term plan to realise a high value bioeconomy, with an initial focus on waste as a feedstock.

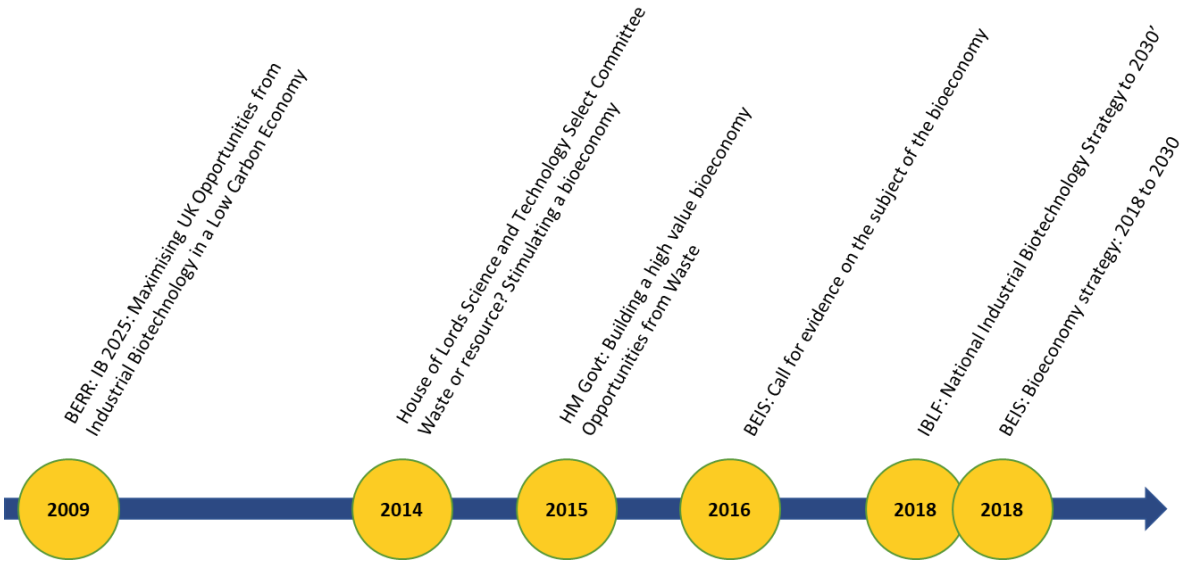


Figure 1. A timeline of UK IB and bioeconomy policy publications

[3] RFA: The Gallagher Review of the indirect effects of biofuels production. https://webarchive.nationalarchives.gov.uk/20110407094724/http://www.renewablefuelsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels

[4] Burning food crops to produce biofuels is a crime against humanity. https://www.theguardian.com/global-development/poverty-matters/2013/nov/26/burning-food-crops-biofuels-crime-humanity

[5] Biofuel impact on food prices index and land use change. https://doi.org/10.1016/j.biombioe.2019.03.003

[6] House of Lords Science and Technology Select Committee - Waste or resource? Stimulating a bioeconomy. https://publications.parliament.uk/pa/ld201314/ldselect/ldsctech/141/141.pdf

A cross-Whitehall and public sector working group was established to ensure a joined-up approach across stakeholder groups. In 2015 the Government published a report on 'Building a high value bioeconomy' which placed an emphasis on the opportunities from waste; the report described the landscape of the UK bioeconomy, the stakeholders involved, and the gaps in knowledge and information.[7]

To address the gaps in knowledge identified in the 2015 Government bioeconomy report, action was taken to collect economic data[8] and undertake a Call for Evidence[9]. The data and information gathered underpinned two strategy documents published in 2018. The first, published by the Industrial Biotechnology Leadership Forum described a UK strategy for the development of Industrial Biotechnology, laying out a roadmap of actions required to grow UK's industrial biotechnology sector.[10] The second publication was a policy paper describing the Government's Bioeconomy Strategy. The paper detailed the Government's view of the bioeconomy, how it relates to other Government strategies, and actions it intended to implement.[11] This is discussed in more detail in Section 4.5

3 Policy owners and influencing organisations

The bioeconomy touches on large swathes of the UK economy; transport, construction, manufacturing, healthcare, and the energy sectors which underpin them. Although some areas of the bioeconomy e.g. bioenergy are directed by specific policies and regulations, for most sectors it is sector specific policy and regulation which influences its development. For example, the development

[7] HM Government - Building a high value bioeconomy Opportunities from waste. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/408940/BIS-15-146_Bioeconomy_report_-_opportunities_from_waste.pdf

[8] Capital Economics, TBR and E4tech - Evidencing the bioeconomy. https://bbsrc.ukri.org/documents/1607-evidencing-the-bioeconomy-report/

[9] BEIS – Growing the Bioeconomy, Government Response to the Bioeconomy Call for Evidence. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/761579/bioeconomy-cfe-government-response.pdf

[10] IBLF - A National Industrial Biotechnology Strategy to 2030. https://www.bioindustry.org/uploads/assets/uploaded/d390c237-04b3-4f2d-be5e776124b3640e.pdf

[11] HM Government - Bioeconomy strategy: 2018 to 2030. https://www.gov.uk/government/publications/bioeconomy-strategy-2018-to-2030

of biobased plastic or biodegradable plastic is determined by the Government's approach to waste, packaging, and environmental policy.

Of the twenty-four current Ministerial Government Departments, five are considered central to the bioeconomy, Figure 2. The involvement of these Government policy owners and associated agencies revolves around the supply of bioeconomy feedstock (primary or waste), balanced with the need to protect land and marine environments, and the creation/operation of markets for bioenergy and biobased products. Although a comprehensive review of Government related stakeholders[12] is beyond the scope of this landscape review, Figure 2 provides a view of the key organisations and their role in the bioeconomy.

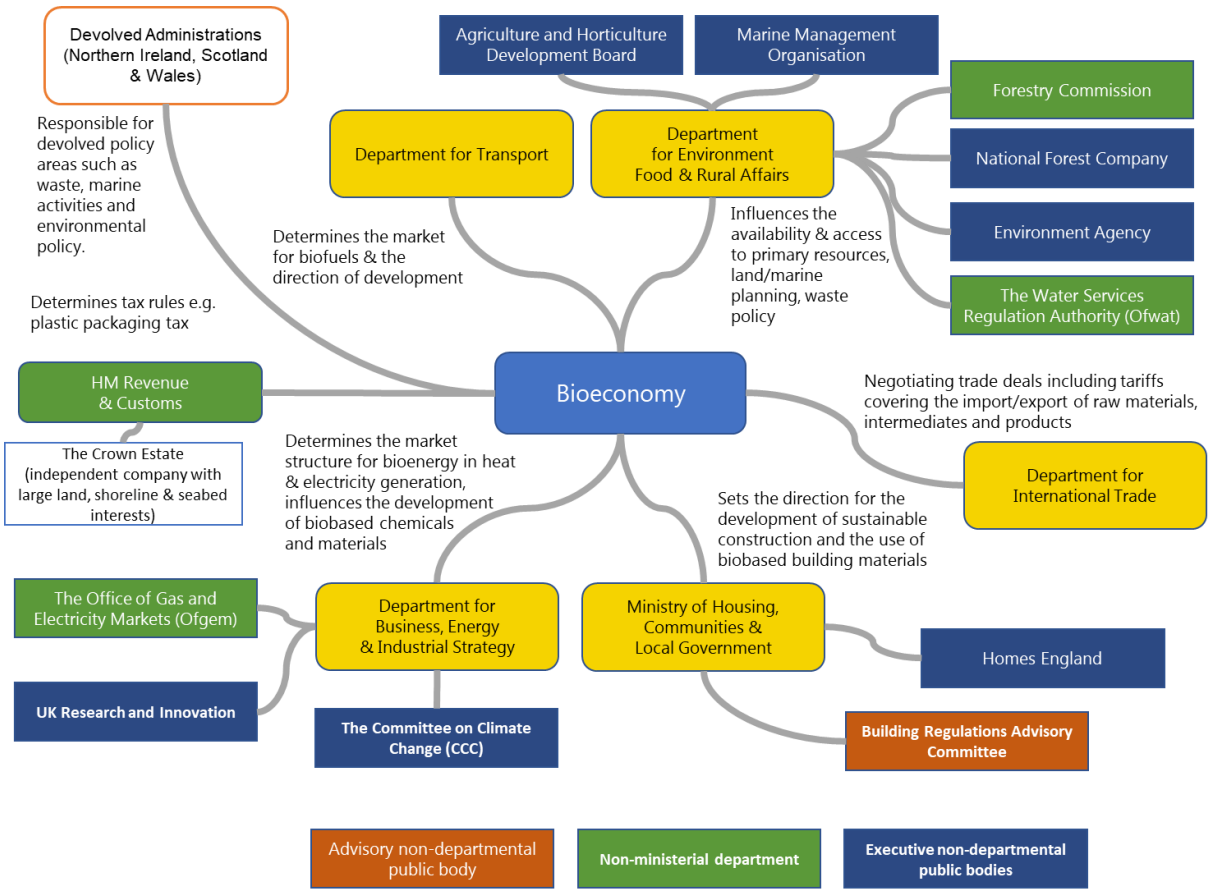


Figure 2. Government Departments and Agencies influencing the bioeconomy.

Outside of Government there are many organisations who provide data, information, research, and expert opinion, all of which influence the direction of bioeconomy development. In addition to academic and RTO groups, organisations, initiatives, and networks; NGOs, trade associations, regional clusters and consultancies make up the complex ecosystem of stakeholders. Figure 3 provides an overview of some of the key stakeholders currently influencing bioeconomy policy and market development.

[12] A comprehensive list of Government Departments, Agencies and Public Bodies is available here https://www.gov.uk/government/organisations

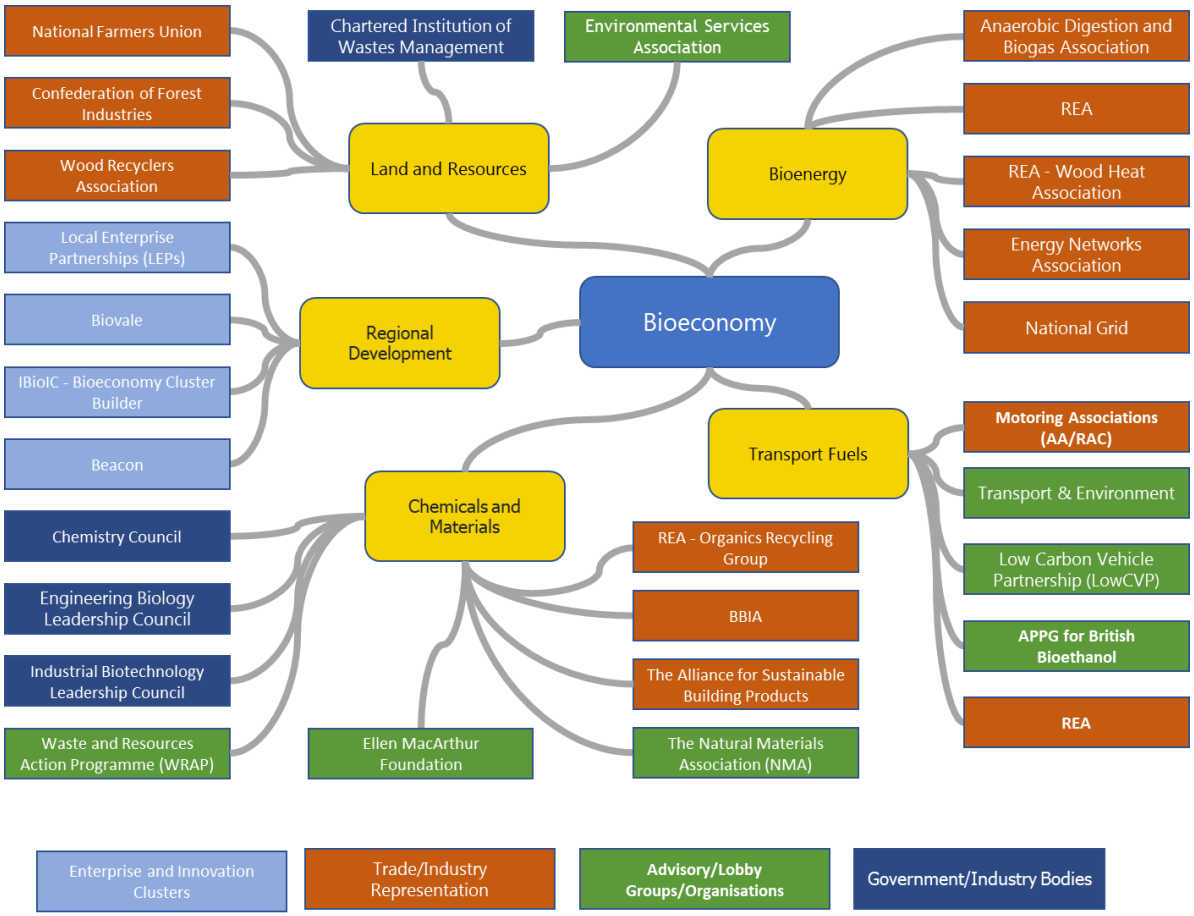


Figure 3. Examples of non-Government stakeholders influencing the bioeconomy.

4 Current policy landscape in brief

The policies impacting bioeconomy development range from strategies to address climate change, where energy provision policies play an important role, to land and agricultural policies which impact the supply of raw material. They encompass industrial and waste policies which influence the development of technology and products, and the end of life treatment of consumer products.

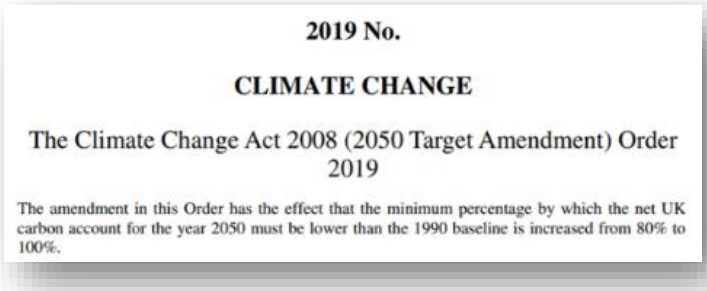
4.1 Climate change and energy policy

Climate Change is undeniably one of the greatest challenges faced by society. The Economics of Climate Change: The Stern Review, was published in 2006 and set the economic case for public intervention in order to reduced climate changing emissions, ultimately leading to the 2008 Climate Change Act. The UK can expect hotter, drier summers and milder winters with increased rainfall. Sea levels are rising, and more extreme weather events can be expected. In response the Government has identified six research priorities, several requiring increased action.[13]

[13] UK Climate Change Risk Assessment 2017. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf

- Flooding and coastal change risks to communities, businesses, and infrastructure,
- Risks to health, well-being, and productivity from high temperatures,
- Risks of shortages in the public water supply, and for agriculture, energy generation and industry, with impacts on freshwater ecology,
- Risks to natural capital, including terrestrial, coastal, marine, and freshwater ecosystems, soils, and biodiversity,
- Risks to domestic and international food production and trade,
- New and emerging pests and diseases, and invasive non-native species, affecting people, plants, and animals.

4.1.1 Climate Change Act


2019 No.

CLIMATE CHANGE

The Climate Change Act 2008 (2050 Target Amendment) Order 2019

The amendment in this Order has the effect that the minimum percentage by which the net UK carbon account for the year 2050 must be lower than the 1990 baseline is increased from 80% to 100%.

In 2008 the UK Government published its Climate Change Act, setting out the Government's target for reducing emissions of greenhouse gases by 2050. The Act was considered ground-breaking in three key areas:

- It set long term (2050) and legally binding emission reduction targets[14],
- It laid out the journey to the 2050 target via a series of legally binding five-year carbon budgets,
- It created a new independent body, the Committee on Climate Change (CCC) to monitor progress and advise on actions.

In 2019 an amendment of the Act was published setting the 2050 target to Net Zero greenhouse gas emissions. Alongside the European Renewable Energy Directive, the Climate Change Act provides the backdrop for UK energy policies.

UK greenhouse gas emissions have fallen by 40% since 1990 and 18% in the last five years (Figure 4). However, nearly all these emission savings have been a result of policies to decarbonise electricity generation. Other areas of the economy have seen minimal reductions, e.g. aviation and road transport.

[14] For 2050 the reduction target is the percentage below what is referred to as the 1990 baseline.

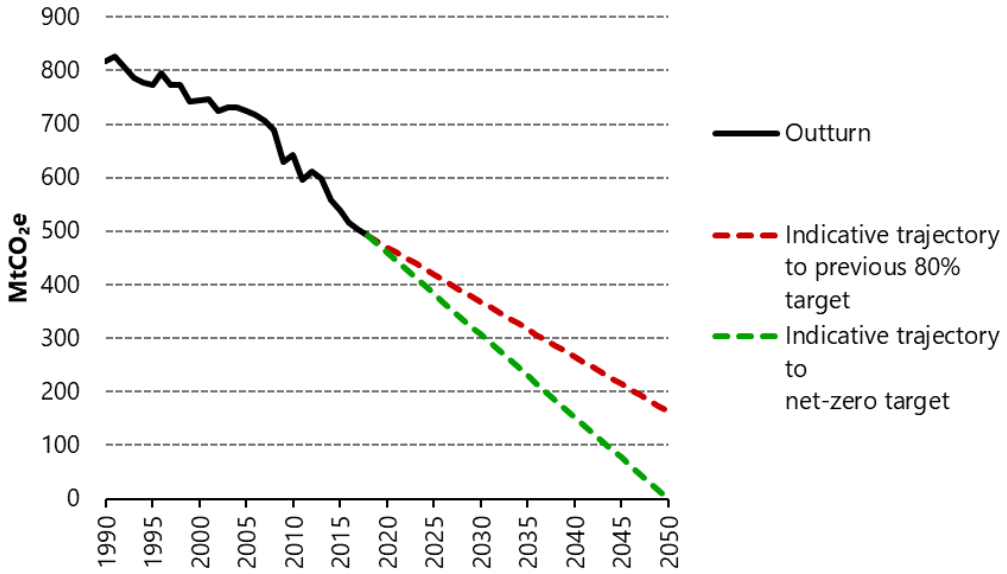


Figure 4. UK Greenhouse Gas emission reductions required to meet Net Zero.[15]

4.1.2 The Net Zero commitment

Since the introduction of the Climate Change Act the UK has made considerable progress in reducing its greenhouse gas emissions. In 2019 emissions were 45.2% below 1990 levels (Figure 4). Except for 1921 and 1926, both of which are years with general strikes, 2019 represents the lowest level of emissions since 1888.[16]

However, emissions reductions to date have largely been achieved through reductions in the carbon intensity of electricity, with a large contribution coming from the phase out of coal fired electricity generation. To achieve the goal of Net Zero emissions by 2050, policy actions will need to be both broader in nature and demonstrate greater ambition.

As advisors to the UK Government, the CCC has described a set of guiding principles and policy areas where specific targeted actions are required:

1. Where possible decarbonise e.g. generate non carbon-based electricity or adopt carbon capture and storage (CCS),
2. Take action to reduce emissions from hard to decarbonise sectors,
3. And adopt atmospheric CO_2 removal programmes.

A primary focus of principle 1 is the decarbonisation of the electricity grid through non carbon-based renewables (wind, solar, etc) and the use of CCS. Although the decarbonisation of heat is considered

[15] CCC, Reducing UK emissions – 2019 Progress Report to Parliament. https://www.theccc.org.uk/publication/reducing-uk-emissions-2019-progress-report-to-parliament/
[16] Carbon Brief. Analysis: UK's CO2 emissions fell for record sixth consecutive year in 2018. https://www.carbonbrief.org/analysis-uks-co2-emissions-fell-for-record-sixth-consecutive-year-in-2018

more challenging a combination of electrical heat, hydrogen fuel and the use of heat pumps provides a route to Net Zero. Decarbonisation of the gas grid through increasing levels of green gases is a current priority and something that can be acted upon immediately.

Transportation of people and goods has to date presented a decarbonisation challenge with only minimal emissions reductions achieved. The long-term plan to decarbonise the domestic road transport and light haulage is with electric vehicles, coupled with a decarbonised electricity grid. The decarbonisation of heavy haulage and marine shipping requires further research and development, with the use of hydrogen or ammonia providing a possible solution. The waste sector is another area identified for decarbonisation with the preferred options being the move to a more circular economy with higher recycling rates, and more effective waste processing of biodegradable materials.

In several important areas of the economy decarbonisation is not considered an option. In these sectors an itemised approach to reducing GHG emission is considered. Adopting best practice and the use of best available technology (BAT) in agriculture e.g. fertiliser choice and application practice, can yield significant GHG reductions. By 2050 the development of 'non carbon fuel' based aviation is not considered realistic and therefore sustainable biofuels and low carbon fossil fuels, coupled with efficiency gains are presented as the route forward.

The inability to fully decarbonise all sectors of the economy results in others having to deliver deeper reductions and the need to capture CO_2 from the atmosphere and lock it away through one of three storage options. The first option is through capture and storage in the environment through afforestation and over land management options such as peat land restoration. The second approach is based on the use of long-lasting biobased products, the often-cited example is the use of timber in construction, but the same principle applies to other durable products with significant lifespans. The final approach is the use of geological storage to lock away CO_2 captured either because of biomass combustion e.g. from electricity generation, or, more speculatively, from the direct capture of atmospheric CO_2.

4.1.3 Renewable energy support instruments

Electricity

Until 2017 the Renewables Obligation (RO) was the main support mechanism for large-scale renewable electricity projects in the UK. Coming into effect in 2002 in England, Wales, and Scotland, followed by Northern Ireland in 2005, it placed an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources. Many biomass and biogas power facilities were funded through the RO with support for these coming to an end in 2027.

Small-scale renewable electricity generation was supported through a Feed-In-Tariff (FIT) scheme, though Anaerobic Digestion (AD) was the only eligible biomass technology. The FIT scheme closed to new applicants on 1 April 2019, but a new Smart Export Guarantee (SEG) has been introduced (from 1 January 2020) to support export of small-scale renewable power to the national power grid. This is an obligation on electricity suppliers rather than the government, to offer a guaranteed price for renewable electricity, for a fixed period, as determined on a case by case basis.

The Contracts for Difference[17] (CfD) scheme is currently the Government's main mechanism for supporting low-carbon electricity generation. Managed by the Low Carbon Contracts Company[18]; CfDs incentivise investment in renewable electricity by providing a protection against volatile future wholesale electricity prices. Eligible electricity producers are paid the difference between a technology electricity 'strike price' (which is determined by a competitive auction) and a 'reference price' (a measure of the market price for electricity in the GB market) for each unit of electricity sold. Auctions are held in two technology categories, each of which potentially support bioenergy:

- Pot 1 supports established technologies: onshore wind (>5MW), solar photovoltaic (PV) (>5MW), energy from waste with combined heat and power (CHP), hydro (>5MW and <50MW), coal-to-biomass conversions, landfill gas and sewage gas.
- Pot 2 supports less established technologies: offshore wind, remote island wind (>5MW), wave, tidal stream, advanced conversion technologies (ACT), anaerobic digestion (AD) (>5MW), dedicated biomass with CHP and geothermal.

Coal-to-biomass conversions have been supported under the CfD scheme as a transitional technology, with support ending in 2027. Although these conversions have played a key role in helping the UK meet its 2020 renewables targets, as electricity generation becomes less carbon intensive, the Government is now proposing[19] to exclude new biomass conversions from future CfD allocation rounds. Limited numbers of other biomass projects have been supported to date, but future allocations should see an increase in capacity as other schemes (RO and FIT) have closed to new applications.

Heat

The supply of renewable heat has been supported through the Renewable Heat Incentive (RHI). The incentive scheme, which is operated by Ofgem[20] has two forms, a domestic scheme and a separate (non-domestic) scheme for businesses, the public sector, and non-profit organisations.

The domestic scheme[21] which was introduced in 2011 is designed to encourage the switching to heating systems that use eligible energy sources including biomass. After a successful application, tariff-based payments are made for 7 years and are based on the amount of renewable heat generated by a domestic heating system.

Under the non-domestic RHI[22], which was introduced in 2014, payments are made over 20 years and like the domestic equivalent are based on the heat output of the system. Eligible sources of heat include biomass and biogas combustion, and biomethane injected into the gas grid.

[17] Contracts for Difference Policy Paper. https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference

[18] Low Carbon Contracts Company. https://www.lowcarboncontracts.uk/

[19] Contracts for Difference for Low Carbon Electricity Generation Consultation on proposed amendments to the scheme. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869778/cfd-ar4-proposed-amendments-consultation.pdf

[20] Ofgem Environmental Programmes. https://www.ofgem.gov.uk/environmental-programmes/

[21] Domestic RHI. https://www.gov.uk/domestic-renewable-heat-incentive

[22] Non-domestic RHI. https://www.gov.uk/non-domestic-renewable-heat-incentive

Both the domestic and non-domestic RHI were set to close at the end of March 2021. However, in its 2020 budget[23] the Government announced it would extend the Domestic RHI in Great Britain until 31 March 2022. It will also consult on introducing a new Clean Heat Grant scheme from April 2022 to support systems of up to 5MW to address both domestic and non-domestic applications, though the only biomass technology supported is likely to be Anaerobic Digestion. Although there are no plans to extend the non-domestic RHI, the 2020 budget announcement included a new flexible round of Tariff Guarantees for eligible technologies (including biomethane injected into the grid). This will prolong support beyond March 2021 bridging a gap in support until a new Green Gas Levy, which was also announced in the budget, is introduced around autumn 2021. BEIS is due to consult on these two mechanisms shortly, with a view to ensuring a seamless continuation of support for the biomethane industry in the next few years.

Transport

The use of bioenergy as a liquid transport fuel is supported through the Renewable Transport Fuel Obligation (RTFO). Under the RTFO suppliers of transport and non-road mobile machinery (NRMM) fuel in the UK must be able to show that a percentage of the fuel they supply comes from renewable and sustainable sources and the size of this obligation increases over time, targeting 12.4% (on a volumetric basis) by 2032.[24]

The RTFO has set limits on the volume of crop-derived biofuels allowed to meet a supplier's obligation. For 2020 the crop cap is 4% of volumetric output with the level decreasing year-on-year from 2021 to reach 3% by 2026 and 2% by 2032. Since 2019 the RTFO has included a specific target for 'development fuels' (rising slowly from 0.1% to 2.8% by 2032). The designation of a fuel as ‘developmental’ considers the fuel type, its production pathway and the feedstock used (which must be a waste, residue or renewable fuel of non-biological origin), with the aim being to incentivise those fuel pathways which need greater support and fit the UK's long-term strategic needs. Importantly the fuel type is tightly defined, restricting production to, hydrogen, aviation fuel, substitute natural gas,[25] or a fuel that can be blended to a level where the final blend has a renewable fraction of at least 25% whilst still meeting the required fuel specification.

The incentive to deliver development fuels is the additional reward on offer driven by a higher buyout price imposed on obligated fuel suppliers who fail to deliver on their development fuel target.

The RTFO also makes provision for the production of Renewable Fuels of Non-Biological Origin (RFNBO), essentially these are fuels where the energy content of the fuel comes from renewable energy excluding biological sources. The feedstock for fuel production must have a zero-energy content, so feedstocks are restricted to water (for electrolysis) and carbon dioxide. While any carbon

[23] HM Treasury - Budget 2020 Delivering on our promises to the British People. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/871799/Budget_2020_Web_Accessible_Complete.pdf

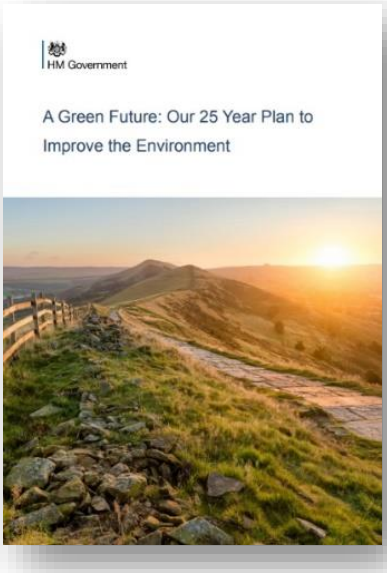
[24] Fuel suppliers who supply at least 450,000 litres of fuel a year are affected. This includes suppliers of biofuels as well as suppliers of fossil fuel.

[25] Renewable methane produced from the product of gasification or pyrolysis (not anaerobic digestion).

dioxide used could be of fossil or biological origin it must not have been produced specifically for the purpose of producing a transport fuel.

4.2 Environment, marine & land-based industries

4.2.1 25-Year environment plan



Published in January 2018, the Government's 25 Year Environment Plan[26] sets out its vision for England's natural landscape and habitats. Importantly for the bioeconomy it lays out an approach for agriculture, forestry, land use and fishing that puts the environment first. At the heart of the vision is an environment with clean air, clean and plentiful water, an ecosystem with thriving plants and wildlife and an enhanced public engagement with the natural environment. Central to the delivery of the vision are actions to mitigate and adapt to climate change, minimise waste, management of chemicals and enhancing biosecurity.

The plan introduces the idea of natural capital as a method of valuing the elements of nature that either directly or indirectly bring value to people and the country. While not all aspects of the natural environment can be monetised, the use of natural capital as a tool to support decision making will allow a greater consideration of sustainability.

Under the plan policies will be developed to manage and use land sustainably. This includes the expansion of woodland and the development of a new Northern Forest, plus encouragement to increase adoption of tree planting as part of a natural flood defence programme.

4.2.2 Agricultural Policy

Following withdrawal from the EU, the UK Government is in the process of overhauling how agriculture in the UK operates and is supported.[27] The intention is to create a more dynamic, self-reliant agriculture industry; where farmers, growers, land managers and foresters have a critical role in protecting the countryside, while supplying world class food, plants and trees.

The policy represents a significant shift to a support system where public money pays for the supply of public goods as described in the 25 Year Environment Plan, namely clean air; clean and plentiful water; thriving plants and wildlife; protection from and mitigation of environmental hazards; beauty, heritage and engagement with the environment, and mitigation of and adaptation to climate change.

[26] 25 Year Environment Plan. https://www.gov.uk/government/publications/25-year-environment-plan
[27] Agriculture Bill to boost environment and food production. https://www.gov.uk/government/news/agriculture-bill-to-boost-environment-and-food-production

4.2.3 Environmental Land Management

A cornerstone of the new agriculture policy will be Environmental Land Management (ELM) payments[28]; where subsidy payments are made for the supply of public goods. The payment scheme is in a design and trial phase before rolling out in 2024. It is envisaged that the scheme could comprise three payment tiers:

Tier 1 would aim to encourage environmentally sustainable farming and forestry and would include broad actions applicable to most farmers and foresters. Tier 1 would include actions such as using cover crops or planting wildflower margins.

Tier 2 would be more specific, being designed to support land managers in the delivery of locally targeted environmental outcomes. These payments are likely to require the collaboration of multiple stakeholders, e.g. farmers, foresters, and town planners.

Tier 3 would focus on the delivery of landscape scale land-use change. Payments would support projects delivering ambitious environmental commitments such as Net Zero through afforestation or peatland restoration.

4.2.4 Environment Bill 2019-2021

The Environment Bill[29,30], currently passing through Parliament, lays out the Government's proposal for legislation to allow the setting of targets, plans and policies to improve the natural environment, the requirements for statements and reports about environmental protection and the creation of the Office for Environmental Protection. It also proposes legislation on waste and resource efficiency, air quality, water, nature, and biodiversity.

4.2.5 Agriculture Bill

The Agriculture Bill[31] is intended to provide the Government with the authority to make direct payments in relation to agriculture and other specified purposes. It makes provision for reports on food security; the acquisition and the use of information connected with food supply chains. It also confers powers to make regulations about the imposition of obligations on business purchasers of agricultural products, rules on marketing standards, and the production of organic products.

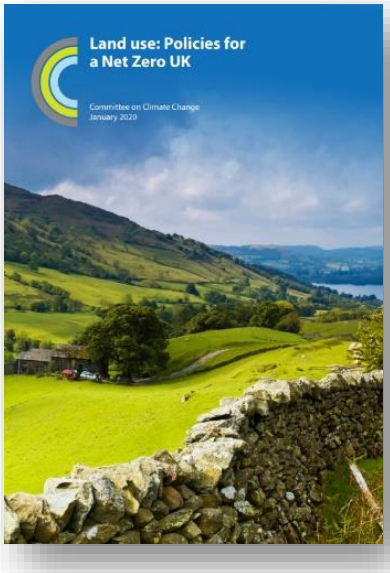
[28] Environmental Land Management Policy discussion document. https://www.gov.uk/government/consultations/environmental-land-management-policy-discussion-document

[29] A Government Bill is a formal proposal for a new law, or a change in the law, that is put forward by the Government for consideration by Parliament.

[30] Environment Bill 2019-2021. https://services.parliament.uk/bills/2019-21/environment.html

[31] Agriculture Bill 2019-2021. https://services.parliament.uk/bills/2019-21/agriculture.html

4.2.6 Land use: Policies for a New Zero UK (Jan 2020)



The CCC has the made the clear statement that it believes that the UK cannot achieve a Net Zero target without changes to the way the UK manages its land.[32]

In 2017 emissions from UK agriculture, land use and peatlands amounted to 58 $MtCO_2eq$, representing 12% of the UK's total GHG emissions. An ambitious land use plan could reduce these emissions by 64% down to 21 $MtCO_2eq$ by 2050.

CCC analysis indicates that through changes to farming practices and consumer behaviour, around 25% of agricultural land could be released to activities targeting climate change mitigation.

The key actions identified by the CCC are:

- The adoption of low-carbon farming practices such as the choice of fertiliser, reduction in cultivations and better utilisation and management of animal manures to reduce fugitive emissions,
- A programme of afforestation and the adoption of agro-forestry targeting the planting of 30,000 hectares of broadleaf and conifer woodland,
- The restoration of 50% of upland and 25% of lowland peat,
- An expansion in the planting of bioenergy crops by 23,000 hectares,
- A move away from the consumption of carbon intensive foods such as beef, lamb, and dairy,
- And reduce the 13.6 million tonnes of food waste produced annually by 20%.

As one of the actions to reduce food waste the CCC is calling for the mandated separate collection of waste across the UK, which follows on from similar proposals in Defra's Resource & Waste Strategy in December 2018.

4.2.7 Marine and Coastal Access Act

The Marine and Coastal Access Act 2009[33] sets out the requirements for marine planning, taking into account the Government's general policies, and where appropriate the general policies of each of the devolved administrations (for Scotland see the Marine (Scotland) Act[34]). The Act covers the licensing of activities in the marine environment and the designation of conservation zones. The Act introduced a holistic approach to planning, replacing the previously more sectorial approach. It also established the Marine Management Organisation[35] (MMO) as an independent body with the objective to

[32] Land use: Policies for a Net Zero UK. https://www.theccc.org.uk/publication/land-use-policies-for-a-net-zero-uk/
[33] Marine and Costal Access Act. https://www.legislation.gov.uk/ukpga/2009/23/contents
[34] Marine Planning. https://www.gov.scot/policies/marine-planning/
[35] Marine Management Organisation. https://www.gov.uk/government/organisations/marine-management-organisation

contribute to sustainable development by considering the impact of decisions in one marine activity on other areas of the marine environment.

4.3 Clean Air Strategy

The Clean Air Strategy[36] is the Government's plan to tackle negative impacts of air pollution on public health. After cancer, heart disease and obesity, air pollution is considered the next largest threat to health.

The strategy points to the need to consider and balance the impacts of new technology and systems between air pollution and climate change mitigation. It addresses emissions to air from heat and power generation, domestic heating, the transport sectors, and agriculture.

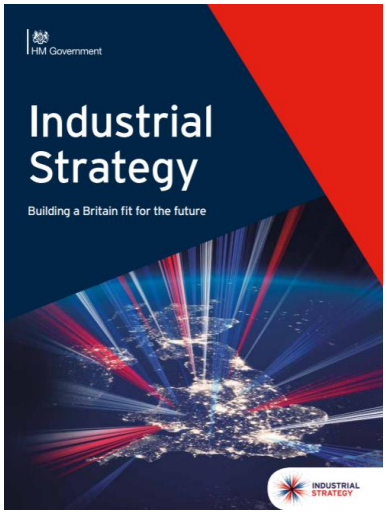
The strategy introduces further controls on air pollutants related to installations already supported by the Renewable Heat Incentive scheme and a ban on new RHI applications from biomass installations in urban areas.

The various sectors of transport require their own approaches to mitigate air pollution. The strategy reinforces the Government's Road to Zero plan[37] to end the sale of new conventional petrol and diesel cars and vans by 2040, and possibly as early as 2035 when planned consultations have been completed. Plans for the Aviation (Aviation 2050) and Maritime (Maritime 2050) sectors are being developed.

In the farming sector there will be regulation to reduce ammonia emissions and to minimise pollution from fertiliser use.

4.4 Innovation and economic growth

4.4.1 Industrial Strategy



Published in 2017, the UK's Industrial Strategy described the plan to achieve the Government's vision of the UK as a the world's most innovative economy; providing good jobs with greater earning power, and the best place to start and grow a business creating prosperous communities across the UK.

The strategy is based on 5 principles (Figure 5). It aims to improve the productivity of industry by investing in infrastructure, ensuring

[36] Clean Air Strategy. https://www.gov.uk/government/publications/clean-air-strategy-2019
[37] Reducing emissions from road transport: Road to Zero Strategy. https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy

that the business environment is conducive to industry, and supporting people and places to ensure an innovative and prosperous economy.

Figure 5. The Industrial Strategy's 5 foundations of productivity

The strategy includes the concept of sector deals.[38] The Government recognises the benefits of the Government and private sector working in partnership together and have signed several sector deals including one with the life science industry. The Life Sciences Sector Deal will help ensure new pioneering treatments and medical technologies are produced in the UK, improving patient lives, and driving economic growth.

The strategy also includes four key challenge areas:

- Artificial Intelligence & Data Economy.
- Clean Growth.
- Future of Mobility.
- Ageing Society.

As part of meeting these challenges, missions have been developed such as the mission to put the UK at the forefront of the design and manufacturing of zero emission vehicles, with all new cars and vans effectively zero emission by 2040.

Of importance for the bioeconomy, the strategy sets out the plan to put UK industry in a position to take advantage of a global shift towards 'clean growth', through the development and use of low carbon technologies, systems and services. The plan describes four priorities, the transformation of construction techniques, high efficiency agriculture, adapting energy intensive industries for clean growth and positioning the UK finance sector as a global leader in clean finance.

[38] Introduction to Sector Deals. https://www.gov.uk/government/publications/industrial-strategy-sector-deals/introduction-to-sector-deals

Industrial Strategy Challenge Fund

An important mechanism for the delivery of the Industrial Strategy is the Challenge Fund. Announced in April 2017, the fund brings together research and business to address key societal and industrial challenges with the aim of improving the UK's productivity and earning power. With £4.7 billion of funds to allocate over 4 years, the challenge fund represents a significant piece of the UK research and innovation funding portfolio. The challenge areas, which are identified by industry, need to meet two criteria:

- the UK has world-leading research and businesses that are ready to innovate,
- and the global market is large or fast-growing and sustainable.

Although neither the bioeconomy nor industrial biotechnology are identified as dedicated challenge areas in their own right, they are components of the Industrial Decarbonisation[39] and Smart Sustainable Plastic Packaging[40] challenges.

4.4.2 Clean Growth Strategy

Government plans to achieve the clean growth envisaged in the Industrial Strategy are described in The Clean Growth Strategy[41] Published in October 2017, the strategy targets increased economic growth at the same time as decreasing GHG emissions. The delivery of decreased GHG emissions is to be achieved at the lowest possible cost to taxpayers, consumers, and business while the Government will aim to maximise the economic and social benefits from the transition to clean growth.

The strategy places an emphasis on business and industrial efficiency [doing more with less], the need to improve the UK housing stock, a shift to low carbon transport and the delivery of clean, smart, flexible power.

The strategy recognises the benefits and value of natural resources. It advocates the increased use of timber in construction and the desire to achieve zero avoidable waste by 2050. This supports the investment in research and development in agriculture technologies (agri-tech) and greenhouse gas recovery technology. There is support for increased investment on waste and energy efficiency which sits alongside a Strategy for Resources and Wastes.

[39] Industrial Decarbonisation Challenge. https://www.ukri.org/innovation/industrial-strategy-challenge-fund/industrial-decarbonisation/
[40] Smart Sustainable Plastic Packaging Challenge. https://www.ukri.org/innovation/industrial-strategy-challenge-fund/smart-sustainable-plastic-packaging/
[41] Clean Growth Strategy. https://www.gov.uk/government/publications/clean-growth-strategy

4.4.3 Waste and Resources Strategy for England (and related strategies in devolved countries)

Published in December 2018, the Waste and Resources Strategy for England[42] seeks to provide a long-term policy direction in line with the 25 Year Environment Plan. The strategy is built on two key principles:

1. Preserving the stock of material resources by minimising waste, promoting resource efficiency, and moving towards a circular economy.
2. Minimising the damage caused to the natural environment by reducing and managing waste safely and carefully, and by tackling waste crime.

The strategy addresses key issues of importance for the bioeconomy, including eliminating avoidable plastic waste over the lifetime of the 25 Year Environment Plan and the elimination of all avoidable waste by 2050.

The strategy addresses sustainable production through several important interventions such as:

- Placing the cost of packaging waste on the packaging value chain through the introduction of an extended producer responsibility scheme.
- Creating greater demand for recycled plastic through the introduction of a tax on single use plastic with less than 30% recycled content.
- An ambition to reduce GHG emissions from landfill by ensuring that every householder and appropriate businesses have a weekly separate food waste collection.

As waste is a devolved policy area, strategies and regulations differ across the UK. For example, 80% of Scottish households already have access to food waste recycling and Scottish waste regulations require all food businesses (except those in rural areas) generating more than 5 kilograms to recycle their food waste.[43,44] Wales has plans for an extended producer responsibility scheme and both Wales and Scotland are considering Deposit Return schemes for bottles.[45,46]

[42] Waste management and policy is a devolved power with England Wales, Scotland and Northern Ireland having separate strategies.

[43] Food waste reduction: action plan. https://www.gov.scot/policies/managing-waste/food-waste/

[44] Zero Waste. https://www.sepa.org.uk/environment/waste/zero-waste/

[45] Welsh Government Consultation, beyond recycling. https://gov.wales/sites/default/files/consultations/2019-12/consultation-circular-economy-strategy.pdf

[46] Scottish Government, Deposit Return Scheme. https://www.gov.scot/news/deposit-return-scheme-1/

4.5 A Bioeconomy strategy

Published in December 2018, the Bioeconomy Strategy[47] represents a collaboration between Government, industry, and the research community.[48]

The strategy aims to grow the bioeconomy and deliver real measurable benefits for the UK economy. This will be achieved through capitalising on the UK's world-class research, development and innovation base, maximising the productivity and potential from existing UK bioeconomy assets and creating the right societal and market conditions to allow innovative bio-based products and services to thrive.

In line with the Industrial Strategy the intention is to focus on addressing the global challenges which create global business opportunities. Several target areas are identified in the strategy including:

- Creating new forms of clean energy and new routes to high value industrial chemicals.
- Producing smarter, cheaper materials such as bio-based plastics and composites for everyday items as part of a more circular, low-carbon economy.
- Reducing plastic waste and pollution by developing a new generation of advanced and environmentally sustainable plastics, such as bio-based and biodegradable packaging and bags (whilst avoiding microplastic pollution).
- Providing sustainable, healthy, affordable, and nutritious food for all.
- Increasing the productivity, sustainability and resilience of agriculture and forestry.
- Manufacturing medicines of the future and making existing ones more efficiently.

The strategy provides fifteen actions designed to stimulate and ensure change. A governance group has been created to support, monitor, and evaluate the delivery of the strategy and related activities. The governance group will establish a set of key bioeconomy metrics, including economic, environmental, and societal impact, and establish a delivery plan setting out the detailed actions and tasks needed to grow the bioeconomy.

5 Direction of travel

5.1 Conflicts and compromise

The bioeconomy is a constrained activity, land is a finite resource and must meet multiple demands from food production to leisure and social health, and ecosystem services. It is therefore no surprise

[47] Bioeconomy strategy: 2018 to 2030. https://www.gov.uk/government/publications/bioeconomy-strategy-2018-to-2030
[48] Members of the consortium include: Food and Drink Sector Council, Biotechnology and Biological Sciences Research Council (BBSRC), Chemistry Council, Department for Business, Energy and Industrial Strategy (BEIS), Department for International Trade, Industrial Biotechnology Leadership Forum, Innovate UK, Knowledge Transfer Network, Medicines Manufacturing Industry Partnership, Synthetic Biology Leadership Council.

that conflicts arise, providing resistance to change, reducing clarity in the direction of travel, and creating barriers to policy development and implementation.

The conflicts within the bioeconomy are generally well known, studied, and debated, though evidence used can be misinterpreted or interpreted to justify specific ends if not carefully scrutinised. This results in issues being typically left without resolution without a strong co-ordinated lobby to provide challenge in the face of well-funded opposition groups and NGO's. High on the list are critical conflicts around approaches to climate change mitigation:

- Through increased biofuel use versus decreased food supply and increases in food prices.
- Through increased biofuel use versus land use change and biodiversity loss.
- By biomass-based power generation versus deforestation and the loss of stored carbon.
- Through increased biomass use in domestic heating versus health issues from particulates.

Not all bioeconomy issues are related to land or the sustainability of feedstock supply and are often indirect issues related to embedded infrastructure or societal behaviour, these issues include:

- A desire from some stakeholders to move to low consumption models rather than new technologies or raw materials (Jevons paradox).[49]
- Concerns over incorrect consumer disposal of compostable packaging and contamination of plastic recycling streams or a risk of increased littering.[50]
- Differing opinions of the direction of waste treatment infrastructure development, recycling versus composting or composting versus anaerobic digestion.[51]
- The impact of introducing higher biofuel blending rates on compatibility with the existing transport fleet and garage forecourt infrastructure.[52]
- Increasing use of timber in construction and development of material fire safety regulations.[53]

A third area of conflict lies around new technologies, particularly in bioscience and the use of genetically modified organisms versus the maintenance of the natural environment. For example, the Scottish Government has a long-standing opposition to the cultivation of GM crops in the open environment on the premise of protecting the clean and green branding of Scotland's food and drink sector.[54]

While these issues create resistance, policy recognises the need to balance each benefit with its associated risks. For example, biofuel policy balances the support offered to biofuel producers with sustainability requirements and limitations on the type, volume and origin of the feedstocks used.

[49] Greenpeace. https://www.greenpeace.org/international/story/26506/the-end-of-infinite-growth/
[50] Recycling and Waste World. https://www.recyclingwasteworld.co.uk/in-depth-article/compostable-packaging-rubbish-plastic-paper/214215/
[51] Packaging Digest. https://www.packagingdigest.com/compostable-vs-recyclable-which-better
[52] RAC. https://www.rac.co.uk/drive/advice/emissions/what-is-e10-fuel-and-how-could-it-affect-you/
[53] Architects Climate Action Network. https://www.architectscan.org/safe-timber
[54] Agriculture and the environment, Genetic modification. https://www.gov.scot/policies/agriculture-and-the-environment/gm-crops/

5.2 Clear destinations

The recognition that the bioeconomy is limited in its long-term ability to meet the needs of the entire economy and society does, when balanced with the availability of alternative technology options, allow the identification of some clear development destinations.

In respect to climate change mitigation the direction of travel is the complete elimination of greenhouse gas emissions. For carbon dioxide emissions this is achieved by either switching to non-carbon technologies or the adoption of systems and infrastructure which allows the capture and storage of carbon dioxide.

Electricity generation has already made a significant switch away from fossil-based carbon sources with the introduction of renewables including wind and solar. The intention is to bring more renewable electricity online combined with introducing carbon capture and storage to carbon-based electricity generation, to deliver a uniquely carbon negative solution to power generation.

For the provision of heat, non-carbon technologies exist in the form of heat pumps.[55] However, the large-scale deployment of heat pumps is challenging and there is a preference to make use of the existing and extensive natural gas grid. Unlike electricity, heat is typically derived from the decentralised combustion of fuel and therefore emissions cannot be captured at the point of fuel combustion. This means a switch to a non-carbon fuel is required. Hydrogen generated from non-carbon sources such as water or the centralised production of hydrogen from carbon sources with carbon capture and storage at the point of conversion is regarded as the long-term solution for reducing GHG emissions from heat.

Like heat, the GHG emissions resulting from transportation are decentralised. Decarbonisation is envisaged to include a mix of new engine technology, new zero emission fuels and low carbon fuels. The direction of travel to reduce GHG emissions from the domestic fleet and light haulage is clearly focussed on the switch to electric vehicles. Heavy goods vehicles and aviation are areas of transportation considered to have a long-term reliance on liquid carbon-based fuels and therefore require decarbonisation through the supply of low carbon, biofuels, or recycled fossil fuels.

The strategy to reduce GHG emissions from the waste industry sits alongside the recognition of the need for the economy to increase resource efficiency and to become more circular in nature. A clear move is the intention for the separate collection of food waste. Furthermore, there is interest within Government in encouraging the production of liquid transport fuels from non-recyclable waste streams.

5.3 Hazy horizons

Approaches to the long-term decarbonisation of maritime shipping are still under discussion. Biofuels such as pyrolysis oils have been considered; however, the use of hydrogen fuel cells or ammonia fuel blends are currently favoured as solutions for long-distance shipping. Ammonia is not currently a low

[55] BEIS - Clean Growth - Transforming Heating Overview of Current Evidence, December 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

carbon fuel. Its production, which requires hydrogen and nitrogen as inputs, is energy intensive and therefore new production pathways are required. Two options are proposed; both involve the supply of carbon-free hydrogen, the first through the capture of carbon emissions resulting from the steam reforming of methane to produce hydrogen, and the second the use of water electrolysis to generate hydrogen and oxygen, using sustainable electricity.[56]

While there is a good level of clarity over the decarbonisation of the various energy vectors, the strategy for the decarbonisation of manufactured products is less clear. There is little support beyond research and technology development grants for low carbon products. Although the transition to products such as chemicals and plastic from renewable biological resources is recognised and proposed as a route to reduce the GHG emissions embedded within products, it has not been backed up with hard policy interventions.

Sequestering biogenic carbon within materials and products with long life spans is one mechanism to remove carbon from the atmosphere and address climate change. The CCC has made the case for a significant increase in the use of timber in UK construction as one action to sequester carbon within the economy.[57] There have also been numerous attempts through social housing and public building projects to promote straw-based and hemp building methods to industry and build knowledge of such technologies. Despite these calls and initiatives, there remains limited policy support for the use of biobased products including timber in the construction industry, despite evidence of the benefits on offer.

The environmental impacts of manufacturing, their use and finally disposal of products goes far beyond just GHG emissions. These impacts are particularly highlighted when products are single use or have short lifetimes; under particular scrutiny are the impacts from single use plastic packaging and fast fashion.

The debate and criticisms around plastic packaging are centred on the large-scale environmental pollution and subsequent harm to wildlife, resulting from the improper disposal of plastic packaging. The policy response to the plastic packaging issue has been manifold but not prescriptive. Policy points to actions to increase recycling through harmonised waste collections, an Extended Producer Responsibility scheme, and through a tax on single use plastic packaging with recycled content below 30%.

UK businesses are addressing the plastic issue through the Plastics Pact[58], a collaborative initiative aiming to create a circular economy for plastics. One of several goals of the Pact is to have 70% of plastic packaging effectively recycled or composted by 2025. This raises the question of which items should be designed for recycling and which for composting? Despite recent guidance from WRAP on the use of compostable plastic there is still debate and conflicting views on how the collection and treatment of plastic waste should be developed, for example, concerns over compostable plastics contaminating recycling streams. Conversely the UK trade body for the biobased and biodegradable

[56] Ammonia: zero-carbon fertiliser, fuel and energy store. https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/green-ammonia/

[57] Wood in Construction in the UK: An Analysis of Carbon Abatement Potential (BioComposites Centre). https://www.theccc.org.uk/publication/wood-in-construction-in-the-uk-an-analysis-of-carbon-abatement-potential-biocomposites-centre/

[58] UK Plastic Pact. https://www.wrap.org.uk/content/the-uk-plastics-pact

products industry (BBIA) makes the case for the need to remove the high levels of non-biodegradable plastics which currently contaminate biogenic waste collections such as food waste, and ultimately result in land contamination through the spreading of compost or digestate.[59,60]

Fast fashion is increasingly being seen as a global environmental issue. Whether it be concerns over microplastics from man-made fibres or ecosystem damage from unsustainable cotton production, there is a growing call for policy intervention. The Government has described the policy instruments it proposes to use to encourage the industry towards greater sustainability.[61] The intentions build on the principles of the Waste and Resources Strategy; there are a range of options companies could adopt from new business models, to design approaches or through alternative materials, and therefore it's too early to say how the textile industry may react and what direction the industry may take.

5.4 A call to action

Within the bioeconomy, policy actions to create market demand and drive growth differ significantly between sectors. While bioenergy sectors have a variety of producer obligations and financial support mechanisms, these 'strong' support measures do not extend to the various sectors covering biobased products.

Some stakeholder groups believe that stronger policy intervention is required if the economic and environmental potential of biobased products is to be realised[62]. Policy support for biobased products has focussed on supporting research and technology development, and market enablers such as standards, certificates, labels, networks, self-commitments, and public awareness. However, these are all soft measures, which can be considered enablers or supporters, and which alone only have a minimal impact on market growth. To increase market demand stronger measures are considered necessary, these measures could include, increased fossil carbon taxes, a tax on CO_2, product quotas, tax credits, the removal of fossil subsidies or the use of mandates or bans.

6 Implications and Conclusions

Government policies are forcing a move in feedstock choice for liquid biofuels, away from food crops and towards industrial by-products, residues, and wastes. This move will free up agricultural products such as starch and sucrose for use as raw materials for chemical production.

Electrification of the domestic car fleet means a decreasing need for technology development supporting alcohol fuel production and a switch to the development of processes to produce drop-in fuels such as diesel for heavy haulage and jet fuel for aviation.

Meaningful electrification of the domestic car fleet, the switch to hydrogen as fuel for domestic heat and the use of ammonia as a marine fuel will result in considerable carbon capture deployment. If

[59] BBIA signs letter calling for ambitious targets for compostable plastics. https://www.theguardian.com/environment/2020/jan/27/creating-a-circular-economy-through-compostables

[60] BBIA position Paper BBIA Position Paper on the Resources and Waste Strategy. https://bbia.org.uk/wp-content/uploads/2019/10/BBIA-Policy-Position-Paper-Rev.pdf

[61] Fixing fashion: clothing consumption and sustainability: Government Response to the Committee's Sixteenth Report. https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/2311/2311.pdf

[62] Which measures could boost the European bio-based economy. https://www.nnfcc.co.uk/bioeconomy-support-measures

carbon capture technology is developed in the right way, it could result in extremely large volumes of carbon dioxide becoming available for the production of liquid fuels and chemicals.

Climate mitigation through afforestation and the use of tree/perennial crop planting as part of flood resilience programmes, may over the long-term result in an increased supply of biomass feedstock. Furthermore, if calls for the increased use of wood in construction are acted on, then increased quantities of timber by-products and forest residues can be expected. These biomass feedstocks should be channelled towards hard to decarbonise sectors of the economy and the production of aviation fuel, chemicals, and materials.

Mandatory food waste collections will result in increased volumes of biogenic feedstock being treated through anaerobic digestion (AD), composting or AD in combination with composting. Although the biomethane generated through AD will initially be used as a transport or heating fuel, it could provide a feedstock for chemical production. Potentially of more importance, mandatory food collections and the development of treatment infrastructure could provide the confidence that the packaging and retail industries require to make a significant move to the use of compostable packaging, which in turn would provide an impetus for the wider development of biobased technologies.

In conclusion, the bioeconomy runs through and touches on large sections of the economy with implications for how we utilise our land and allocate the resources it provides. Competing views on how to balance these requirements produces barriers and hinders policy development with consequences for research, and market development. The need to decarbonise the economy is clear with policies increasingly moving towards zero emission technologies (non-carbon or carbon with capture). However, for many sectors, including chemicals, plastics and some fuels, a move away from carbon is not an option and requires the supply of renewable carbon in combination with low emission processes to avoid continued fossil carbon emissions. Therefore, the sustainable use of land alongside the technologies required for cultivation, processing, use, and disposal, of food, feed and biobased products remains key for bioeconomy innovation.

7 Chronology of key policy documents

Climate Change Act, 2008 (Amended 2019)

Review of the Indirect Effects of Biofuels - the 'Gallagher Review', RFA, 2008.

IB 2025: Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy, BERR, 2009.

Marine and Coastal Access Act, 2009 (Amended 2011)

Waste or resource? Stimulating a bioeconomy, House of Lords Science and Technology Select Committee, 2014.

Building a high value bioeconomy Opportunities from waste, HM Government, 2015.

Clean Growth Strategy: Leading the way to a low carbon future, BEIS, 2017.

Industrial Strategy: building a Britain fit for the future, HM Government, 2017.

A Green Future: Our 25 Year Plan to Improve the Environment, HM Government, 2018.

A National Industrial Biotechnology Strategy to 2030, IBLF, 2018.

Bioeconomy strategy: 2018 to 2030, HM Government, 2018.

Growing the Bioeconomy, Government Response to the Bioeconomy Call for Evidence, BEIS, 2018.

Waste and Resources Strategy for England, Defra, 2018.

Agriculture Bill 2019-2021, HM Government, 2019.

Clear Air Strategy, HM Government, 2019.

Environment Bill 2019-2021, HM Government, 2019

Reducing UK emissions – 2019 Progress Report to Parliament, Climate Change Committee, 2019.

Environmental Land Management Policy discussion document, Defra, 2020.

Land use: Policies for a Net Zero UK, Climate Change Committee, 2020.

NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels, and bio-based products.

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