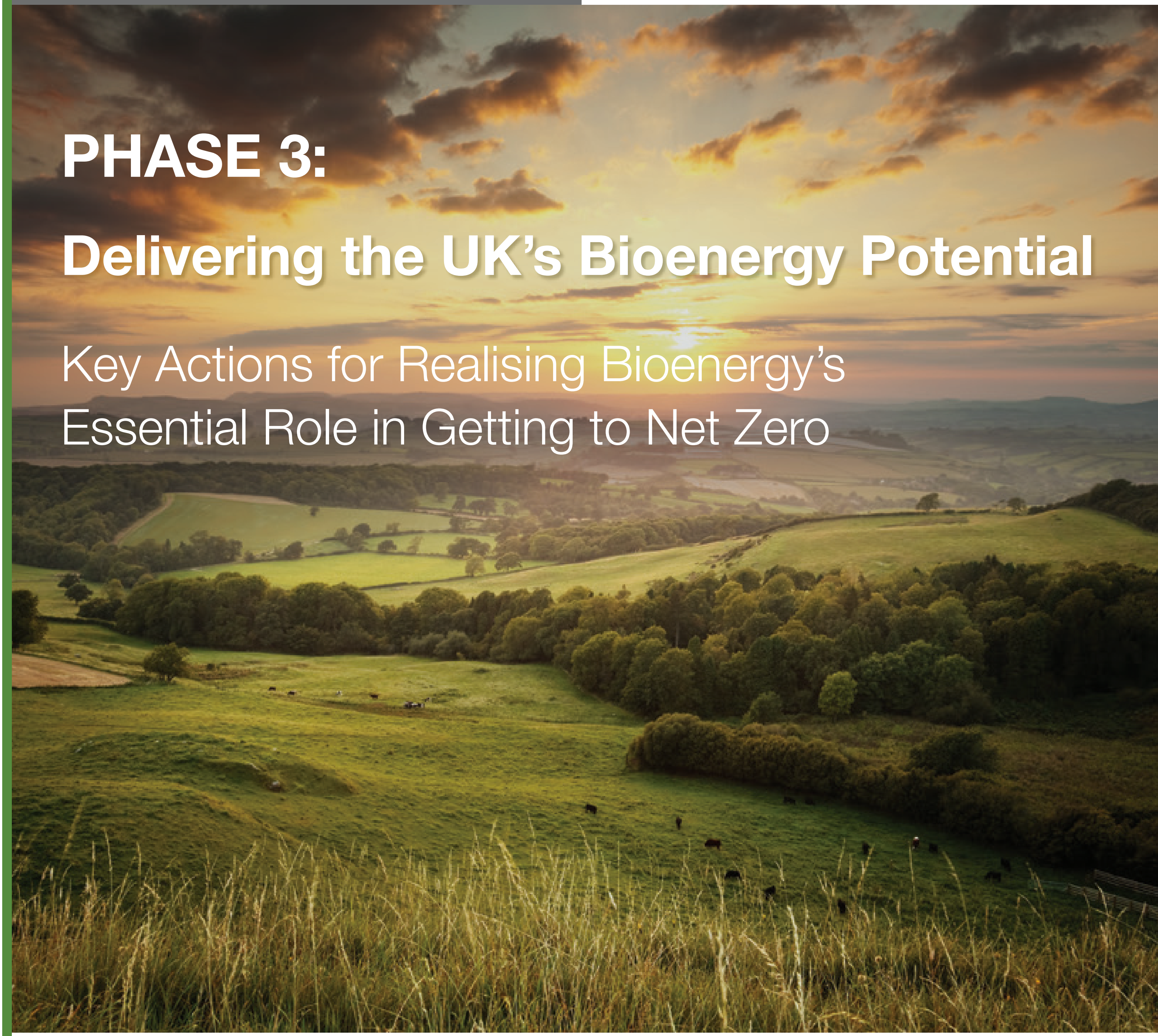
RENEWABLE ENERGY ASSOCIATION

| BIOENERGY STRATEGY

PHASE 3:

Delivering the UK’s Bioenergy Potential

Key Actions for Realising Bioenergy’s Essential Role in Getting to Net Zero



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Acknowledgements

The **Bioenergy Strategy** is supported by a number of key funders, to whom we are very grateful for their support, these are:

AMP Clean Energy

Bioenergy Infrastructure Group

Drax

Enviva

Glennmont Partners

MGT Teeside

National Farmers Union (NFU)

re:heat

US Industrial Pellet Association (USIPA)

We would also like to thank Supergen Bioenergy Hub for their support and academic input into the Bioenergy Strategy Report.

Thank you also to all the industry stakeholders who participated in the numerous working group discussions and workshops across power, heat and transport. In addition, thank you to those who fed directly into the public Call for Evidence carried out in January – February of 2019. A list of organisations who fed into the REA Bioenergy Strategy can be found at the back of this report.

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The REA Bioenergy Strategy Project

The REA has led an industry wide strategy paper for bioenergy in the UK, which we believe is timely due to:

- The rapidly evolving UK and international perspective on bioenergy
- Its critical role in the UK renewable energy scene now and potentially in the future
- The absence of an up-to-date UK government strategy for bioenergy or plans to develop one

Objective

The objective of this work is to provide an industry led perspective on:

- The current contribution of bioenergy to UK energy supply and demand, including looking at the benefits that this brings
- An appreciation of the strengths of the current UK bioenergy industry and its capabilities
- To identify the barriers, including those related to policy and regulation, which are holding back more rapid deployment
- To develop the vision of what the sector could provide (by 2032) and how this could help UK policy objectives relating to environment, energy security and to economic development
- The actions needed to deliver the vision, including what policy and regulatory framework would be needed to allow industry to deliver this future, along with the complementary actions by government, or other players, that would help deliver it, for example investment in research, design and demonstration (R,D&D); the removal of specific regulatory barriers and options for supporting finance

The project has examined bioenergy as a whole, and has considered the current and potential contributions from bioenergy to electricity, heat and transport, and in the context of the development of a sustainable bioeconomy.

Executive Summary

Key Messages

The REA Bioenergy Strategy demonstrates that getting to net-zero carbon emissions by 2050 will require sustainable bioenergy deployment across power, heat and transport.

Sustainable bioenergy use could increase by a factor of 2.5 in the UK by 2032, with associated GHG savings of around 80 million tonnes of CO2 equivalent. Such savings could help address the current predicted shortfall in emissions reductions required to meet the 5th Carbon Budget and put the UK on track to meet its net-zero carbon ambitions by 2050.

The delivery of the Bioenergy Strategy will provide energy security, as well as immediate and affordable decarbonisation in the heat and transport sectors.

Increased levels of biomass power will provide dispatchable generation within a decentralised energy system. Likewise, bioenergy applications in the heat and transport sectors provide the cheapest and most technologically-available routes to immediate carbon reductions while also helping to moderate growing electricity demand. Together, bioenergy deployment closes the potential 'nuclear gap' left by recently-shelved nuclear power projects.

Action is urgently required to avoid losing supply chains, expertise and jobs within the bioenergy sector, as well as delivering future bioenergy applications needed in the UK's low carbon economy.

Many of the world-leading measures that helped establish the UK's bioenergy sector have now lapsed, been cut or lack the ambition necessary to drive the sector forward. The policy actions and industry commitments listed in this report are now required to realise the sectors potential. These recommendations will ensure price signals within the market that constrain high carbon alternatives whilst realising bioenergy's role in delivering the wider energy transition.

Bioenergy and the UK's Low Carbon Strategy

The UK is committed to the development of a low carbon economy. However, it is not currently on track to meet existing interim targets embodied in the fourth and fifth carbon budgets, let alone the more ambitious net-zero targets recently written into law.

The current UK decarbonisation strategy, as set out in the Clean Growth Strategy, rightly focuses on increased electrification of the energy system, including for heating and transport. According to the Committee on Climate Change (CCC), achieving net-zero will require a four-fold increase in low carbon electricity generation. However, there are risks associated with this approach including the costs and practicalities of expanding the transmission and distribution system, especially when meeting the seasonal loads associated with heating. At the same time, there are also potentially significant shortfalls in the UK's future low carbon generation portfolio, with the cancellation of at least three nuclear power projects just last year.

Bioenergy, therefore, is crucial in helping to mitigate these non-delivery risks and by reducing the electricity generation and distribution infrastructure needed in a low carbon economy:

- **Heat:** Bioenergy can provide a substantially larger contribution to buildings and industry, both directly and via heat networks. It will play a particular role in providing heating in off-gas grid properties and those where heating via heat pumps is likely to be most challenging. It can also provide low carbon supplies of gas into the gas network, utilising existing infrastructure, while further decarbonising on gas-grid areas

- **Transport:** Biofuels can provide immediate Greenhouse Gas (GHG) savings in road transport using existing vehicles and infrastructure, without in any way impeding the development of electric vehicles or their associated infrastructure. Biofuels also offer a long-term, low carbon solution for commercial vehicles which is compatible with local clean air requirements through the use of biomethane and high-blend biofuels. They also provide low carbon alternatives to difficult to decarbonise sectors such as aviation and shipping

- **Power:** Bioelectricity provides alternatives to nuclear as a low carbon dispatchable source of electricity, with lower costs of power generation than nuclear. Capacity can be built more quickly (with potentially 3 GW online by 2032) and be funded by the private sector while avoiding the long-term sustainability issues associated nuclear waste storage. Bioelectricity generation can also be linked to carbon capture and use or storage (CCUS), thereby providing a “negative emissions” technology which is recognised as essential to realising net-zero

These applications also provide market pull that stimulates GHG savings in non-energy sectors, contributing to the establishment of a wider bioeconomy. This includes improved waste management practices that transition away from landfill, better agricultural waste management and the stimulation of improved forestry practices.

In the longer-term, deployment of Bioenergy with Carbon Capture, Use and Storage (BECCUS), is expected to play a crucial role in achieving net zero from 2032, particularly in connection to the production of biomethane, advanced biofuels (e.g. aviation fuels) and hydrogen.

Bioenergy – Vision to 2032

The REA Bioenergy Strategy has developed a quantitative vision for the role that bioenergy could play by 2032. The Vision takes account of factors such as the volume of biomass resources available in line with stringent sustainability criteria and the rate at which markets could realistically be developed. It draws on both established, commercially-available technologies and some at an early stage of development, including those that are likely to be significantly deployed only after 2032 (e.g. bioenergy with CCUS).

Overall, the Vision finds that the role of bioenergy could be sustainably increased by more than 50% between 2020 and 2026 and by a factor of over 2.5 by 2032.

This means that the share of bioenergy in final energy consumption rises to 10% by 2026 and 16% by 2032.

Developing the use of bioenergy in this way would significantly increase its environmental and economic benefits:

- Associated GHG savings are estimated to increase to around 80 million tonnes of CO2 equivalent by 2032 - more than enough to bring the UK back on track to meet its net-zero ambition
- The expansion of bioenergy for heating and low carbon power generation would close the potential “nuclear gap”
- The expanded bioenergy industry sector would become a £20 billion-a-year business, supporting up to 120,000 jobs

Strengthening Existing Markets to Build a Pathway to Future Bioenergy Uses

The Vision also takes account of how bioenergy use may change over time, as new bioenergy technologies mature and the overall energy system becomes less GHG intensive. It recognises that some of these bioenergy options are not yet commercialised, including the large-scale thermal gasification of biomass to produce biomethane and the production of biofuels for aviation. There are also few examples of BECCS globally, even at pilot-scale; although there are a handful of BECCUS projects, which use, rather than store, captured CO_2.

However, rather than do nothing until these solutions are available, the approach proposed is to deploy bioenergy as soon as practicable using technologies that are available now so long as they are low cost and can provide immediate GHG savings alongside other co-benefits. This maintains existing markets while establishing supply chains and expertise that provide the necessary pathway to future bioenergy applications.

Utilising Available Feedstock

The Bioenergy Strategy demonstrates that the Vision outlined can be met by developing available sustainable feedstocks.

This includes making full use of residues and wastes while acknowledging that on-site uses are preferable, when possible, thereby avoiding transport costs and emissions. Bioenergy will also drive reforestation across the UK, where the production of sustainable biomass plays a role in optimising land use and creating a viable market for forestry residue products, incentivising landowners to plant and manage woodland. This also recognises that, from a GHG perspective, the best use of biomass is in the direct production of heat with a conversion efficiency equivalent to fossil fuels (approaching 90%) and which also takes advantage of local forest-based industries to meet dispersed heat needs.

Also, there will be a need to produce and use energy crops, including “dry” cellulosic crops such as miscanthus, short rotation coppice and crops suitable for digestion. As such, reaching higher levels of bioenergy contributions will depend on the development of crops grown specifically for energy, while also bringing carbon and other benefits to agriculture.

Additional imported resources are also required, notably solid biomass pellets for large-scale power and liquid biofuels. The necessary materials can be procured whilst still meeting rigorous sustainability criteria (see chapter 3 and additional sustainability working paper).

Specific strategies will be needed within these sectors to meet such policy objectives.

Actions Required

The Vision for bioenergy can only be realised with an appropriate enabling policy and regulatory framework. Previous policies have successfully stimulated bioenergy deployment, helped to reduce costs and built up expertise, as well as establish the necessary feedstock supply chains. Yet many of the world-leading measures that helped develop the initial market have lapsed, been cut or lack the ambition necessary to realise the sectors full potential.

Both policy action by the government and commitments from industry are now urgently required.

Mind the Growing Policy Gap

The current energy policy framework is insufficient to deliver the decarbonisation required to meet the fourth and fifth carbon budgets. This policy gap is currently expected to grow if action is not taken to update sectoral support measures.

This includes:

- Introducing a replacement to the Renewable Heat Incentive (RHI), currently funded until 2021. A replacement scheme is required to secure a market for renewable heat technologies including biomass boilers, anaerobic digestion and biofuels. A heat premium feed-in scheme could ensure continued growth in these markets

- Growing biomethane production as a way of greening the gas grid via the introduction of a “Green Gas Obligation”

- Introducing the much delayed 10% ethanol blend for petrol (E10) in the transport sector, and raising ambitions within the Renewable Transport Fuel Obligation (RTFO)

- Supporting the development of Bioenergy with Carbon Capture Use and Storage (BECCUS) including a Contract for Difference (CfD) for bioelectricity with CCUS

Introduce Strong Carbon Price Signals in All Sectors of the Energy Economy

Sectoral support measures need to be complemented by a commitment to progressively increase carbon prices across the energy economy; this includes reaching carbon prices of £70-80/t CO_2 by 2026, and over £120 by 2032. This should also be met by revising favourable tax duties placed on fossil fuels to constrain the use of high carbon alternatives; such as gradual increases in domestic VAT on fossil heating fuels and a review of transport fuel duties.

Continue to ensure Sustainable Feedstock Availability and Evolving Governance

Fundamental to growing the bioenergy sector is the sustainable production, transportation and use of feedstocks. The UK has a world-leading and comprehensive sustainability governance system developed by Government and industry. This framework, however, continues to evolve as experience has grown and the scientific understanding of a number of issues has developed. Given the importance of sustainability, a review of UK governance is included within this project alongside several recommendations as to how the framework can continue to develop. The REA will look to take these forward by establishing an industry task force aimed at ensuring the continued sustainable delivery of bioenergy as part of a low carbon economy.

Delivering Infrastructure and Innovation for Future Bioenergy Applications

The deployment rate of strategically-important bioenergy technologies will depend on the availability of infrastructure. As part of the Government strategic thinking on infrastructure priorities, there must be a focus on areas such as the development of heat networks, addressing capacity constraints on the gas network to allow for increased injection of biomethane and identifying carbon storage regions within the UK for BECCS.

Similarly, innovation in these areas will require a coordinated approach, with better integration of early-stage university research with industry-focused development and demonstration. Continuing the coordination established between industry, the Supergen Bioenergy Hub and Government during the development of this Strategy will help to build such linkages and expedite the deployment of much-needed technologies.

The REA Bioenergy Strategy is an ambitious agenda that highlights bioenergy as a crucial part of the UK's future pathway to net-zero. It lays out a roadmap for government and industry to follow in order to realise the benefits of UK bioenergy.

Photo shot by Daniel Kay of Peak District on iStock

CONTENTS

1. Introduction

Bioenergy will be necessary to deliver a net zero carbon economy by providing low carbon energy as heat, electricity and transport fuels. The use of bioenergy with carbon capture and storage (BECCS), which delivers negative emissions, shall also be essential for reaching this goal by 2050.

Bioenergy is already making a significant contribution through fully commercialised technologies and fuels, which are compatible with current energy infrastructure and the devices that use this energy. They provide many of the lowest-cost low carbon solutions for each end use. These will be complemented by a range of additional conversion technologies which are still at the development, demonstration and commercialisation stages.

However, bioenergy is a complicated subject, with many possible combinations of feedstocks, conversion technologies and energy products. It involves many interactions with other parts of the bioeconomy, such as the agriculture, forestry and the waste management sectors. It can also be a controversial topic, particularly as far as ensuring the sustainability of the production and use of biomass. Development of bioenergy requires a set of enabling policy measures coupled with a strict but fair sustainability governance system.

Given the importance of bioenergy to the UK energy economy now and in the future, it is crucial that there is a clear UK strategy for its future deployment. The last comprehensive UK Bioenergy Strategy was published by the then Department for Energy and Climate Change (DECC) in 2012.[1] Much has changed since then – bioenergy has been deployed more extensively, costs have reduced, and the issues around sustainability are better understood and managed.
To address this strategic need, the REA decided to facilitate the development of an industry-led strategy for bioenergy. The aim of the project is described in the foreword, which also provides references to the first two phases of this report and two additional working papers produced during the project (Figure 1).

Figure 1 • REA Bioenergy Strategy – Phase 1 and 2, Plus Working Papers

Phase 1: Bioenergy in the UK – The State of Play
Current progress in bioenergy deployment
GHG and other sustainability benefits
Industry strengths and capabilities
Current policy and regulatory framework

Phase 2: Bioenergy in the UK – A Vision to 2032 and Beyond
Potential for expansion of role of sustainable bioenergy
Likely benefits

Working Paper – Sustainable Bioenergy in the Bioeconomy
Bioenergy in the wider bioeconomy
Review of UK bioenergy sustainability governance

Working Paper –Actions to Deliver the Vision
What actions are needed by the main stakeholders to allow the vision to be achieved?

This final report summarises the main findings.

- Chapter 2 identifies the strategic role that bioenergy can play in helping meet UK policy goals relating to greenhouse gas (GHG) reductions and the environment more widely
- Chapter 3 looks at Bioenergy in the wider bioeconomy and reviews the UK bioenergy sustainability governance framework
- Chapter 4 discusses how the contribution of bioenergy to the UK economy has been growing, and establishes a vision for further growth through to 2032 and beyond. It also estimates the benefits that the current level of bioenergy delivers, in terms of GHG reductions, jobs and economic activity and contributions to other policy objectives
- Chapter 6 spells out the key actions that need to be taken by Government, industry and other stakeholders to deliver the vision

Box 1: What is Bioenergy?

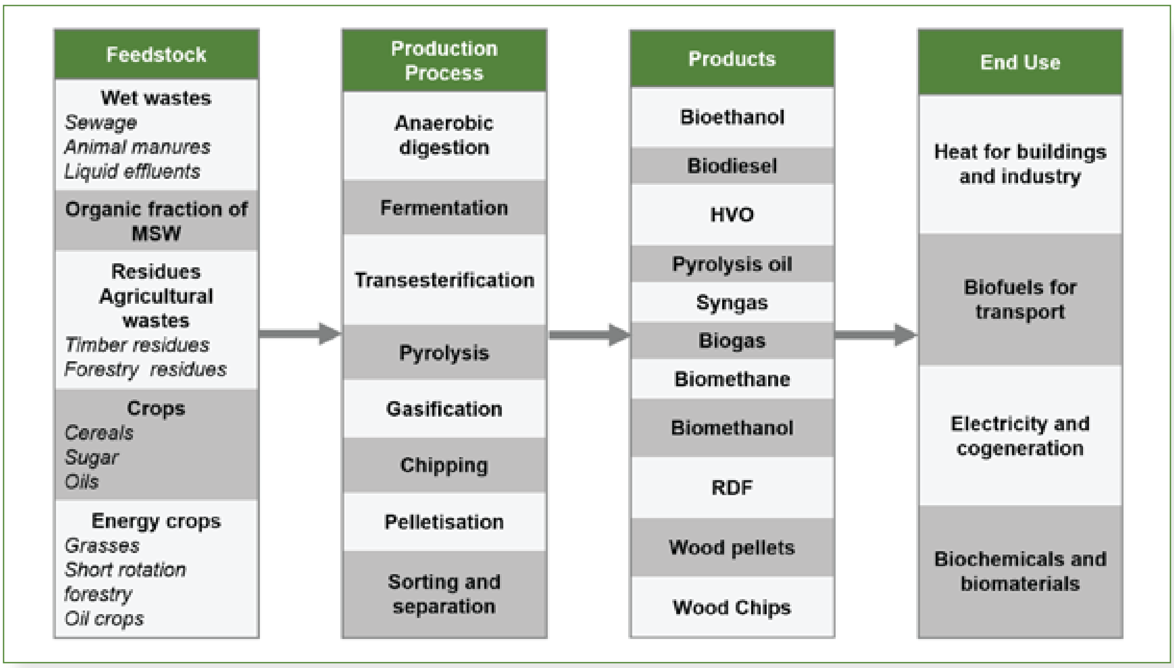
Bioenergy involves the use of organic feedstocks for energy purposes, replacing fossil fuels and reducing emissions of greenhouse gases including CO_2 on a full life-cycle basis (see Box 4). A wide range of biomass feedstocks can be used for bioenergy production.

These include:

- Wet organic wastes, such as sewage sludge, animal wastes and organic liquid effluent
- The organic fraction of municipal solid waste (MSW)
- Residues and co-products from agro-industries and the timber industry and from forestry
- Crops such as corn, wheat, sugar and vegetable oils produced from palm, rapeseed and other raw materials
- Non-food crops such as perennial lignocellulosic plants (e.g. grasses such as miscanthus and trees such as short-rotation willow).

Modern technologies can convert this organic matter to solid, liquid and gaseous forms that can efficiently provide energy needs and replace fossil fuels. Many processes are available to turn these feedstocks into a product that can be used for electricity, heat or transport. Figure 2 illustrates a number of the main pathways available for these applications.[2]

Figure 2 • Potential bioenergy pathways: from biomass to final energy use



Source: Adapted from IEA and FAO (2017), How2Guide for Bioenergy [3]

The most common pathways to date have been: the production of heat and power from wood, agricultural residues and the biogenic fraction of wastes; maize and sugarcane to ethanol; and rapeseed, soybean and oil crops to biodiesel. Some other processes are not yet fully commercialised. In particular, there is potential to combine a number of these technologies with carbon capture and storage, which produces energy whilst also stopping carbon dioxide from entering the atmosphere (see Box 7), although these technologies are so far only at the demonstration stage.

Each of these bioenergy pathways consists of several steps, which include biomass production, collection or harvesting, processing, pre-treatment to alter chemical properties, and finally conversion of the biomass to useful energy. The number of these steps may differ depending on the type, location and source of biomass, and the technology used to provide the relevant final energy use.

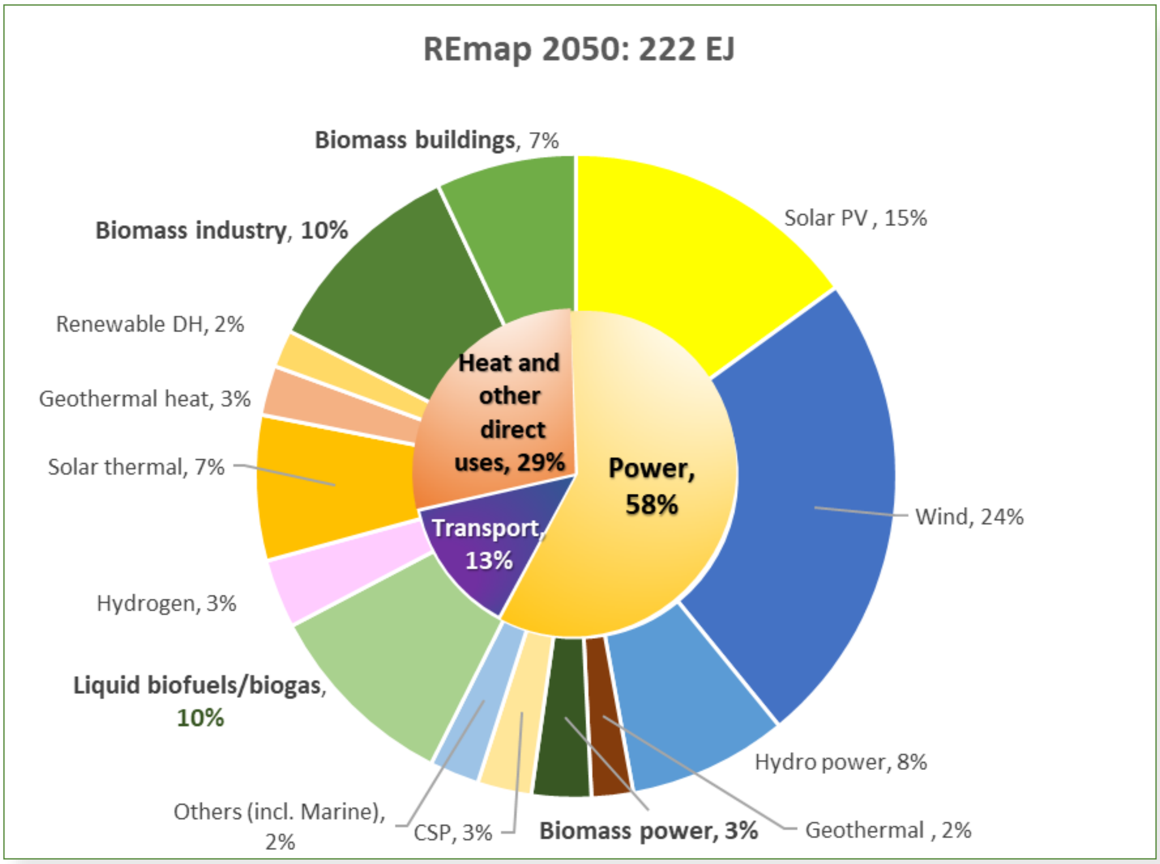
2. The Strategic Role of Bioenergy

International Perspective

Bioenergy already plays an important role in the global energy economy, making the largest contribution to global final energy demand of any renewable energy technology, more than five times that of wind and solar combined. This includes contributing the bulk of heat and transport decarbonisation to date.[4]

The important role of bioenergy is recognised in international low carbon scenarios. In the International Renewable Energy Agency (IRENA) global REMap scenario for 2030, bioenergy provides 22% of total global energy needs for transport, 14% of energy for buildings, 19% of industrial energy needs and 4% of electricity generation (See Figure 3 on the following page).[5]

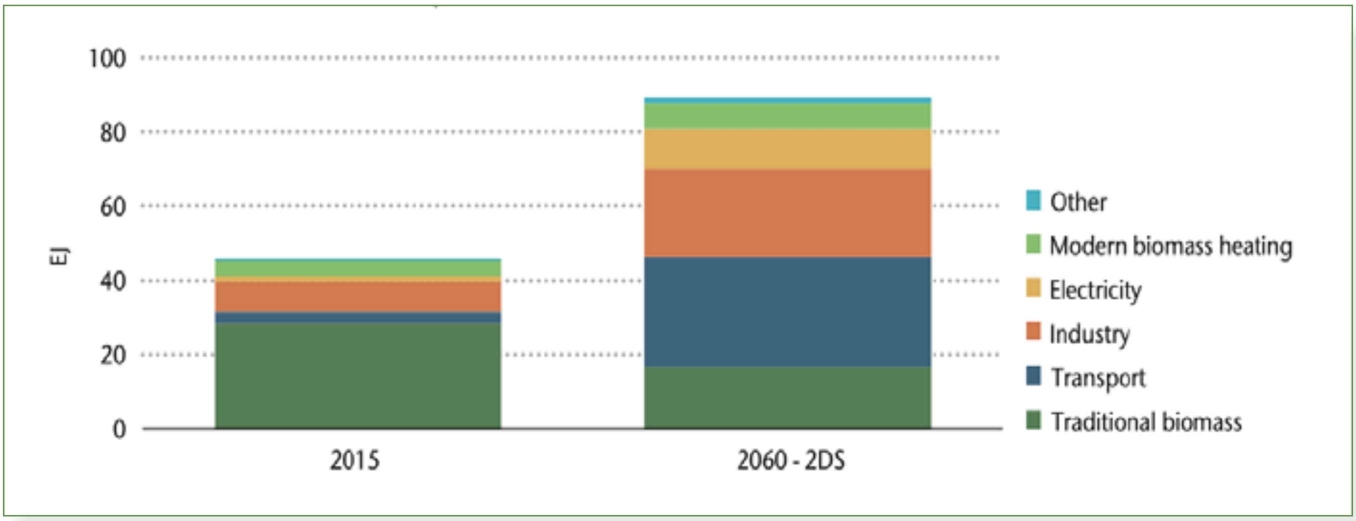
Figure 3 • IRENA REMap – Role of bioenergy in final energy consumption, 2030



Source: IRENA REmap

The International Energy Agency (IEA) 'Two Degrees Scenario' (2DS) deploys the full array of low carbon energy technologies in order to restrict global warming below 2°C. In this scenario, the contribution of sustainable bioenergy increases fourfold by 2060, accompanied by a reduction in the "traditional use of biomass" (Figure 4).[6] It plays a vital role in decarbonising hard to reach sectors in industry and transport (notably aviation and shipping). BECCS provides "negative emissions" to offset some remaining fossil fuel emissions.

Figure 4 • Role of Bioenergy in IEA 2°C Scenario



Source: IEA (2017) Bioenergy Roadmap, All rights reserved [7]

UK Perspective

Phase One of the REA Bioenergy Strategy demonstrates how bioenergy already plays a fundamental role in the UK energy system.[8] The production and use of bioenergy in the UK has grown rapidly over the last decade. Bioenergy is the largest renewable contributor to final UK energy consumption, helping to decarbonise electricity, heat and transport. There is substantial potential to sustainably increase this contribution by using biomass materials for further energy production (see Chapter 4).

The UK Low Carbon Strategy and Bioenergy

UK Ambition and Targets

The UK Government is committed to reducing greenhouse gas (GHG) emissions. Most recently the Government amended the UK Climate Change Act to commit to meeting net zero carbon emissions by 2050. This followed the recommendations of the Committee on Climate Changes (CCC) who demonstrated that such a target is required to honour the UK's international commitments.

To meet the Climate Change Act, the Government has set five-yearly carbon budgets, which currently run until 2032, based on advice from the CCC. The fourth and fifth carbon budgets account for the periods between 2023 – 2027 and 2028 – 2032, with targets of 51% and 57% emissions reductions below 1990 levels.

The CCC has noted that these targets are both possible and affordable, but that Government must urgently adopt a clear, stable and well-designed set of policies across the economy if these ambitions are to be realised.

Progress to the GHG Targets and the UK Low Carbon Strategy

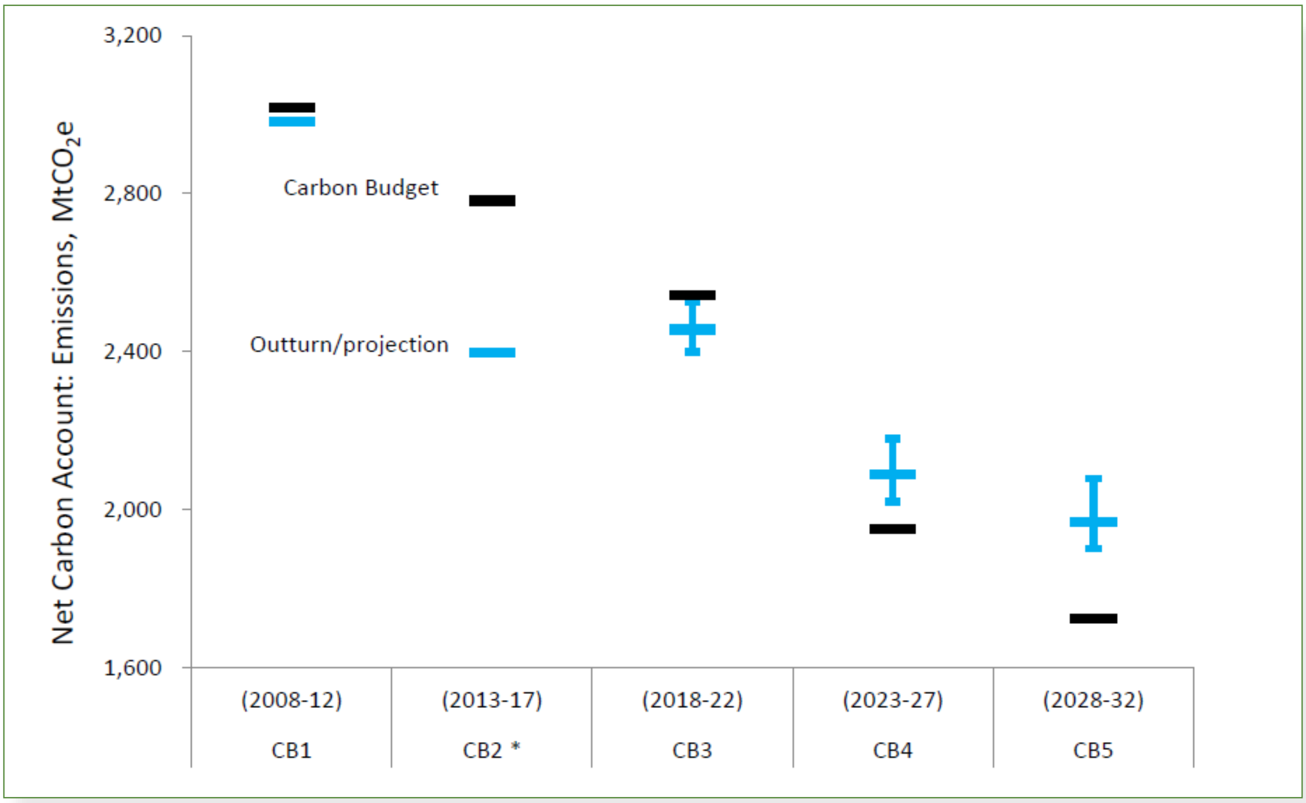
The UK has made progress in reducing emissions. The first carbon budget (2008 to 2012) and second (2013 to 2017) were met and the UK is currently on track to outperform on the third (2018 to 2022) budgetary period. There has been progress in decarbonising the power sector – with major reductions in coal use, and growing use of renewable sources of electricity. However, there has been significantly slower progress in the harder to decarbonise heating and transport sectors.[9]

In 2017 the Government produced a Clean Growth Strategy (CGS), which focuses on achieving the 5th Carbon budget by 2032.[10] The strategy is designed to meet GHG reduction commitments at the lowest possible net cost to UK taxpayers, consumers and businesses, while maximising the social and economic benefits for the UK from this transition.

However, in its 2019 Progress Report to Parliament the CCC notes that UK action to curb greenhouse gas emissions is lagging far behind what is needed, even to meet previous, less stringent, emissions targets. Many of the elements within the CGS have yet to be actioned. Over the past year, the Government has delivered just 1 of 25 critical policies needed to get emissions reductions back on track.[11]

The Government's own analysis, produced by the Department for Business Energy and Industrial Strategy (BEIS), suggests emissions are likely to exceed the budgets by some 139 million tonnes of CO_2 equivalent ($MTCO_2e$) and 245 $MTCO_2e$ for the two five- year periods respectively.[12]

Figure 5 • Actual and Projected Performance Against Carbon Budgets



Source: BEIS Updated Energy and Emissions Projections 2018

The adoption of more ambitious net zero objectives will require yet more rapid progress in reducing emissions and the CCC are to propose revised interim carbon budgets. The required annual rate of emissions reductions is 50% higher than that needed under the original 80% reduction goal, and 30% higher than has been achieved since 1990.[13]

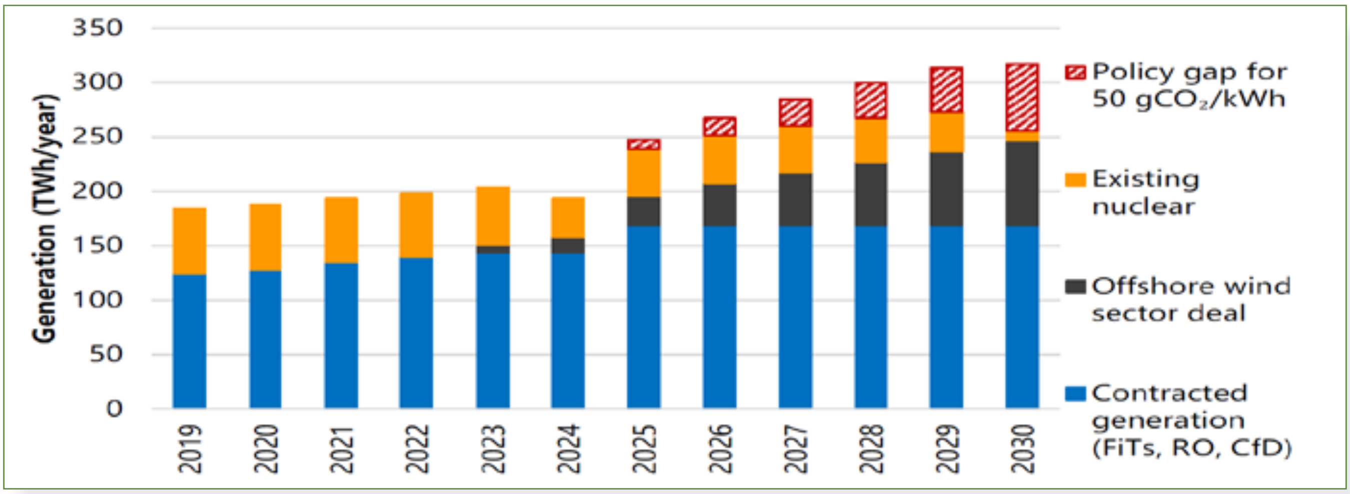
The Challenges of Electrification

Like most national low carbon strategies, the plan being developed in the UK relies heavily on electrifying a wide range of energy services, notably for heating (directly or via the use of heat pumps) and for transport. This is understandable given the well-developed set of low cost renewable electricity technologies and the inherent higher efficiency associated with many applications. The CCC estimates that the amount of low-carbon electricity generated and used in the UK will have to raise by a factor of four in a scenario compatible with net zero emissions.[14]

While electrification remains a foundation of decarbonisation polices, bioenergy has a critical role in mitigating some of the challenges associated with greater levels of electrification. Such challenges include:

- Developing, building and operating the necessary transmission and distribution infrastructure to meet expanded, but highly seasonal demand. For example, energy demand in buildings in winter is typically 6 times higher than in the summer months.
- Much progress has been made in understanding how to manage electricity systems with high shares of variable renewables.[15] However, dispatchable renewable electricity capacity will still be essential to cope with periods of low generation and to provide system services, which in turn further supports deployment of wind and solar.
- UK plans currently include a substantial expansion of nuclear capacity. However, constructing nuclear plants on schedule and on budget has proved difficult. The developers of three of the proposed new nuclear plants (Hitachi and Toshiba) have now stopped development work on the projects at Wylfa, Oldbury and Moorside. This will leave an estimated 72 TWh/year capacity gap by 2030, which will need to be replaced by other renewable solutions.[16]

Figure 6 • Deployment of low carbon electricity capacity to meet 50gCO_2/kWh by 2050



Source: Committee on Climate Change (2019) Reducing Emissions 2019 Progress Report to Parliament

Phase Two of the Bioenergy Strategy[17] demonstrated how increased use of bioenergy will help mitigate these risks and be necessary for the delivery of the low carbon goal by:

- Providing alternative low carbon solutions to provide heat directly where it is needed and decarbonise transport where electrification may not be appropriate, reducing the extent to which the electricity transmission and distribution systems needs to be enhanced
- Provide a low carbon and lower cost alternative to nuclear, financed by the private sector, through the generation of electricity from biomass, and linked to carbon capture use and storage (CCUS)

The Missing Role of Bioenergy in Current Plans

However, current planning, as embodied in BEIS Energy and Emissions Projections fail to envisage a significantly enhanced role for bioenergy by 2032.[18] In the reference scenario, based on central estimates of economic growth and fossil fuel prices, and taking account of all existing and well-defined planned policies, the role of renewables as a whole in final energy consumption rises by only 35% between 2017 and 2026 (outside of the electricity sector), and remains at that level in 2032. Bioenergy, which is likely to be the most significant renewable technology in non-electricity sectors, therefore only grows slowly.

The Government has published a number of discussion papers relating to the development of a low carbon economy, notably in regards to heating. These include “Transforming Heating”, published in December 2018.[19] This document reviews the low carbon options for heating in advance of developing an appropriate long-term policy approach. It accepts that there are number of potential approaches and discusses the benefits and challenges of each. It focusses on using electricity while acknowledging that this approach will be challenging for older, poorly insulated buildings, where meeting the required heat demand in winter by using heat pumps combined with improved insulation levels, will be both difficult and costly. It also focuses on the use of hydrogen and biomethane from biological and thermal processes.

The report does not consider in detail the option for heat networks in urban situations despite their potential to play a role in facilitating heat recovery from buildings and industry, as well as the use of bioenergy heat (e.g. energy production from MSW, CHP etc.) and other uses of biomass. Neither does it give much consideration to the direct use of solid biomass for heating, even though this is the most efficient way to use biomass and can play a particularly important role in rural properties, including for those most difficult to heat using electricity. The bioenergy industry believes that it can play a much more important role through the direct production of bioenergy for heat.

CCC Bioenergy Reports

The lack of focus on bioenergy within current energy policy goes counter to the role identified for it by the CCC. The CCC has published two reports relevant to the role of bioenergy in the UK in 2018 – 'Biomass in a Low-Carbon Economy'[20] and 'Land Use- Reducing Emissions and Preparing for Climate Change'.[21]

The reports:

- Highlight the importance of managing biomass stocks as a component of climate change mitigation and as part of a sustainable land use strategy
- Note that there is scope to increase carbon stocks while, at the same time, increasing the amount of biomass used sustainably as a feedstock for bioenergy, globally and in the UK, when there is good sustainability governance in place
- Recognise that biomass can play an important role in meeting long term climate targets provided it is used appropriately, prioritising uses that lead to carbon sequestration either in products or via CCS
- Indicate that bioenergy could provide up to 15% of UK energy needs by 2050 and highlight the important role of bioenergy associated with CCS and in hard to decarbonise sectors, such as the production of transport fuels for aviation

An Enhanced Role for Bioenergy in UK Low Carbon Futures

As demonstrated, the potential for bioenergy in the UK is seriously understated in current strategic thinking. Bioenergy could provide a much enhanced contribution to the UK energy economy, helping deliver low carbon ambitions, while also contributing to other important UK policy areas (Figure 7). Bioenergy has a crucial role to play across the entire energy system:

- Decarbonising Heat:
    - Efficient use of biomass feedstocks for heating buildings and industry both directly and via heat networks. This could be in both inefficient off gas-grid properties, where heating via heat pumps is likely to be most challenging, or delivering large heat loads in urban areas, for example in public buildings and schools
    - Providing low carbon supplies of gas into the gas network, decarbonising existing infrastructure

- Decarbonising Transport:
    - Utilising biofuels to deliver immediate GHG savings while using existing vehicles and infrastructure, without impeding the development of electric vehicles as the technologies and infrastructure develops
    - Providing a long-term low carbon solution for commercial vehicles, compatible with local clean air requirements through the use of biomethane, other drop-in fuels and high blend biofuels
    - Decarbonising the difficult to treat transport sectors of aviation and shipping

- Decarbonising Power and Providing 'Negative Emissions':
    - Providing a low carbon, dispatchable source of electricity, while making use of waste materials (complementing good waste management practice)
    - Coupling power production with carbon capture and use or storage (BECCUS) to produce "negative emissions" energy

Furthermore, bioenergy provides the market pull that stimulates GHG savings in non-energy sectors including:

- Delivering improved waste management practices and reducing landfill
    - Stimulating better management of agricultural residues, farm and industrial wastes
    - Creating further demand for forestry products that drive improved forestry management practices and afforestation.

The quantitative vision for what bioenergy can deliver to the UK in terms of decarbonisation, jobs and additional benefits to non-energy sectors is detailed in Phase Two of the REA Bioenergy Strategy and summarised in Chapter 4 of this report.

Figure 7 • Bioenergy – Policy benefits

Bioenergy Policy Benefits

Energy related GHG emission reductions	Other GHG emission reductions	Economic benefits
• Provides low carbon energy for heat, transport and electricity • Bioenergy with CCS provides 'negative emission' energy • Reduces need for low carbon heating electricity	• Complements waste management strategy, reducing emissions from landfill • Reduced emissions from farm wastes • Stimulates forest management and afforestation • Stimulates wider bioeconomy	• Jobs • Economic activity • Energy diversity and security • Complements land use developments

Bioenergy and the Bioeconomy

The development of an enhanced bioenergy sector will also pave the way for the development of the wider bioeconomy by providing complementary income streams for projects which also produce non-energy products (Box 2).

Bioenergy provides a proving ground and early large-scale market opportunities for a range of technologies which will be essential to the wider bioeconomy. These include biomass gasification, technologies for producing sugars from lignocellulosic materials, and processes to produce tailored projects from carbon rich gas streams. Bioenergy has also been the testing ground for sustainability regulation and management which will need to apply equally to supply chains designed for other bioeconomy products.

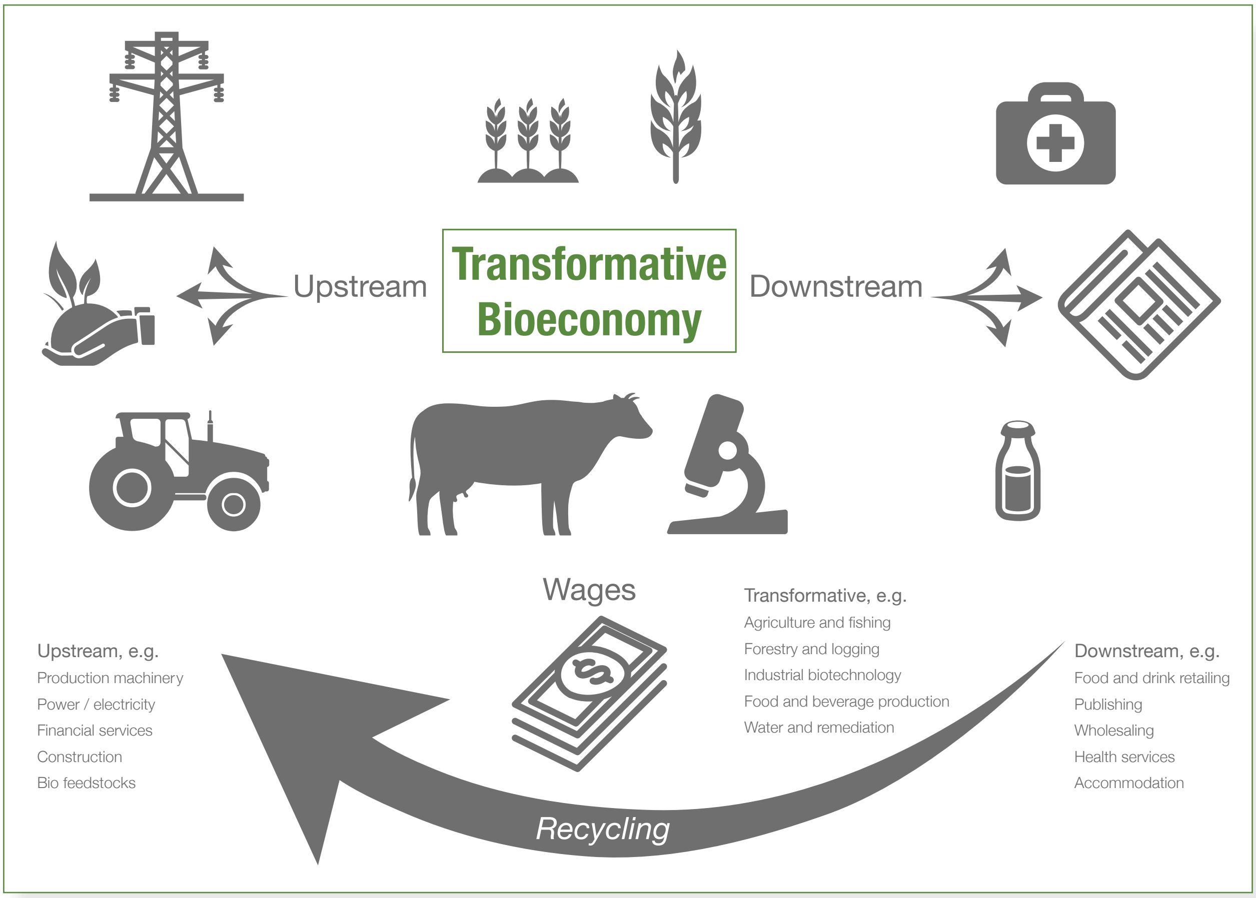
In the longer run there is potential to develop routes to some important intermediate organic chemicals based on biomass feedstocks or on carbon captured from other bioenergy processes, which could be an important low GHG feedstock.[22] For example, acrylonitrile is a precursor to synthetic resins, elastomers, rubber and carbon fibre. These will require the development of bio-based pathways but also an appropriate mechanism for incentivising carbon capture and use.

Box 2: Bioenergy and the Bioeconomy

There is a well-established “traditional bioeconomy” which has been largely been concerned with the production of food, feed for animals, forest products (including construction materials, paper and pulp, and textiles). Bioenergy has been an integral part of this bioeconomy, providing energy to industry, businesses and homes.

There is now greater recognition of the potential for an expanded bioeconomy with the capacity to replace dependence on fossil fuels and many other finite resources (Figure 8). This is leading to increased emphasis on recycling bio-based materials within a circular economy and the development of a wider range of high added-value products based on sustainably produced biomass feedstocks. These products include speciality chemicals based on cellulose or lignin, building materials, wood-based textiles, and bio-based plastics and many others. They include very high-value specialist bio-based materials such as graphene for electricity storage applications, and novel supply chains such as producing insect protein animal feed from low-value residues.[23] The expansion of modern and efficient production of bioenergy, including the production of new advanced processes and fuels, is an integral part of these new developments.

Figure 8 • The modern bioeconomy



Source: E4Tech, Evidencing the Bioeconomy[24]

New and existing products of the bioeconomy can provide energy and carbon savings compared to fossil-intensive products. For example, using both traditional and advanced engineered forms of wood as a construction material reduces the need for steel and concrete in buildings as well as sequestering carbon for an extended period. While estimates of the actual energy and carbon benefits vary widely, depending on assumptions about lifetimes and eventual disposal methods, these uses are generally considered to be highly carbon efficient as they replace materials that are produced by carbon-intensive processes.[25]

Biomass feedstocks may have chemical advantages over fossil fuels for the production of some products or intermediates. There is increased consumer-led demand for bio-based plastics (e.g. for soft drinks bottles) and other bio-packaging materials, complementing concerns about over reliance on single use-plastics.

From a business point of view, producing higher value bio-based products can be more profitable and provide distinctive products and markets. But it should be noted that in general high added value products have restricted overall market size, and that it is important to seek high added value products rather than just high value products per se. For lower value products, the challenge is to develop supply chains on a scale that matches competition from petroleum-based resources.

Bioenergy can improve the economics and carbon benefits of primary bio-products, helping to maintain existing industries and supply chains in light of changing market conditions. For example, increasing the use of timber in construction also increases the availability of lower value by-products like sawdust and offcuts, which can be used for bioenergy. Revenue from these by-products contributes to a reduction in the cost of the primary saw-log product so creating a virtuous circle. The coproduction of bioenergy can also strengthen the overall economic case for new projects, as economies of scale help to bring down costs of new technologies and reduce reliance on single markets.

Box 3: Bioenergy and Agriculture and Forestry Policy

The significant opportunity for bioenergy in the UK aligns with two clear emerging priorities: first, changes to agricultural policy and proposed support for multifunctional use of agricultural land through the Agriculture Bill; second, the recognition of the economic value of woodland, and a commitment to grow the UK's forested areas.

1. **Agriculture**

In the Committee on Climate Change's (CCC) net-zero emissions report, it called on the government to provide support for land managers to transition to alternative land uses. The report called for up to a fifth of agricultural land to shift to alternative uses that support emissions reduction such as afforestation, biomass production and peatland restoration. The report also called for increased woodland and hedgerow planting on farms - a doubling of current tree planting rates and the extension of hedgerow length by 40 percent.[i]

The CCC report also noted that the UK Agriculture Bill intends to redirect subsidies towards public goods and could support the major transition in land use and farming practices required by a net-zero targets. As part of this, the report called for farmer payments to be linked to actions to reduce and sequester emissions, to take effect from 2022. It suggested that refocusing of financial payments could be used to promote the uptake of low-carbon farming practices and to encourage transformational land use change in line with its 'Further Ambition' scenario.

Government can support farmers in ways that can benefit agriculture as well as the wider environment. Increasing the standing stock of woody biomass alongside agricultural crops or livestock may enhance productivity while improving soil health, creating wildlife habitats and sequestering carbon.

However, the Agriculture Bill does not currently include or mention trees, nor recognise the vital role that trees play in both the natural and agricultural environment or the potential benefits of agro-forestry to farmers. Government policy could reflect the positive role that on-farm woodland planting, improved hedgerow management and establishment of new shelter belts can play by providing incentives that will encourage tree planting. They could also provide funding and training for the next generation of farm and forestry advisors to successfully fuse forestry and agricultural advice and expertise. Active management of trees and hedgerows for bioenergy would provide farmers with a strong incentive for a range of activities that fall under the broad heading of agroforestry.

As identified by the Soil Association, the careful siting of trees on farmland can improve soil infiltration and water retention.[ii] By integrating trees into arable settings, soil erosion may be reduced by up to 65%, thereby reducing the impact of flooding. In turn, this will benefit the wider environment through the sequestration of carbon in soil. As identified in the Committee on Climate Change's net-zero emissions report, the managing of carbon stocks in soils so that they increase over time should be considered an essential activity. The report also noted that enhanced monitoring and reporting should play a key role in this, including making use of satellite mapping, geographically-specific datasets, track and trace initiatives and enhanced levels of soil carbon monitoring.

2. Economic Value of Woodland

While 58% of woodland in England is already in active management, the UK imports around 80% of the wood it consumes.[iii] The availability of domestic softwood is set to decline owing to a lack of conifer planting over the last 20 years. Therefore, there is a clear and growing need, both environmentally and economically, for significant reforestation across the UK. By looking at other parts of the world, we can see that sustainable bioenergy can play a crucial role in optimising land use.

In the United States, for example, overall forest resources have increased by more than 50% during the last 60 years and by 94% in the US Southeast.[iv] This has been achieved by incentivising landowners to convert underutilised land to forestry and has been accompanied by an even larger increase in the demand for forest products from sustainably managed forest, including feedstocks for bioenergy.

Most of the trees harvested in the SE US forest-based economy are used to make long-lived products such as housing construction and furniture. The US Southeast provides one-sixth of the timber that is used globally each year, and forests cover 99 million hectares (Mha) of land (more than 45% of total area) in the region. The forest industry contributes nearly USD 48 billion annually to the regional economy.

In Sweden, the total standing volume of trees has doubled in the last 100 years, largely because of Sweden's commitment to bioenergy. The current forest cover in Sweden amounts to 28 Mha, of which 23 Mha are productively managed forests, (a land area similar to that of the United Kingdom). Around 300,000 small-scale private forest owners own half of the forest land.[v]
The market for bioenergy provides jobs for the whole country, of great significance for smaller, rural, communities.

These examples suggest that the best incentive for landowners to plant trees is to create a viable market for them. This could be achieved both through tax incentives, as well as smoothing the route to market for forestry products. As seen in Sweden, there can be significant benefits from creating a diverse forestry sector that is composed of smaller, localised supply chains, that evolve to mutually support one another. Bioenergy jobs are created in forest management (rural areas), in the production of wood pellets (manufacturing), in the supply chain (logistics and transport) and in the energy plants. There is a significant opportunity to expand the use of wood fuels from local forest-based industries, particularly to meet the dispersed rural heat load in areas not connected to the gas grid.

[i] **CCC (2019)** Net zero: The UK's Contribution to Stopping Global Warming, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[ii] **Woodland Trust & Soil Associaton (2018)** Agroforestry in England: Benefits, Barriers & Opportunities, https://www.woodlandtrust.org.uk/mediafile/100822604/agroforestry-in-england.pdf?cb=bee3beffbd404e32a0e74a3f4459c822

[iii] **House of Commons Environment, Food and Rural Affairs Committee (2017)** Forestry in England: Seeing the wood for the trees
https://publications.parliament.uk/pa/cm201617/cmselect/cmenvfru/619/619.pdf

[iv] **USDA Forest Service (2009)** US Forest Resource Facts and Historical Trends.
https://www.fia.fs.fed.us/library/brochures/docs/Forest%20Facts%201952-2007%20English%20rev072411.pdf

[v] **European Association of Remote Sensing Companies (2016)** Copernicus Sentinels' Products Economic Value: A Case Study of Forest Management in Sweden
https://www.fia.fs.fed.us/library/brochures/docs/Forest%20Facts%201952-2007%20English%20rev072411.pdf

3. Sustainable Bioenergy

Bioenergy has a key role to play in a low carbon economy, globally and in the UK (see Box 4). However, it can only do this if it is (and is perceived to be) 'sustainable', which is to say:

"The production and use of bioenergy must significantly and unequivocally reduce GHG emissions on a whole life-cycle basis compared to fossil sources, while contributing positively to other sustainable development goals and minimising negative environmental, social or economic impacts".[26]

Transparent compliance alongside sustainability principles is essential in order to gain and maintain public and political support for the policy measures needed to promote bioenergy growth at sufficient scale. Industry also needs to be sure that the bioenergy it produces and uses meets these criteria, or else it risks reputational damage as well as putting long-term investments at risk.

Given the importance of these issues, a review of the UK sustainability governance framework has been undertaken as part of this project.[27] This working paper discusses the full range of potential sustainability benefits and risks associated with bioenergy in the UK. It reviews the current sustainability governance regulations and makes some recommendations for how these might evolve in the future.

The UK has a world leading and comprehensive sustainability governance system developed by Government and industry, which goes well beyond the EU Renewable Energy Directive requirements. The framework has evolved as experience of deployment has grown and as the scientific understanding of a number of issues has developed. Meeting sustainability requirements is a condition for receiving support under all UK Government bioenergy support schemes.

No similar governance system applies to other energy supply options. This paper argues that more transparent reporting of the full life-cycle emission associated with fossil and other low carbon sources should be established so that bioenergy solutions are seen in proper context. Similarly, the impact of such sources against a wider range of sustainability indicators should be assessed.

The Sustainabilit Working Paper shows that the most significant risks and issues are covered to avoid bad practice, either by regulation or through sustainability certification schemes. In some cases, the regulatory framework needs to be amended to account for updated scientific understanding – for example, by embodying the guidelines on which forestry products have the highest GHG saving potential in the Woodfuel Guidance (Box 5). Table 1 summarises the regulatory approach currently taken for the most significant sustainability issues along with recommendations for how the governance framework could evolve in the future.

Moving forward there is now a need to evolve the regulations so as to encourage the development and deployment of technologies with improved performance as far as GHG reduction and other factors are concerned. This can be achieved by progressively moving to systems where benefits depend on quantitative measures of carbon emissions, such as consistent carbon pricing or schemes like the Low Carbon Fuel Standards, as discussed in the Actions section below. This approach is preferable to further tightening minimum standards (for example for GHG emissions), which risks cutting off solutions that provide very significant benefits compared to fossil fuel use. The regulatory framework will also need to adapt to new technologies and fuels (e.g. BECCUS or the production and use of energy crops) which will be needed to realise the potential for bioenergy as part of a low carbon UK economy.

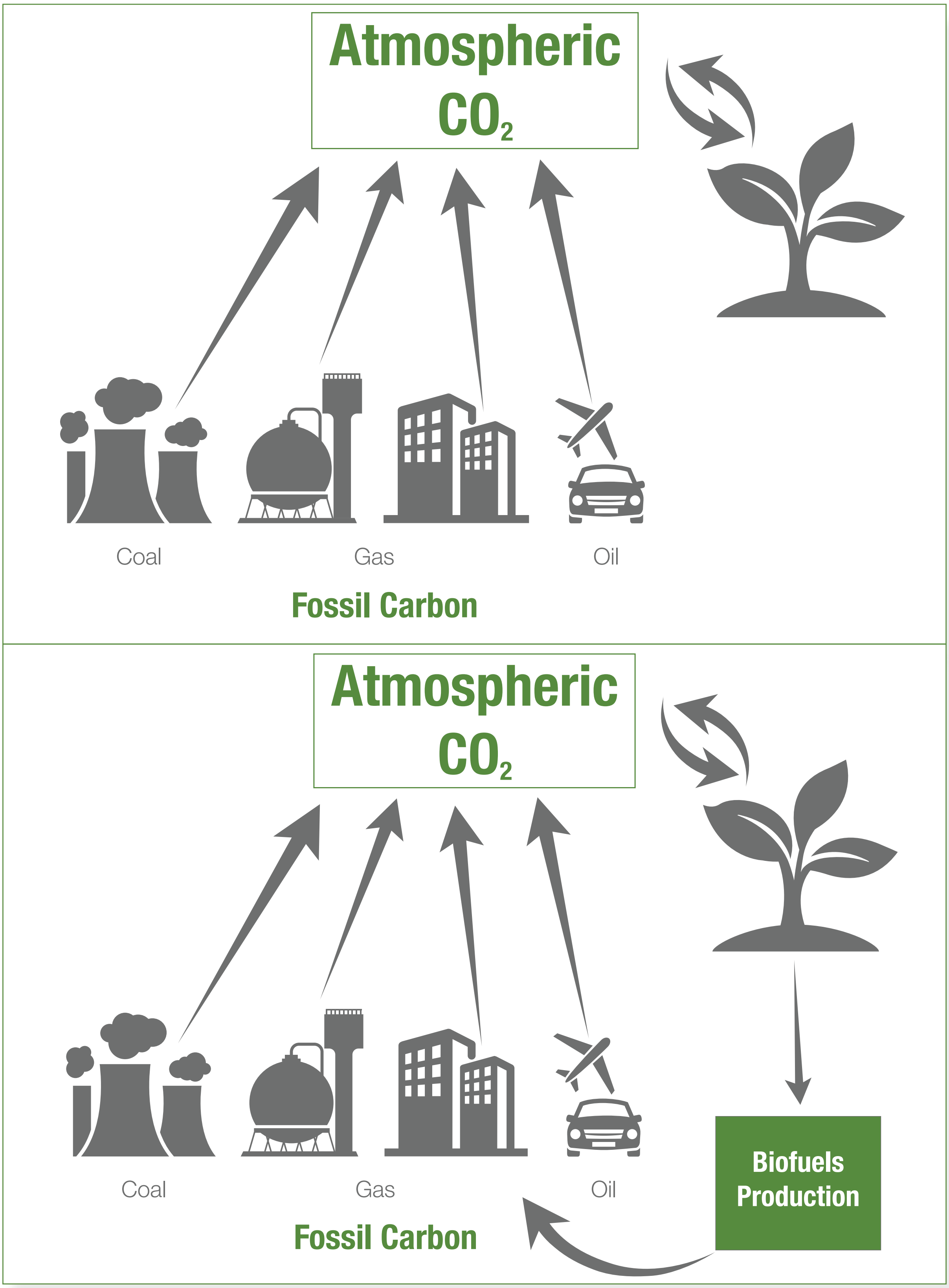
The UK is a pioneer of importing large volumes of biomass from overseas markets. Such imports (as well as exports) of bioenergy feedstocks will be necessary if biomass is to play its enhanced role in a low carbon future. The sustainability framework that has been developed to manage such feedstock pathways provides a model for the future. There are signs that other countries which are starting to import significant biomass supplies are being influenced by UK experience and standards.

Box 4: How does Bioenergy Reduce GHG Emissions?

Biomass based systems form part of a natural cycle of growth and decomposition, operating within the carbon cycle (the atmosphere, ocean, vegetation and soil). Plants absorb CO_2 from the atmosphere as they grow. This is then reduced by photosynthesis to form cellulose, sugars and other biochemicals. When the plant dies most of the carbon in the plant material turns back into CO_2 and is returned to the atmosphere through natural biological and physical oxidation (for example through decay or by fire), so completing the cycle. In using biomass as an energy source, the carbon cycle is intercepted. The stored energy released during oxidation is used productively, rather than just being released into nature.

This means that producing energy from biomass in principle leads to no net carbon emissions. This contrasts with the use of fossil fuel which involves transfers of carbon from geological reservoirs into the atmosphere, adding to atmospheric CO_2 levels.[28] (Figure 9)

Figure 9 • Bioenergy and fossil fuels and the carbon cycle



The system is, of course, more complex than this.

- Some of the carbon fixed by photosynthesis is held in the soil
- If the biomass is used for long lasting products (such as in buildings) then a portion of the carbon is "sequestrated", at least during the product life-time
- If fossil fuels are required in the processes to produce, convert, transport and use biomass for energy or other applications, or if other GHGs are produced, then these can lead to "supply chain emissions" which reduce the overall climate change benefit. These can be quantified with confidence using life-cycle analysis techniques. As the energy economy decarbonises these emissions will reduce proportionately
- Bioenergy production can also lead to emissions if its production and use leads to changes in carbon stocks in soils or vegetation, or affects the way in which the carbon cycle operates in other ways. These are classed as "biogenic emissions" and are often discussed in terms of "direct" and "indirect land-use change" emissions in reference to energy crops and "forest carbon" for woody biomass sources
- While supply chain emissions can be quantified with some certainty, it is more difficult to understand and quantify biogenic emissions and timing effects. However, much progress has been made recently in understanding the issues and developing strategies to avoid risks

Table 1 • UK Sustainability Governance – Current Framework and Recommendations

TOPIC	CURRENT UK REGULATORY APPROACH	RECOMMENDED ACTIONS
Bioenergy and the Carbon Cycle		
Supply chain emissions	• All UK bioenergy support schemes have maximum levels of GHG emissions for the fuels involved, and based on a specific life cycle analysis (LCA)	• Review and update emissions calculation methodologies to remove any inconsistences and to update figures in light of changes in emission levels • Review and publish realistic life cycle emissions for fossil fuel and other energy sources • Move to support mechanisms which better reward GHG performance

Direct land use change	• Feedstocks from land associated with converted high carbon stock land prohibited • Other direct land use emissions factored into LCA	• Continued work is needed to refine the assumptions and data used in these calculations, notably those associated with soil carbon calculations
Indirect land use change	• 4% UK constraints on food crops and those grown on agricultural land in RTFO • "Double counting" incentives for waste based biofuels	• The real world impact of indirect land use change (ILUC) should be kept under review • The RHI and its successors will need to be made consistent with the RTFO to allow production and use of energy crops for biomethane which meet sustainability criteria
Bioenergy and Forest Carbon	• Sustainability provisions for forest based fuels for electricity and heat production embodied within the Woodfuel Advice Note	• Continue to reinforce sustainability regulations for forest products used in bioenergy and expose reporting to wider peer review • Embody the Forest Research criteria in wood fuel sustainability guidance • Continue research into the carbon aspects of forestry management and its relationship with bioenergy • Continue to engage with a wider range of stakeholders to clarify these benefits, to identify legitimate concerns and to ensure that these are taken into account when further developing sustainability governance in this area
Bioenergy with CCUS	• Accounting procedures for "negative emissions" associated with BECCUS not yet clear	• Develop GHG accounting procedures and LCA methodologies which properly account for GHG benefits associated with BECCUS
Other environmental social and economic issues		
Air quality	• Robust air quality legislation in place but not always enforced	• Tighten and enforce strict regulations for uncontrolled biomass combustion in open grates, and badly regulated stoves, especially in urban areas

Air quality	• Biomass boilers have to meet DEFRA Exempt Appliances Standard, and from 2022 will have to meet stricter Ecodesign standards • Large scale plants need to meet EU Best Available Techniques (BAT) requirements, with tougher standards from 2021	• Set technology neutral performance standards for emissions from biomass heating and power generation systems rather than unnecessarily banning projects on air quality grounds • Government and industry to establish and rollout a Biomass Quality Management scheme to improve installation standards and best practice
Biodiverdsity	• Feedstocks from areas of high biodiversity value prohibited	• Develop evidence to check that current measures are providing the necessary protection and publicise the results • Develop ways of incentivising best practice as far as biodiversity and other factors as part of the arrangements for stimulating the increased production of perennial and annual energy crops within the UK
Bioenergy and food	• Covered by provisions relating to indirect land-use change	• Keep under review evidence of relationship between bioenergy, food availability and costs
Waste and resource management	• Importance of use of wastes for energy recognised in the Waste and Resources Strategy • Landfill tax encourages and makes economic use of wastes for energy • Separate collection of food wastes in Scotland and Wales to be introduced in England	• Pursue separate collection of food waste and provide additional resources to early movers to encourage adoption. • Maintain and progressively increase landfill tax rates • Provide support for heat from EfW plants under any RHI successor, without imposing constraints on the size of heat load which currently limit the use of heat from economically sized EfW plants

Waste and resource management		• Focus schemes like the Heat Networks Investment Project (HNIP) designed to promote heat networks on schemes fueled by waste biomass and other low carbon sources, rather than on gas fired plants
Other social and economic issues	• Criteria on other social and economic issues including land and labour rights covered in the Woodfuel Guidance, voluntary certification schemes, and the RTFO	• Review the need to make social and economic criteria mandatory requirements for all Government bioenergy support schemes

Box 5: Bioenergy and Forestry Products

The use of feedstocks from forestry sources is the most sensitive and controversial area as far as the sustainability of bioenergy is concerned, particularly where this involves imported forestry based feedstocks. In the last few years, there has been a vigorous debate about how to interpret the science in respect of recommendations and conclusions as to which forestry products should be used for bioenergy.[29] On the other hand, systems for ensuring good forest management are well developed, and can be used as the basis for bioenergy sustainability governance. The continuing debate is probably because of two main factors:

- Wider sensitivities about the sustainability of forestry and the need to protect the resource against illegal logging and exploitation. This includes the extent to which forests should be managed or exploited as a resource, particularly for energy purposes
- The more complex factors which affect the extent and timing of GHG savings associated with the use of some forestry products for energy purposes, compared to those for other bioenergy feedstocks

In principle, materials produced in forests are the same as other biomass materials as far as the carbon cycle is concerned. The forest absorbs CO_2 from the atmosphere, which is held in the forest material until it dies, decays and returns to the atmosphere. Using the material for energy purposes interrupts this process and makes use of the energy otherwise dissipated during decay. However, the carbon cycle for forestry is more complex because of the carbon that stays in the soil, and particularly because the biogenic carbon cycle for some forests and forestry materials can be considerable, since forest rotations are lengthy and biomass decay can be a relatively slow process. This differs from many other potential bioenergy sources with a short carbon life cycle, such as annual crops and their residues. This introduces important time considerations to the potential carbon benefits or disbenefits of using forestry products for energy purposes.

Research to understand these complex issues and to reduce uncertainty over the extent and timing of carbon savings from the use of forest products for bioenergy is continuing and scientific understanding has improved in recent years.[30] Despite the complexity, it is now increasingly possible to distinguish between cases where there are clear and unambiguous short-term carbon savings, where uncertainties and risks exist, and where the energy use of forest materials is best avoided on carbon grounds.

The most recent work by Forest Research (FR) has concluded that bioenergy production which involves additional harvesting can create significant risks of high GHG emissions. By contrast, harvesting in order to produce long lasting timber products, with small/early thinnings, forest residues and industrial residues used for bioenergy production is low risk and leads to low GHG emissions. FR has produced a number of criteria which summarise their findings by working to exclude high risk options. These could be embodied in the UK regulatory framework to provide additional assurance that the materials used as fuel are producing significant and genuine GHG savings.

There is an alignment between these sustainability criteria, the interests of producers and uses of forest products for energy. For practical and economic reasons, using products which are co-produced with much higher added value products such as timber and panel boards will be favoured by forest owners (who wish to maximise their revenues) and by biomass energy producers, who wish to reduce their costs. This also allows them to take advantage the existing supply chain infrastructure to produce higher added value products.

Despite the regulatory frameworks in place, the use of forestry resources (especially those sourced for the Southern US) is still controversial, with some stakeholders continuing claims that materials are sourced in an unsustainable way, and do not lead to material carbon savings. This includes the much-repeated assertion that using biomass feedstocks for power production leads to higher emissions than using coal.[31] This is based on a selective view which misrepresents research into the GHG impacts of using forestry materials for energy. This claim was underpinned by a view of focussing on one extreme scenario (in which all forestry products are used entirely for energy production), despite the fact that the research covered over 120 scenarios, many of which showed significant climate benefits.[32]

This shows that despite the research, analysis and regulatory approach, there is still a widespread misunderstanding of the benefits conferred by using appropriate forest products as an energy source, where the proper sustainability principles are applied. There is therefore a continued need for work to clarify these benefits, to identify legitimate concerns of a wide range of stakeholders and to ensure that these are taken into account in further developing sustainability governance in this area.

Despite the UK's rigorous sustainability frameworks, there are still widespread misconceptions about the role of bioenergy in a low carbon economy and its sustainability credentials.
There is an urgent need for industry and Government to engage with a broader range of stakeholders in order to address these misconceptions, understand remaining concerns and improve communication. The REA will play a role, working with government, industry and other stakeholders, to convene such discussions.

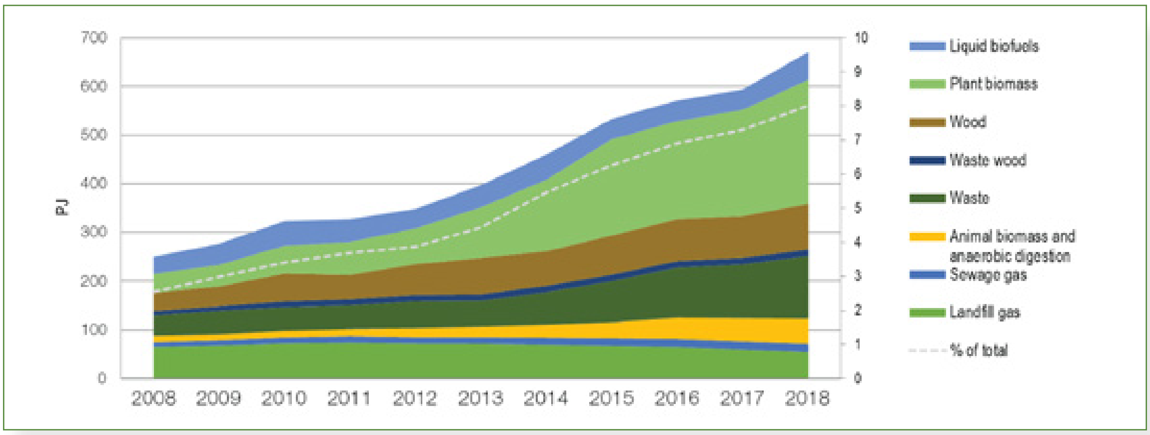
4. UK Bioenergy – Now and in the Future

Growth of Bioenergy to 2018

Phase One of the Bioenergy Strategy demonstrated what bioenergy contributes to primary energy supply in the UK, which is summarised briefly in this section.

The BEIS Digest of UK Energy Statistics (DUKES) records the contribution of bioenergy and wastes to UK energy supply has grown by a factor of more than 2.5 in ten years, from 250 to 673 Petajoules (PJ)/year (Figure 10). Biomass and wastes now supply around 8% of UK total primary energy supply compared to 2.6% in 2008. The growth in the use of bioenergy has so far been concentrated in the electricity sector (Figure 10).

Figure 10 • Bioenergy and wastes in UK primary energy supply



Source: BEIS Digest of Energy Statistics 2019

Electricity

Stimulated by the Renewables Obligation and Feed-in Tariffs, since 2008, bio-electricity generation grew by a factor of 3.3, providing 35 TWh in 2018. This accounts for nearly a third of all renewable electricity generation and 12% of UK electricity generation;[33] equivalent to four Sizewell B nuclear plants or 1.5 times the anticipated output from Hinkley Point C.[34]

A steady contribution from landfill gas has been supplemented by strong growth in the use of plant biomass for power generation, based on a mixture of indigenous sources and imported wood. There has also been growth in other sources such as energy from waste and anaerobic digestion.

Bioenergy for Heating

Bioenergy use for heating saw 3-fold growth between 2008 and 2018, with bioenergy now providing nearly 5% of UK heat, up from 1.4% in 2008.[35] Official statistics show Domestic (residential) use makes the largest contribution (over 40% of the total) at 94 PJ in 2018 and the proportion of biomass in household energy supply has risen steadily from 2% to 5% since 2008. However, industry questions this level of wood use and believes that the rate of growth in this sector has been significantly overestimated, with the actual amount of energy provided by wood being closer to 45 PJ.[36]

Biomass use for heating in industry has also grown to provide around 5% of heat needs (up from just over 1% in 2008). Use is concentrated in the paper, printing and minerals sectors, and in agriculture. Use in the commercial and public administration sectors has also risen by a factor of four since 2008.

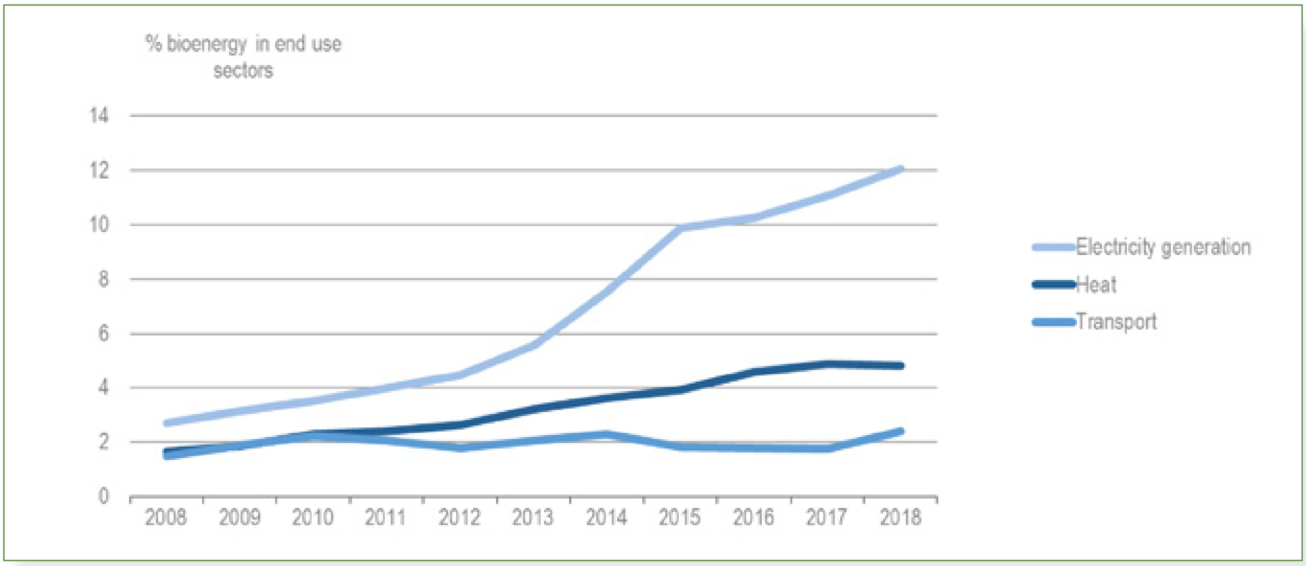
Biomethane production and injection into the gas grid has grown rapidly between 2014 and 2018. In 2018, 8 PJ of biomethane received payments under the Renewable Heat Incentive (RHI). UK capacity for biomethane is estimated at 16 PJ, which may rise to 25 PJ by 2020.[37]

Biofuels in Transport

The use of biofuels in the transport sector has not significantly risen since 2008 and rests below 3% of total UK transport fuel requirement on an energy basis, despite the provisions of the Renewable Transport Fuel Obligation (RTFO)[38] and a 37% growth in biofuels used between 2017 and 2018.

The proportion of bioethanol in the biofuels mix increased in 2013 and, in recent years, made up 42% of the total. Biodiesel production has increasingly switched to waste-based feedstocks, which are prompted by the "double counting" provision within the RTFO and provide higher GHG savings compared to crop based feedstocks.

Figure 11 • Growth in bioenergy by sector



The Future Role of Bioenergy in the UK

Approach

Phase Two of the REA Bioenergy Strategy developed a quantitative vision of the role that bioenergy can play in the UK by 2032, which is summarised below.[39] The vision was developed in discussion with industry members of the REA, assuming a supportive policy and regulatory environment. The potential vision takes account of:

- The availability of biomass resources consistent with sustainability criteria
- The rate at which markets could be developed
- A mix of well-established and commercially available technologies, as well as technologies still at earlier development and commercial stages, which are likely significantly deployed nearer to, and after, 2032 to be
- The principles relating to the efficient use of biomass have been respected (See Box 6). Local use of biomass for heat is preferred where possible

The vision acknowledges that the ways in which bioenergy is used may change over time, as new technologies mature and as the overall energy system becomes less GHG intensive. In the long-term, there will be opportunities for bioenergy linked to carbon capture usage and storage (CCUS), and in decarbonising particularly challenging sectors, like aviation, as identified by the CCC. This being said, there is also a recongnition that using local biomass will always offer some advantages in terms of efficiency and cost.

Rather than do nothing until new solutions become available, The Vision is founded on the need for early deployment of existing bioenergy technologies as soon as practicable, so long as GHG reductions and low costs are realised.

This approach will:

- Lead to immediate GHG, economic and other benefits
- Develop national and international supply chains which will support the large-scale use of bioenergy in the future, and which will take time to evolve
- Maintain and develop UK expertise in bioenergy
- Provide opportunities to develop projects which serve as a stepping stone towards the longer-term options (e.g. by providing initial market opportunities for biomass gasification or for projects associated with carbon capture and use)
- Provide insurance against delays or longer-term problems in deploying the new technical options
- Having a large scale and active UK bioenergy sector will also make it easier to deploy new technologies when the time is right, as it will be easier to develop and finance such projects when there is a mature biomass supply chain in place

Strategic Aims

Overall, the strategic aims for the proposed vision are to:

- Immediately expand GHG savings from bioenergy based on well-developed and affordable technologies which also provide significant co-benefits
- Develop and deploy some additional technology options which can also contribute GHG and other benefits by 2032, whilst also opening up options over the longer term
- Demonstrating bioenergy production coupled to CCS or CCU by between 2023 -2026 and expanding the contribution to carbon savings substantially by 2032

Box 6: The "Best" Use of Biomass

There are many ways in which biomass may be used to provide energy, and the "best use" of bioenergy is dependent on the whole energy system and, in a low carbon context, the other opportunities available to decarbonise. However, the specific characteristics of biomass as an energy feedstock impose a number of principles that need to be respected.

These include:

- Production of residues or wastes on-site is, where possible, preferable as the most economic, energy and carbon efficient. This is because transport costs and related emissions are avoided
- The most efficient use of biomass with best GHG balance is in the direct production of heat with a conversion efficiency matching those of fossil fuels and approaching 90%. Heat production efficiency and capital cost are not strongly dependent on scale
- Transformation to other products or vectors always means a loss of efficiency – for example efficiencies for conversion to electricity are usually between 20 - 40%, and thermal conversion to methane has an efficiency of around 50%
- When biomass needs to be converted to other products or vectors rather than used directly there is an advantage in moving to larger scale projects in order to gain improved efficiencies and lower unit capital costs. For example, the efficiency of power generation is very sensitive to scale, rising from 10-15% to 40% at large scales

The technologies that will enable some of the low carbon bioenergy options are not as yet technically proven and commercialised. For example:

- Large-scale thermal gasification of biomass to enable production of biomethane (bioSNG) is not yet commercialised
- Biofuels for aviation are at an early stage of development and so far provide some 0.01% of aviation fuel
- There are very few examples of bioenergy production with CCU or CCS even at a pilot scale

As these new technologies become available more opportunities to use bioenergy will open up. Developing solutions based on conventional technology now, will not stand in the way of new technologies and applications in the longer term. Rather this approach will provide a solid basis for the introduction of these technologies as market opportunities develop.

The opportunities for power, heat and transport are classified into three groups:

- Immediate opportunities - technologies which can be further deployed immediately
- Development opportunities - technologies or resources which need further technology or market development, but which could make a contribution to energy needs between 2026 and 2032
- Strategic opportunities – options involving carbon capture use and storage which will be needed in the longer term, and which need to be demonstrated by 2026, and deployed at a significant scale by 2032 with a view to further expansion thereafter

Bioenergy for Heat Supply

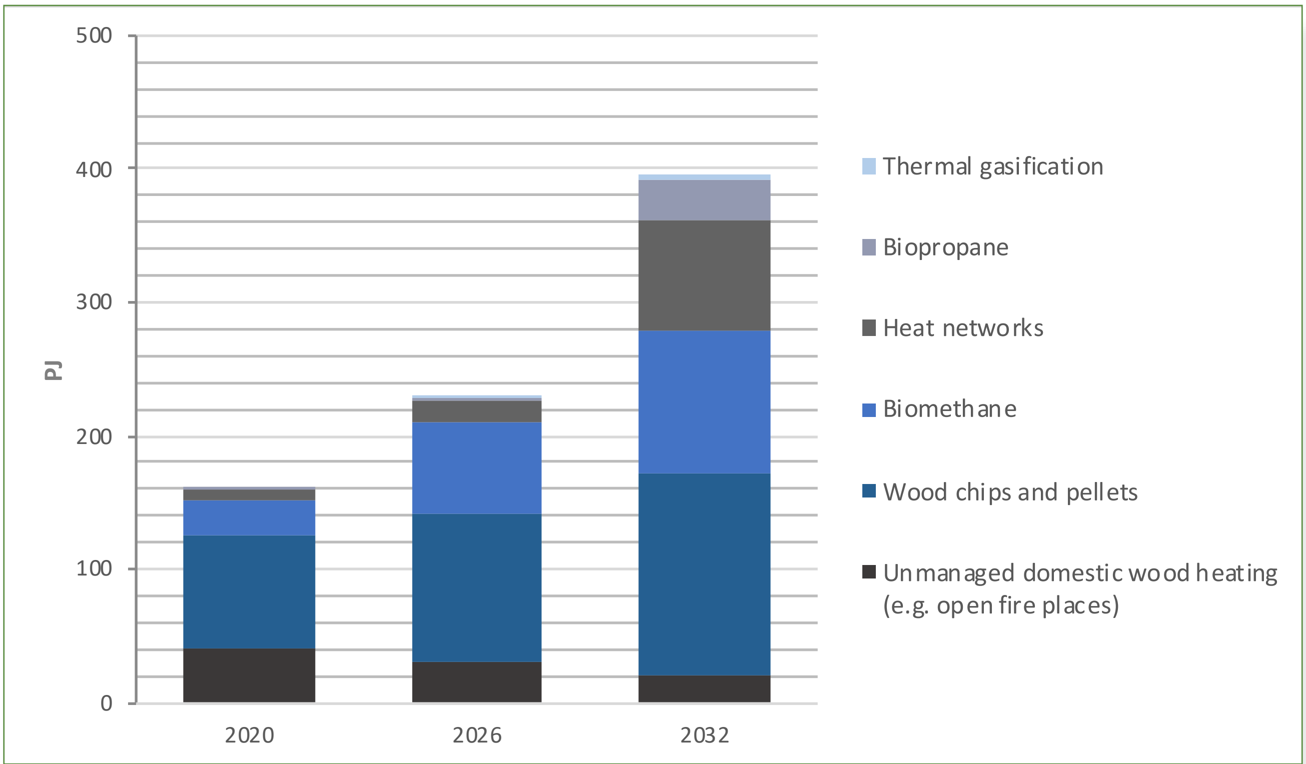
There are significant opportunities to expand the role of bioenergy in providing low carbon sources of heat. Bioenergy can play a particularly useful role in decarbonising heat demands not connected to the gas grid but bioenergy can also help decarbonise gas supplied through the network (as biomethane), and provide low carbon heat in urban situations via the use of bioenergy in heat networks. Analysis of the potential role for bioenergy to provide heat for the UK is explored in detail in Phase 2 of the REA Bioenergy Strategy, pages 26 – 35.[40]

Table 2 • Bioenergy for heat – Opportunities and potential to 2026 and 2032

Opportunity		*Potential*	
		2026 PJ (TWh)	*2032 PJ (TWh)*
Immediate Opportunities			
Expansion of use of pellets/chips	Replacement of fossil fuel use for heating in buildings and industry, particularly in larger residential developments and for commercial and industrial sites which are not on the gas grid.	112	152
***Anaerobic digestion (AD)* based Biomethane for gas main injection**	Expansion of biomethane production via AD using existing infrastructure and appliances.	68 (18)	107 (30)
Use of bio-based liquid fuels	Using a blend of biofuels or other low carbon fuels, using existing heating systems and distribution channels.	6	11
Development Opportunities			
Expansion of bioenergy use in heat networks	Low carbon options for heat networks using biomass fuels heat from existing installations such as EfW combined heat and power (CHP) plant as well as new biomass-based installations.	16	83
Thermal biomethane	Expansion of biomethane supply for pipeline injection through the conversion of solid biomass sources via thermal gasification.		5
Biopropane for buildings	Replacement of fossil LPG in buildings and industry us existing devices and supply/storage systems.	2	29

Figure 12 summarises the potential contribution of bioenergy to UK heat supply from the opportunities discussed above. The contribution from bioenergy to the heating sector can increase by nearly 40% by 2026 to 235 PJ (some 11% of total UK heating needs), and by a factor of 2.3 by 2032 to 407 PJ (20% of heating needs).

Figure 12 • Potential Total Growth in Bioenergy for Heat Production



Heat Case Studies

Severn Trent – Utilising Food Waste for Green Gas Production

Severn Trent generates close to 10% of the UK's total biogas, producing bio-methane and electricity from anaerobic digestion (AD). Around 40% of the biogas is produced by Severn Trent Green Power (STGP) which operates 8 food waste AD facilities nationwide. STGP work with over 50 local authorities, food manufacturers, food packers, distributors and retailers, catering and hospitality outlets and waste managements firms to source a variety of surplus, inedible or unavoidable food and liquid wastes. They also grow crops for AD on dedicated land which is ineligible to grow food for human consumption.

In 2018, Severn Trent processed a quarter of all the household food waste collected in England, recycling 400 thousand tonnes of food waste and generating over 0.5 TWh of green gas, enough tom satisfy the heating and cooking requirements of 45 thousand homes.

In addition, STGP facilities produce over half a million tonnes a year of nutrient rich organic feritliser, known as digestate, that is spread over 35 thousand acres. The digestate is PAS110 certified and replaces petrochemical fertilisers; providing organic nutrients to restore depleted soils. It further helps farmers mitigate fluctuations in global commodity prices, reducing costs, while improving sustainability and increasing crop growth yields. Every tonne of food waste treated in AD saves 500kg of CO2 equivalent emissions.

Ncn'ean Distillery – Utilising Biomass Heat in Sustainable Whisky Production

Ncn'ean distillery on the remote Morvean Peninsula began production in March 2017 and was planned from the ground up to be the most sustainable new whisky distillery in the country. As well as drawing on local spring water, 100% renewable electricity and using the spent grain to feed cows on the adjacent farm, they also opted for sustainable biomass as the most environmentally sound and cost-effective way to prove steam for the distilling process.

Capable of utilising woodchips at up to 50% moisture content, the distillery energy centre has an 850kW Kohlbach at its heart. Providing steam at 7 bar, the boiler delivers 100% of the process energy on site without any backup, and also heats the offices, bar and other facilities, with the waste heat created by the grate cooling system used in the nearby bonded warehouse.

By consuming around 1,000 tonnes of timber rather than 220,000 litres of imported fuel oil, the distillery not only avoids over 600 tonnes of fossil carbon emissions each year, but also makes a valuable contribution to sustaining the local rural economy. All the timber used for fuel is grown within sight of the distillery on the surrounding Drimnin Estate, which now has an outlet for its low-grade and unmerchantable timber, improving the overall economics of their forestry operations and creating employment in the supply chain.

Wallington Hall, Northumberland – Biomass Heating for a National Trust Historic Estate

The National Trust aims to supply 50% of its total energy requirements from renewable by 2020, substantially reducing carbon emissions at its properties. Their estates commonly comprise a large number of historic buildings, often with variable levels of energy efficiency. As such, National Trust has chosen to install a number of efficient biomass boilers in order to provide a renewable energy solution which can reliably deliver the heat loads required by such properties. In 2017, the National Trust's Wallington Hall in Northumberland installed two 130 kW wood chip fired biomass boilers to provide heat and hot water to the complex of buildings on-site, including the main hall, estate cottages, offices, gift shop and cafe.

The biomass heating system replaced the estates oil fired boilers, reducing carbon emissions. The system was designed and installed by re:heat and is finely tuned to ensure high quality, efficient and relaible heat production, while high performance filters ensures any emissions are minimal.

Nethybridge Centre – Biomass Powered Small District Heating System

Abernethy Trust is a Christian education charity who runs the Nethybridge adventure centre in Scotland. In 2015, they choose to replace their inefficient electric heaters with a district heating system powered by a 70 kW biomass pellet boiler to heat a group of three holiday cottages and two staff cottages.

Dunster Energy installed the system along with a bulk pellet biomass store, an automated feed system and a 1,500-litre thermal store, allowing the boiler to operate at peak efficiency even when demand is low in the summer. The networking of the controls ensures that water is only pumped around the system when required, further reducing losses, and allows remote monitoring of the system over the internet. Supported through non-domestic RHI, the district heating system has meant the site is able to reduce their carbon emissions by more than 30 tonnes CO2 equivalent per annum.

Bioenergy for Transport

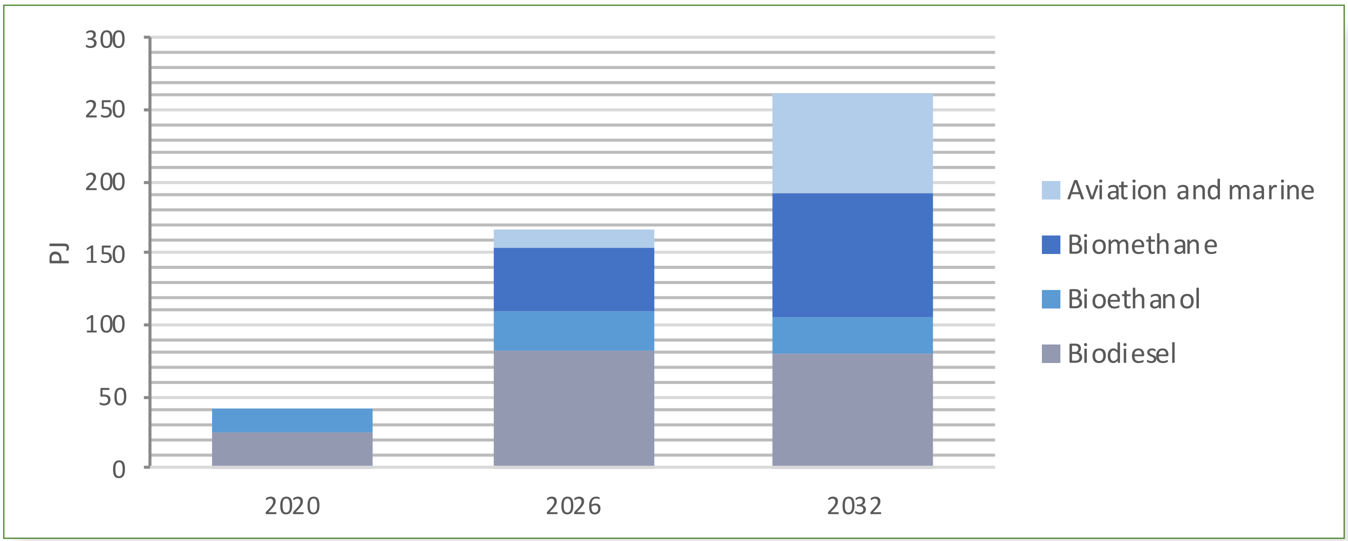
Biofuels already make a substantial contribution to decarbonising road transport and have a longer term role to play in some transport sectors. By replacing fossil fuels they make use of existing infrastructure and vehicles since the fuels can either be blended with fossil fuels or designed as like-for-like "drop-in" replacements. Bioenergy solutions can play a greater role while complementing the electrification of transport; in particular they can be used for heavy and long-haul transport applications including aviation and shipping. As such, the increased use of biofuels does not obstruct the greater use of electricity in transport as the technologies improve, costs come down and the necessary electricity supply infrastructure is put in place.

Table 3 • Biofuels for Transport – Opportunities and potential to 2026 and 2032

Opportunity		Potential	
		2026 PJ	2032 PJ
Immediate Opportunities			
Expansion of bioethanol and biodiesel use	Expansion of bioethanol and biodiesel use by ramping up the blending levels, adopting an E10 blend of ethanol within gasoline and B7 and other higher blend levels for biodiesel.	110	106
Expansion of bioethanol and biodiesel use	Expansion of bioethanol and biodiesel use by ramping up the blending levels, adopting an E10 blend of ethanol within gasoline and B7 and other higher blend levels for biodiesel.	110	106
Development Opportunities			
Biofuels in aviation and shipping	Replacement of aviation and shipping fuels with sustainable biofuels.	13	68

Figure 13 summarises the potential contribution of bioenergy to UK transport energy supply from the opportunities discussed above. The contribution for bioenergy rises by a factor of 4 by 2026, and by a factor of over 6 by 2032.

Figure 13 • Potential Total Growth in Bioenergy for Transport Energy to 2032



Transport Case Study

Ensus – Bioethanol Production in Teeside

The Ensus facility on Teesside produces bioethanol along with two important co-products; a protein rich cattle feed and food-grade CO2 which is used in the beverage industry. The bioethanol is sold to refineries, which blend it at levels of up to 5% with petrol to produce E5, which is the main petrol grade consumed in the UK.

The feedstocks for the process is primarily UK-grown feed wheat, which is fermented, turning the starch into alcohol.
Feed wheat has relatively low levels of protein – making it unsuitable for milling to make bread. As such, it is this DDGS (Distillers Dried Grains and Soluables) that is supplied as a livestock feed, and which substitutes for imported soy-bean based feeds from South America (which has a higher carbon footprint and are associated with greater concerns surrounding land use change and deforestation).

In 2018, the bioethanol produced at Ensus had a 64% carbon saving (in comparison fossil petrol) and this year its GHG savings will be even greater. The company has recently been striving to go beyond the GHG savings required by the Renewable Transport Fuel Obligation, through a variety of energy efficiency measures, alternative feedstocks sourcing and capturing and utilizing its biogenic CO2 emissions. The GHG reporting regulations have provided the stimulus for this, and it makes sense for this policy mechanism to remain in place rather than fall away after the year 2020.

The Ensus facility supports 100 direct employees, and an additional 3000 indirect jobs in UK agriculture and the associated supply chain. Its long-term survival is critically-dependent on the introduction of E10.

Bioenergy for Power Generation

The production of electricity from biomass sources has expanded rapidly in the UK in last ten years and now provides around 11% of all electricity generated in the UK, from a wide range of sources.[41] There is scope to further grow the production of bioelectricity, however, it is necessary to acknowledge that the costs of generation from some bioenergy sources (measured in terms of the levelised cost of energy [LCOE] generation) are now sometimes higher than those of wind power and solar, and that the scope for cost reduction in the future is lower. Cost analyses of electricity generation indicate that bioelectricity generation is most attractive when:

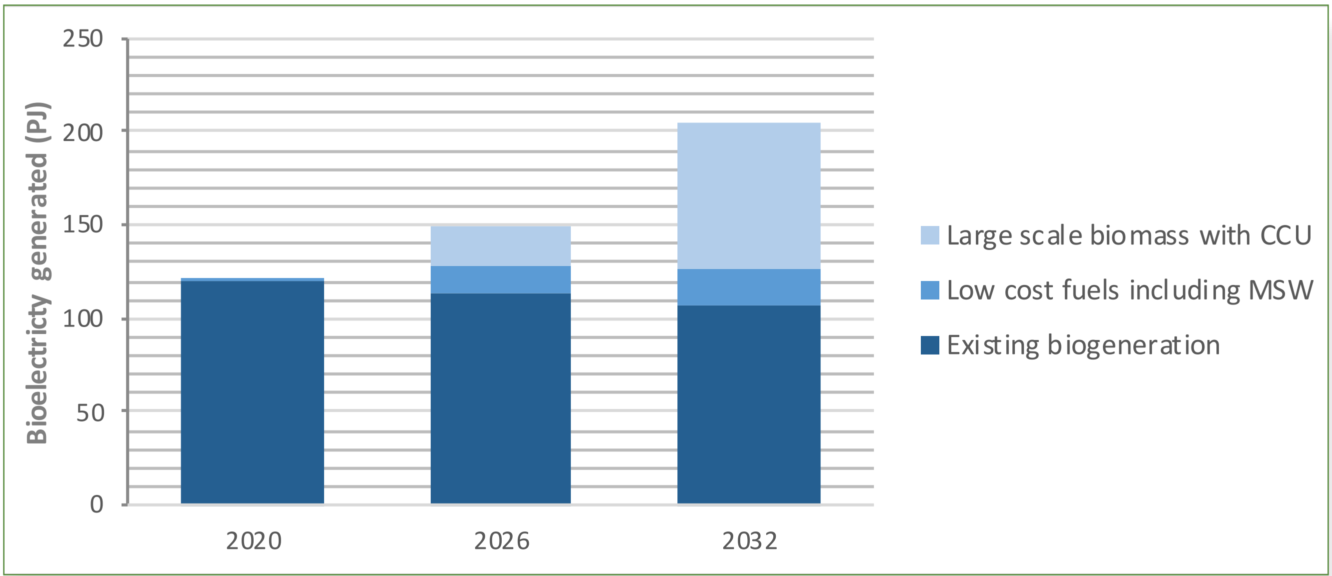
- Low cost feedstocks such as wastes can be used
- Existing fossil fuel assets can be used (for example, through the conversion of plants previously fired by coal)
- Bioenergy plants are configured as combined heat and power (CHP) projects that are able to export a high proportion of heat in addition to power
- Large scale operation leads to lower capital costs and higher generation efficiencies
- Bioenergy plants can play a role in providing firm and dispatchable power so facilitating integration of higher shares of variable renewable energy (VRE) from wind and solar generation
- Bioelectricity production is linked to carbon capture and storage, and is therefore a "negative emission" technology; producing electricity while effectively reducing overall emissions

Table 4 • Bioelectricity – Opportunities and potential to 2026 and 2032

Opportunity		Potential	
		2026 PJ	2032 PJ
Immediate Opportunities			
Maintaining current bioelectricity generation	To maintain generation from existing bioelectricity plants following the closure of current support mechanisms so as to ensure continued environmental benefits from low carbon electricity and heat generation	113	107
Low cost fuels including MSW	Expansion of residual biogenic waste use including those from municipal, commercial and industrial waste streams (after economic reuse and recycling activities), waste wood and other waste fuels for lower cost bioelectricity generation (and where possible linked to CHP opportunities).	16	19
Development Opportunities			
Large scale bioelectricity generation with CCUS	To demonstrate and start to deploy large-scale bioelectricity generation with CCUS by demonstrating carbon capture with subsequent use or storage and new bioelectricity capacity specifically designed for CCUS (c. 300 MW scale biomass pellet fired plants).	20	79

Figure 14 summarise the potential contribution of bioenergy to UK electricity supply from the opportunities discussed above. The contribution rises by 20% by 2026, and by 70% by 2032.

Figure 14 • Potential Total Growth in Bioelectricity Production



Power Case Study

Ince Biopower Ltd – Using Gasification of Waste Wood to Produce Energy

Ince Biopower Ltd, located near Ellesmere Port in Ince, Chesire, is the largest plant of its kind operating in the UK. It uses advanced thermal treatment (ATT) technology – otherwise known as gasification – which is an alternative to incineration that turns waste into a combustible gas by heating it in a low-oxygen environment.

The plant uses waste wood to generate low carbon energy, though the technology can also be used to gasify municipal waste and refused derived fuel. Each year, Ince will process up to 170,000 tonnes of waste wood, converting this fuel into syngas and generating 21.5MW of electricity, enough to power over 40,000 homes.

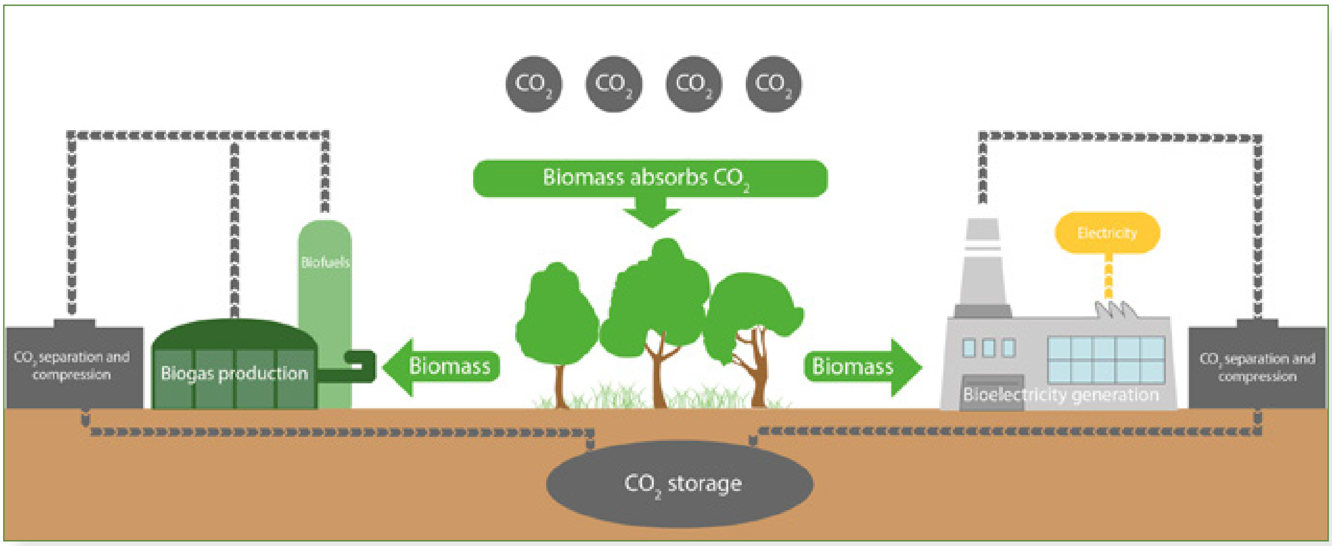
The plant will deliver a net reduction in greenhouse gas emissions worth around 65,000 tonnes of CO2 per annum, the equivalent of taking more than 40,000 cars off the road. Around 150 jobs were created during the construction of Ince Bio Power. The plant will be operated and managed by about 25 full-time employees. The knowledge accumulated during the project will help to develop gasification technology, such that it can be used to synthesise fuels which can be used in more advanced applications uses beyond electricity generation.

Development of Strategic Options with Carbon Capture and Use or Storage

Box 7: Bioenergy with carbon capture and use or storage (BECCUS)

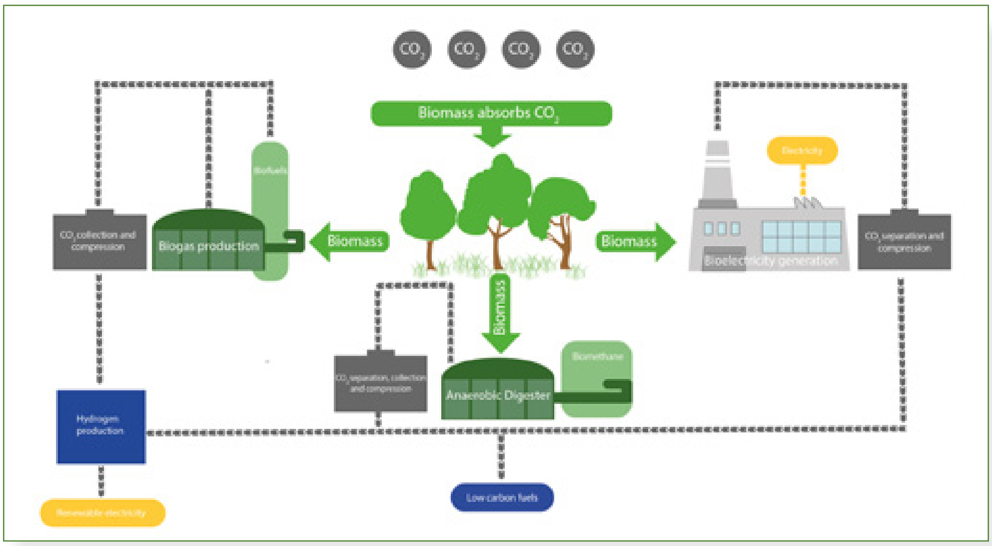
Bioenergy produces energy without requiring fossil fuels to be extracted and used, thereby avoiding the associated CO_2 and other GHG emissions (see Box 4). The life cycle GHG emissions of using bioenergy needs to be carefully assessed but can be close to zero.
It is possible to capture the CO_2 released when biomass feedstocks are converted to energy carriers (such as ethanol or biomethane) or burned (for example to produce electricity). If the CO_2 is subsequently put into permanent storage, then there is a net reduction in GHG emissions for each unit of energy produced. (see Figure 15)

Figure 15 • Bioenergy with CCS



Alternatively, if the infrastructure for transporting and storing the captured CO_2 is not yet in place, then the gas can be reacted with hydrogen (ideally produced by the electrolysis of water using renewable or other low carbon electricity) to produce a range of low carbon fuels, including biomethane, biomethanol, bioethanol, hydrocarbon fuels including bio-kerosene or bio-jet-fuels, or a range of more complex chemicals that could be used either as fuels or as building blocks within a sustainable bioeconomy. (see Figure 16)

Figure 16 • Bioenergy with carbon capture and use



While not taking carbon definitively out of the atmosphere, such processes have a carbon benefit because the fuels produced displace fossil fuels. Using carbon in this way effectively increases the volume of low carbon products from biomass feedstocks.

The strategy outlined above will enable the demonstration of a number of technology options that can be linked to carbon capture use or storage (BECCUS), (see Box 7). These include:

- Large scale power generation
- Thermal gasification of bioenergy to produce biomethane or (other fuels) for heat or transport fuel production

In addition to the CO_2 captured by newly installed systems there are other sources of CO_2 already produced in bioenergy production that could be collected and used or stored – for example when biomethane is separated from biogas, or during the fermentation processes involved with producing bioethanol.

Carbon capture associated with bioenergy production has been demonstrated in a number of cases in the UK, with the gas used for various economic purposes such as in the food industry and for enhancing growth in greenhouses. However, the carbon benefit of these uses is limited (unless the carbon dioxide being replaced is being specifically produced from fossil fuels) and the scale of such potential uses is limited. Carbon capture and storage, when carbon is taken out of the atmosphere and permanently stored, has not yet been demonstrated at scale in the UK and no infrastructure is currently in place. If such infrastructure is developed (for example around a 'Heavy Industry Hub') then nearby bioenergy sources could make use of it.

In the absence of such infrastructure, a "half-way house" is to capture and then use the CO_2 to produce fuels through its combination with hydrogen (bioenergy with carbon capture and use – BECCU. The ability to use the carbon in this way can provide an opportunity to demonstrate the capture process even in the absence of carbon storage infrastructure and may have merits over the long term in its own right. Carbon capture and use can be demonstrated at a scale appropriate to the bioenergy production facility and does not require large-scale capture and storage infrastructure. However, such projects do need access to supplies of hydrogen. This would ideally be produced by electrolysis using renewable electricity rather than from methane.

While CCU systems can be deployed now, further research, development and deployment (R,D&D) is needed to identify the optimum routes for using captured CO_2 in terms of product value and the associated GHG benefits. A potentially interesting option is to “integrate” the carbon re-use into the gasification process by adding hydrogen during the gasification stage. This turns the CO_2 formed during gasification into further hydrocarbons, with little or no emission of CO_2. One effect of such a process is to very significantly increase the yield of biofuels from a given amount of biomass.[42]

It is estimated that some 23 $MTCO_2e$, could be saved due to recycling or storage of CO_2 separated from existing bioenergy processes (6 $MTCO_2e$) and from newly installed capacity with purposed designed capture systems (17 $MTCO_2e$).

To stimulate both BECCS and BECCU projects, a favorable policy and regulatory framework which indicates that making BECCS or BECCU financially rewarding (or mandatory) will be a prerequisite before companies commit to the necessary investment in R,D&D to develop and demonstrate the technologies.

Further analysis on the opportunities of BECCS can be read in the REA’s recently published report “Going Negative: Policy Proposals for the UK Bioenergy with Carbon Capture and Storage”.[43]

BECCS Case Study

Delivering BECCS – Drax aiming to be the world’s first negative emission power station

Drax Power Station, in Yorkshire, has undergone a decarbonisation transition to operate on sustainability sourced biomass wood pellets in place of coal, converting four of its six-generation units. Each one of the four 660 MW biomass units will be fitted with carbon capture and storage (BECCS), becoming operational between 2027 and 2035. Upon completion of this process, the four units will provide 2.4 GW of clean ‘firm’ power on the system, whilst capturing 16 MtCO2 per year, creating the world’s first negative emissions power station.

In February 2019, Drax announced the operation of their BECCS demonstration plant, using innovative technology developed by Leeds-based C-Capture, to capture a tonne of CO2 a day during the pilot. This is the first time carbon dioxide gas has been captured from the combustion of a 100% biomass feedstock anywhere in the world.

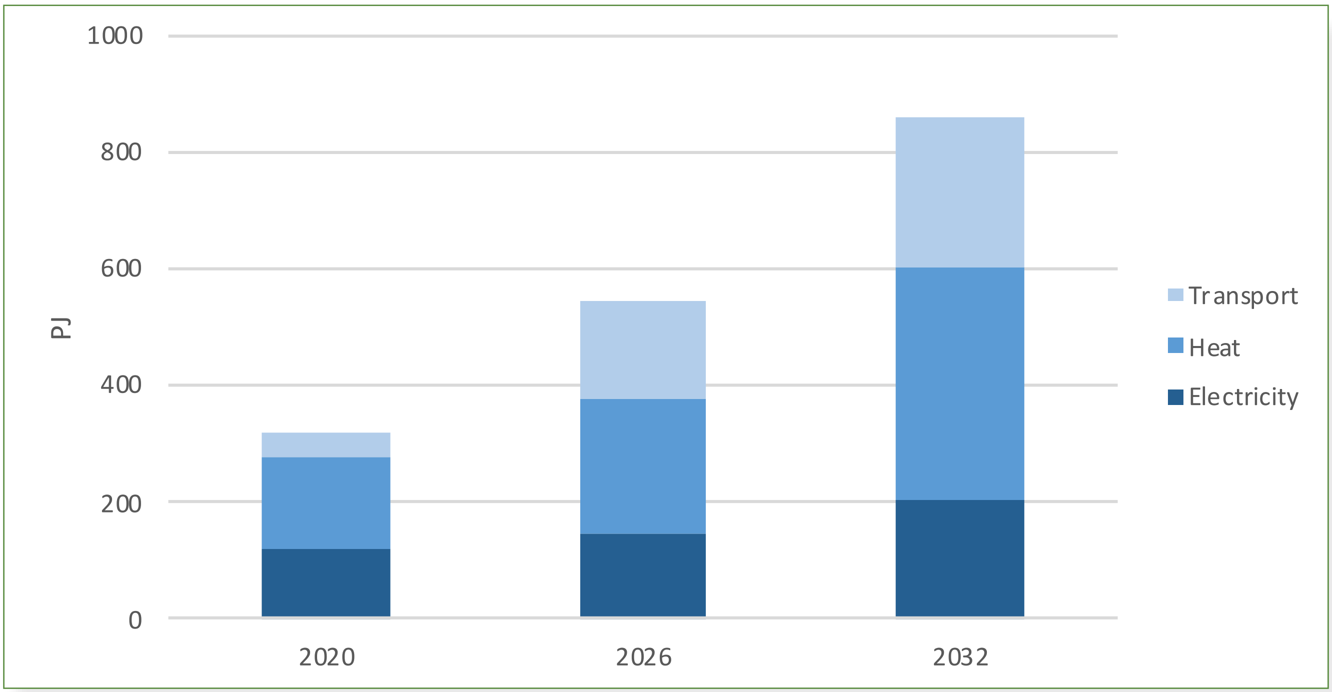
The CCC’s Net Zero report identified BECCS, “as one of the required key near-term actions that are on the ‘critical path’ towards the UK achieving net zero emissions by 2050”, reaffirming its vital role by adding that for industry, hydrogen production, electricity generation and negative emissions technologies, “CCS is a necessity not an option for reaching net-zero GHG (greenhouse gas) emissions”.

As such, the deployment of BECCS at Drax Power Station should be considered an ‘anchor project’ for wider deployment of the technology in the Humber region and further across the UK.

Overall Vision for Bioenergy Contribution

Figure 17 summarises the potential contribution of bioenergy to UK energy supply in the electricity, heat and transport sectors as discussed above. The overall contribution to energy supply rises by a factor of 1.6 between 2020 and 2026 to 530 PJ, and by a factor of 2.6 by 2032 reaching 843 PJ. This means the share of bioenergy in final energy consumption rises to 10% by 2026 and 16% by 2032.[44]

Figure 17 • Potential Overall Growth in Bioenergy to 2032



Growth is particularly targeted at the heat and transport sectors, where bioenergy can play a unique role in decarbonisation efforts. The vision also embraces important stepping-stones in the development pathways for technologies that can be adapted to CCS when the need arises and to the development of the supply chains that will be a prerequisite for an enhanced future role for bioenergy.

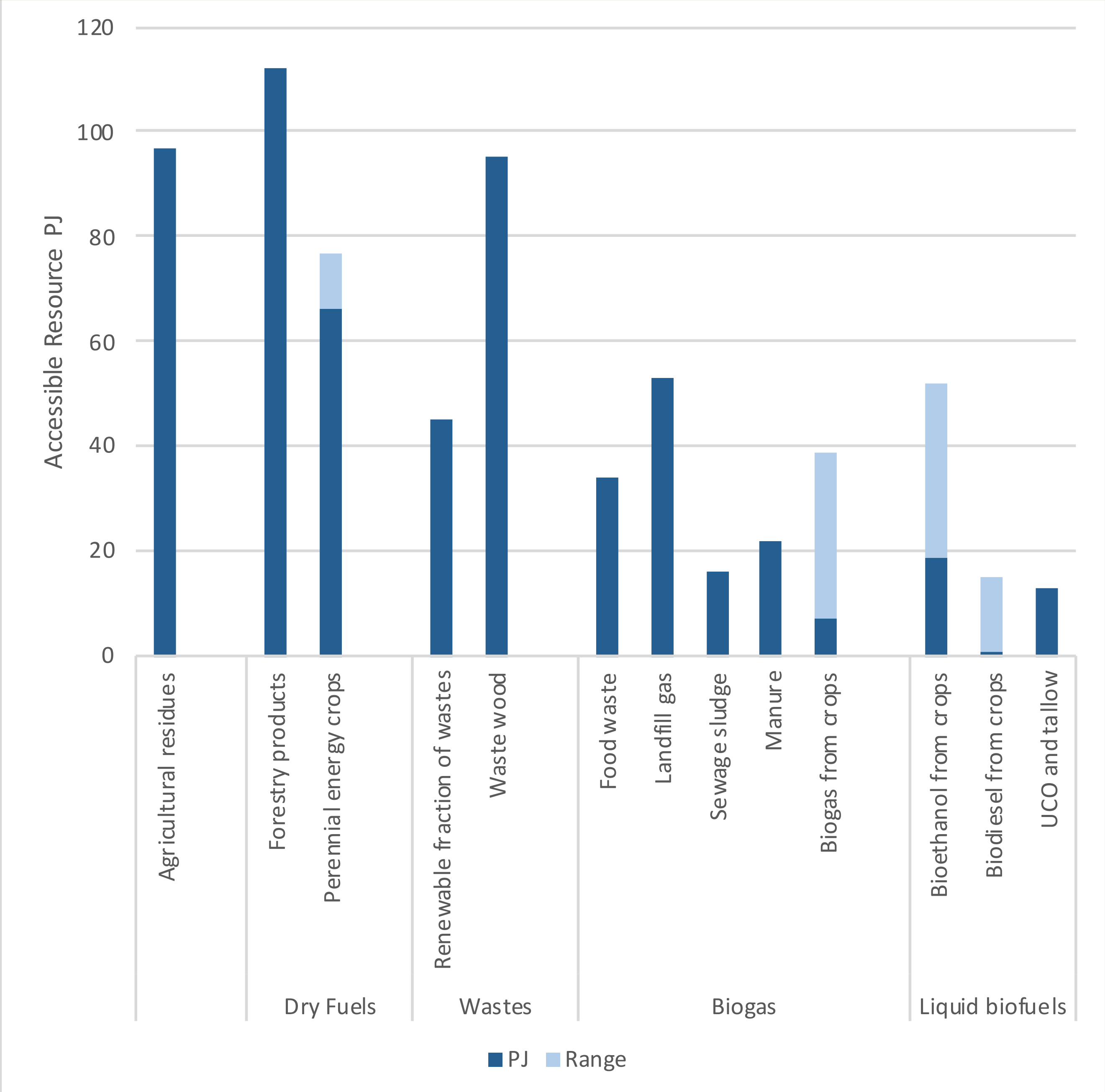
Biomass Resources

UK Feedstock Availability

There have been many reviews of the availability of bioenergy feedstocks for use in the UK. Most notably, BEIS has a UK supply model, recently updated by Ricardo. This provides estimates of both UK and internationally available resources, taking into account appropriate sustainability criteria, competing non-energy uses and potential barriers to making the feedstocks available.[45] Their estimate of the accessible UK based supply feedstock supply for 2030 is summarised in Figure 18. The total resource amounts to between 580 PJ and 672 PJ, made up of the following categories:

- Relatively dry feedstocks appropriate for combustion or thermal treatment including:
    - Agricultural residues (principally straw)
    - Products from forestry and timber industries including forest residues, stemwood, sawmill coproducts and arboricultural arisings
    - Perennial energy crops (such as miscanthus and short rotation coppice)
    - Wood waste
    - The renewable fraction of wastes (RFW)
- Feedstocks suitable for anaerobic digestion to produce biogas or biomethane including
    - Food waste
    - Sewage gas, sludge and landfill gas
    - Livestock manures
    - Crops appropriate for biogas production
- Feedstocks for biofuels production including
    - Bioethanol and biodiesel crops
    - Used cooking oil (UCO) and tallow

Figure 18 • Acessible UK Bioenergy feedstock Resource, 2030



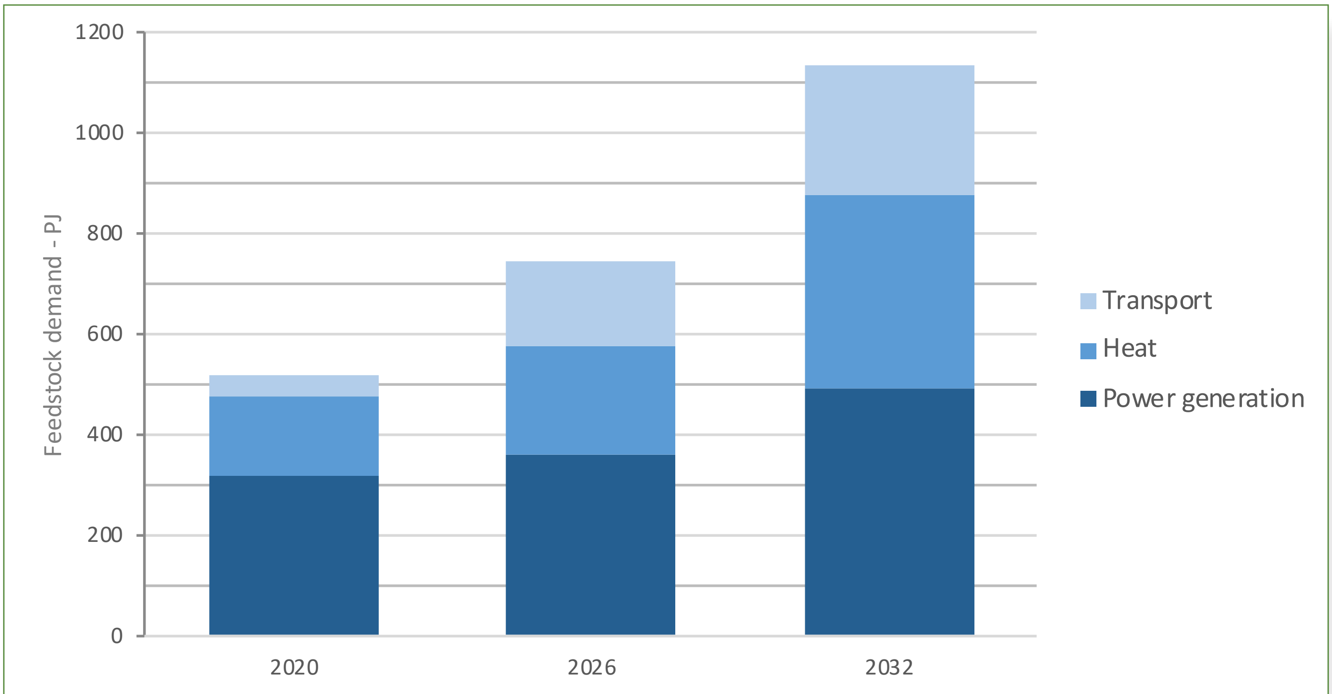
Source: BEIS Digest of Energy Statistics 2018

Bioenergy Vision - Feedstock Requirements

The curent pattern of bioenergy production in the UK makes use of a wide range of domestic feedstocks including: municipal solid waste, landfill and sewage gas, wood wastes and wood fuels, animal wastes, bedding, straw, energy crops, miscanthus and short-rotation forestry. The UK also uses imported materials in the form of biofuels for transport (biodiesel and bioethanol) and wood pellets for use in large scale power generation and heat.

The use of the higher levels of bioenergy proposed in the vision set out above implies a greater use of biomass resources by 2032. Table 19 shows how the feedstock demand would need to increase to meet bioenergy demand in the heat, transport and electricity sectors.

Figure 19 • Bioenergy Vision – Feedstock Requirements to 2032



Meeting these levels would make full use of the potential feedstocks that are available, or that could be developed, within the UK by 2032 according to the Ricardo study. Fuel use is made up of the potential supplies from forestry, wood industries and from wastes (with ambitions to stop the landfilling of organic wastes by 2026). In addition, the strategy relies on the development of energy crops – "dry" cellulosic crops such as miscanthus, short rotation coppice and crops suitable for digestion. An active programme will be required to develop the necessary supplies and infrastructure.

Additional imported resource would be required, notably solid biomass pellets for large scale power generation where the volumes imported would need to double to around 400 PJ. Additional liquid biofuels for transport would need to come from international markets (between 100 and 150 PJ, depending on the volumes available from the UK), but in industry's view the necessary materials could be procured whilst respecting stringent sustainability criteria.

The paragraphs below are simplifications, but indicate the principal ways in which feedstocks are likely to be used by 2032, taking account of the characteristics of fuels involved.

Wood fuels: the UK-based supplies of wood fuel from forestry, sawmill residues and arboricultural applications are assumed to be principally used to supply heat markets, where there is good matching between the widely dispersed nature of the supply which aligns well with the most likely markets in rural areas.

Perennial crops (such as miscanthus and short rotation forestry): will also be used to supplement the products from forestry and timber industries in the heating market. The volumes required by 2032 imply a planted area of some 450,000 hectares by then (assuming a yield of around 10 oven-dry tonnes/ha/year).

Solid biomass fuels (such as wood pellets): from overseas markets, currently used for large scale generation, are likely to be the fuel of choice for expansion of this type of use, given the need for such large scale supply. Delivering the fuels in quantity by sea and rail has cost and GHG benefits.

Waste fuels (such as MSW and waste wood): are assumed to be principally used in large scale CHP plants given the neeed for the plants to be fitted to meet Waste Incineration Directive Emission standards. They will supply a proportion of the heat required for the expansion of urban heat networks. Some material could also be diverted to thermal gasification when the technology is in operation, or used in industrial processes such as cement manufacture.

"Wet wastes" (such as food wastes, sewage sludge and animal manures): will be primarily used to produce biogas (along with landfill and sewage gas) which can either be used directly or upgraded to methane for heat and transport uses.

Crops designed for biogas production: will be used to complement wet waste supplies.

Agricultural wastes (mostly cereal straw): will be used in a number of applications, but its characteristics favour its use to complement other agricutural resources as a feedstock for anaerobic digestion, or as a feedstock for making cellulosic ethanol as a supplement to other ethanol feedstocks, rather as a feedstock for combustion or gasification.

Other biofuels crops: can be produced where this provides agricultural benefits without impacting on food production, and supplemented by fuels imported from the international market (principally to serve the transport market but with other applications such as biopropane for heating, or as a blending fuel in heating oils).

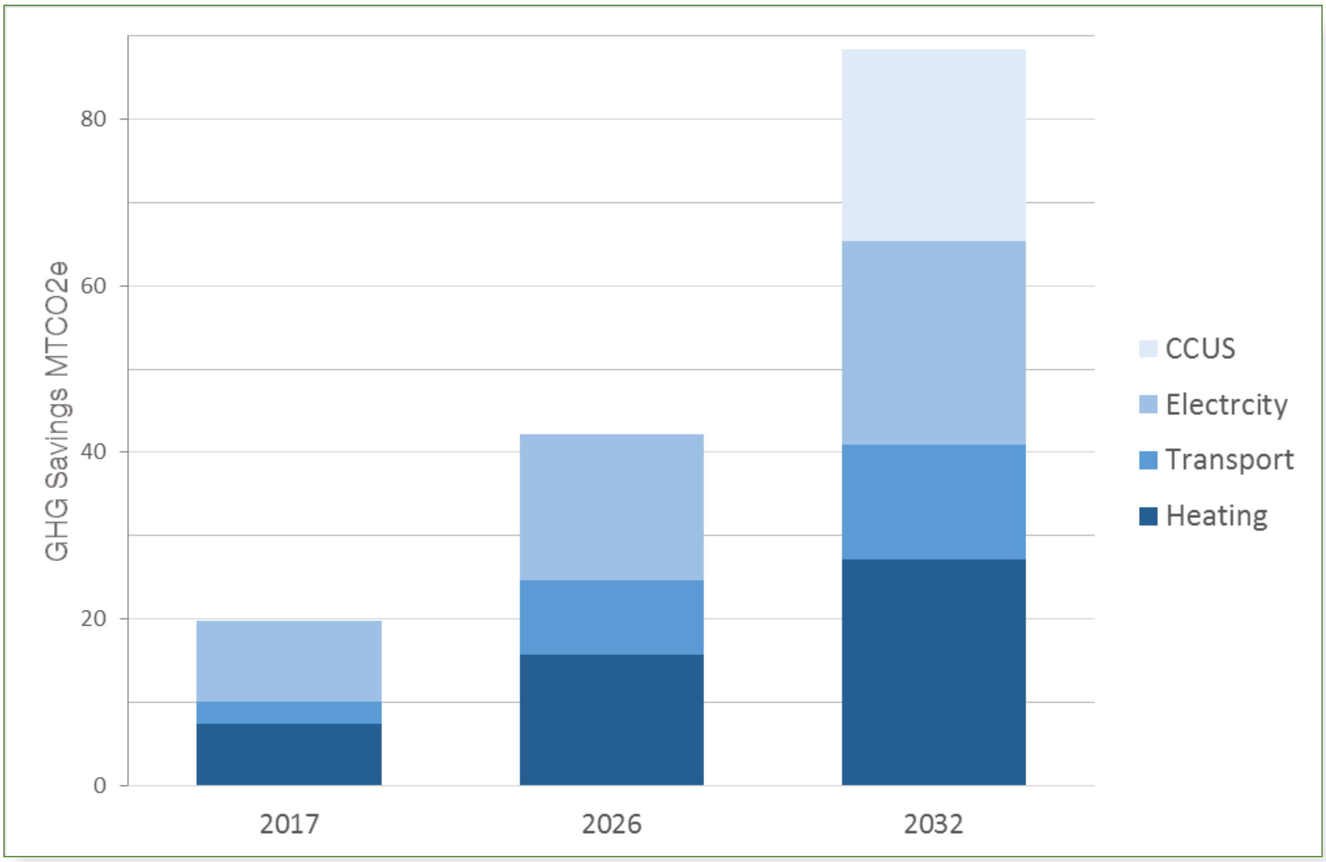
Benefits

GHG Benefits

The GHG benefits associated with the current contribution from bioenergy have been estimated using the current GHG performance of the range of bioenergy options presently deployed and the fuels which they are replacing.[46] A consideration of all three major sectors – electricity, heat and transport indicates that, in total, bioenergy reduced GHG emissions by some 19.7 $MTCO_2e$ in 2017. This corresponds to around 3.8% of total UK emissions for that year (513 M Tonnes CO_2e).

The GHG benefits associated with the contribution from bioenergy in 2026 and 2032 have also been estimated based on emission factors for the fuels most likely to be replaced (Figure 20).

Figure 20 • Emissions Savings Associated with Bioenergy Vision – 2032

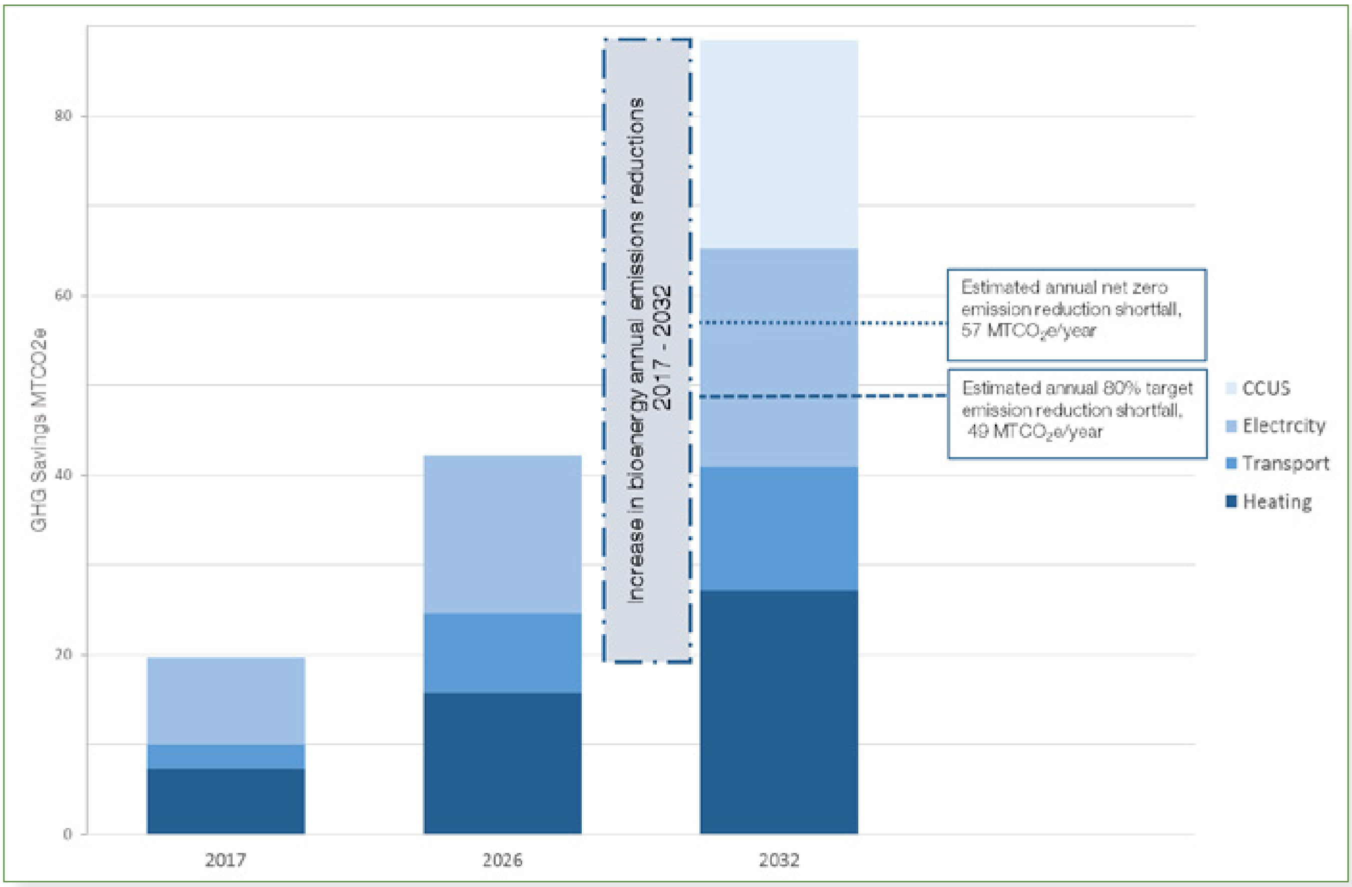


In total the reduction in GHG emissions due to fossil fuel replacement amounts to some 65 $MTCO_2e$ in 2032. A further 23 $MTCO_2e$, could be saved due to recycling or storage of CO_2 separated from bioenergy processes (existing processes and newly installed capacity with purposed designed capture systems), making a total of 80 $MTCO_2e$. This compares with total projected annual GHG emissions of 353 $MTCO_2e$ in 2032.[47]

The predicted emissions overshoot for the 5th carbon accounting period is estimated at 245 $MTCO_2e$, based on the current 80% GHG reduction target for 2050 (i.e. 49 $MTCO_2e$/year). The shortfall against the net zero carbon trajectory has not yet been published by the CCC, but will be significantly higher since the annual reduction needs to be some 50% higher than for the 80% GHG target.[48] This implies that emissions need to reduce by a further 400 $MTCO_2e$ by the 5th carbon accounting period, increasing the likely deficit to 285 $MTCO_2e$, or 57 $MTCO_2e$ annually.

Achieving the level of bioenergy deployment described in the Vision Phase set out here would reduce annual GHG emissions by some 80 $MTCO_2e$ annually, an increase of around 60 $MTCO_2e$ compared to those estimated for 2017. This increase would therefore be more than sufficient to recover the currently projected annual deficit and put the UK on course to meet the net zero carbon trajectory by 2050. (Fig 21)

Figure 21 • Annual GHG reductions from bioenergy and the 5th carbon accounting period deficit



Energy Demand and Security

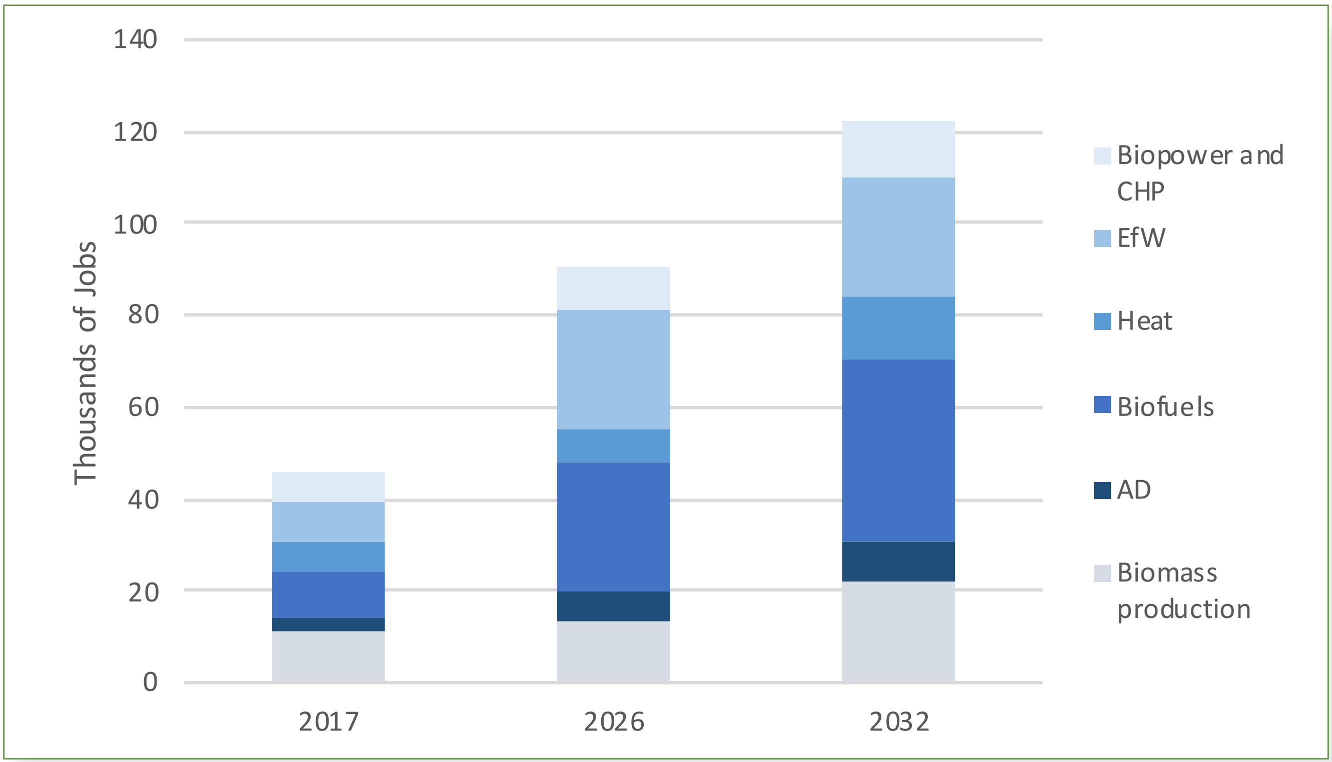
The proposed deployment would contribute an additional 60 TWh to the supply of heat in the UK without calling on the electricity supply and distribution system. In addition, the bioelectricity generated would amount to some 57 TWh.

Taken together these two contributions reduce the need for other low carbon generation needed to supply the growing demands for heat, transport and other uses by 117 TWh – more than enough to close the predicted “nuclear gap” of 72 TWh.

Jobs

In 2017 the REA conducted a survey which indicated that there were over 46,000 jobs associated with bioenergy activities in the UK. The survey also provided a sectoral breakdown.[49] A preliminary estimate has been made of the number of jobs that would be stimulated if the vision presented here was delivered, by scaling up the number of jobs in each sector according to the proposed increases in energy delivered. The results are shown in Figure 22, which indicates that the total might rise to 90,000 by 2026 and to 120,000 jobs by 2032.

Figure 22 • Employment in Bioenergy Sector

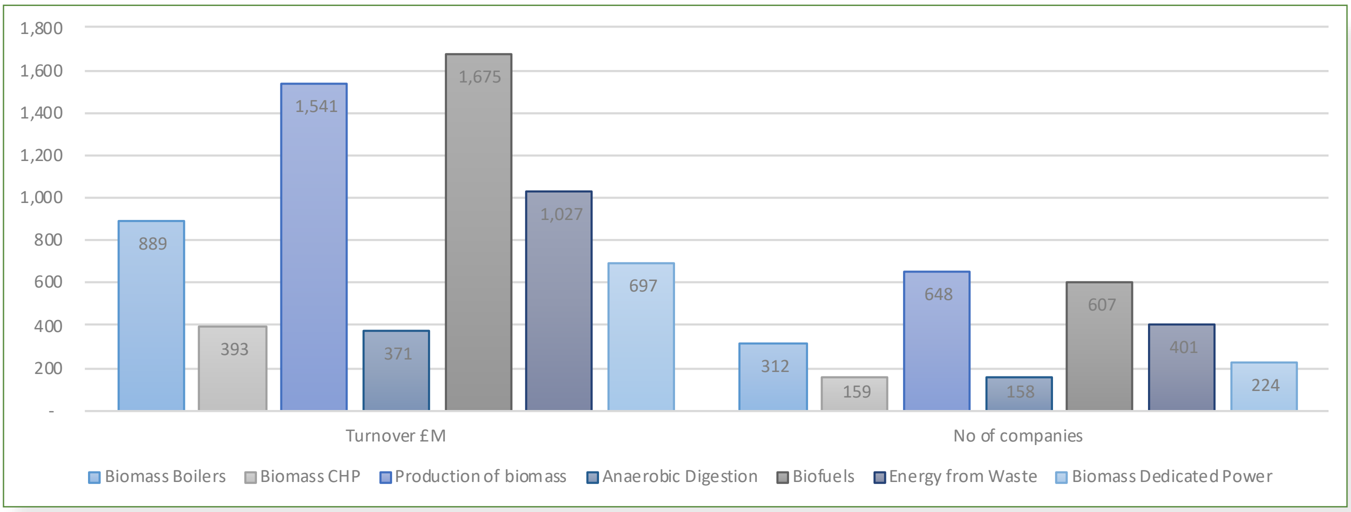


This estimate may overstate the level of employment, as some economies of scale should be possible. Further work would be needed to identify more precisely the number of jobs and other socio-economic benefits associated with such growth in the sector. Nonetheless, the total is likely to rise to over 80,000 by 2026 and over 100,000 by 2032.

Business Activity

According to the REA's economic survey of renewable energy activities there are more than 2500 companies involved in bioenergy related activities in the UK.[50] Their bioenergy-related activities generated a turnover exceeding £6.5 billion in 2017. The distribution turnover and the number of companies involved in each of the different bioenergy activities are shown in Figure 23.

Figure 23 • Bioenergy related turnover in 2017



While it is difficult to estimate how the turnover related to bioenergy would grow if we adopted the expanded case presented in the vision, a conservative estimate suggests that; if turnover rose in proportion to the total energy produced, then by 2032 the UK bioenergy industry would grow by a factor of at least three and be a £20 bn/year business.

5. Actions Required

The CCC point out that a policy and regulatory framework which enables low carbon developments is a “sine qua non” for the whole of the UK low carbon strategy, and especially now that the level of ambition has been raised. This is particularly the case for bioenergy. The Vision set out above, and its very significant benefits, will only be realised with a policy and regulatory framework that enables finance by providing long-term confidence to investors, while also respecting strict bioenergy sustainability criteria. Although bioenergy deployment has grown in recent years, and costs have declined significantly, continuing support for the deployment for bioenergy technologies is both justified and necessary because:

- Bioenergy (and other low carbon technologies) are competing with higher carbon alternatives, and the energy pricing system takes little account of the environmental costs associated with the GHG emissions
- Several important technologies are still at early stages of deployment, with significant technical, commercial and policy risks associated with their deployment

As highlighted in Phase 1 of the Bioenergy Strategy, progress in bioenergy over the last ten years has been stimulated by a number of supportive policy measures. The policy framework has been successful in accelerating initial deployment of key technologies, helped to develop expertise, build supply chains and enabled cost reduction.

However, key components of this supportive framework have been progressively removed over the last few years. The Renewables Obligation (RO) and Feed in-Tariff (FIT) schemes have now closed, and the Renewable Heat Incentive closes to new applicants in 2021.

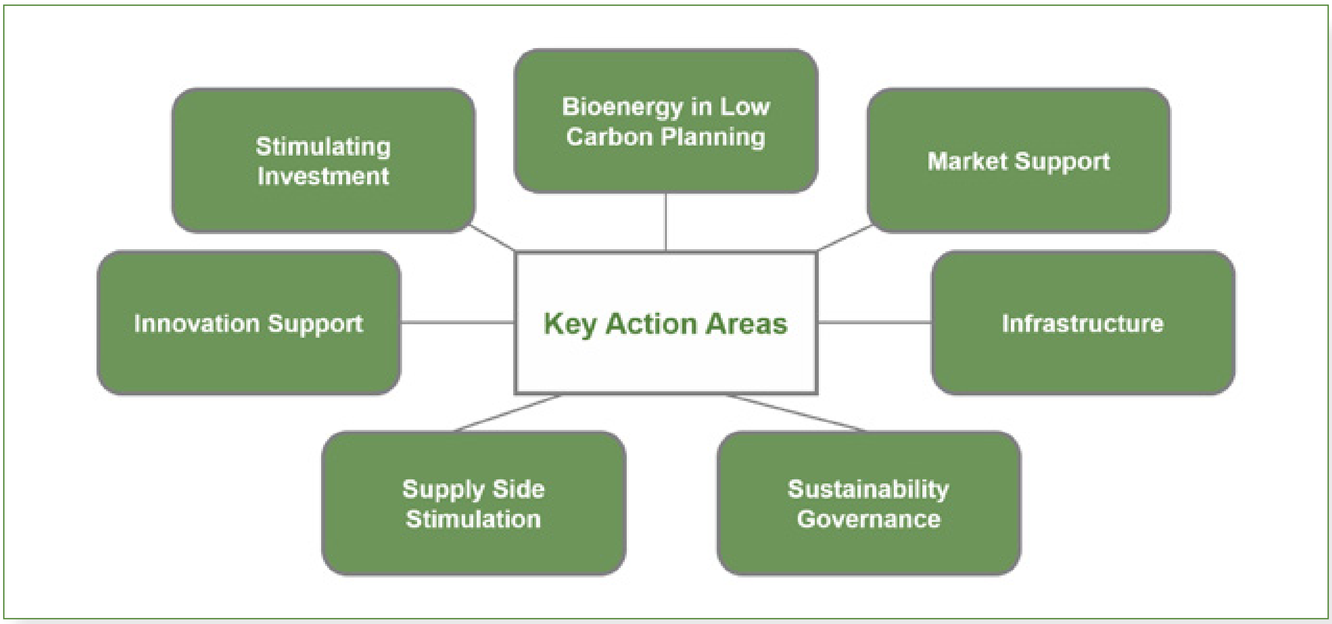
This hiatus threatens the delivery of the enhanced contribution to a low carbon UK energy economy outlined in the REA's bioenergy Vision. Business momentum and expertise will be lost and supply chains will be at risk. Immediate low cost carbon saving opportunities will also be forefeited. It will take time to rebuild the industry capability needed to deliver the benefits outlined over the medium to longer term.

The benefits of an enlarged bioenergy sector will only be realised if there is a clear enabling policy and regulatory framework which:

- Recognises the important role bioenergy can play within a portfolio of low carbon technologies
- Rewards the environmental services and co-benefits that it can deliver
- Addresses some of the barriers to the development of sustainable bioenergy
- Provides a long-term stable policy environment needed to secure investment in the sector and allows the establishment of cost effective and sustainable feedstock supply chains
- Sets a clear evidence-based sustainability governance framework
- Supports the innovation necessary to develop, demonstrate and commercialise new technologies

Seven key areas have been identified where government, industry and other stakeholders will need to take action in order to deliver the Vision (Figure 24).

Figure 24 • REA Bioenergy Vision – Key Action Areas



Bioenergy in Low Carbon Planning

Chapter 4 demonstrated the significant potential for bioenergy to provide an immediate and low-cost contribution to UK energy supply, as well as the later contributions to further GHG reductions realised through the deployment of solutions involving bioenergy with carbon capture and use or storage.

Government planning for the low carbon economy tends to unnecessarily play down the immediate potential of bioenergy in favour of focusing on future opportunities for what they see as the “best use” of bioresources. This approach tends to focus on advanced technologies linked to carbon capture and storage, making assumptions about the availability of biomass feedstocks and sustainability criteria, without considering the role of available technologies today.

As explained in Chapter 4 the “best use of biomass” has to take account of the basic characteristics of biomass feedstocks and understand how new technologies will mature. The deployment of available bioenergy technologies will realise immediate GHG reductions and provide low cost, low carbon solutions. Their deployment also provides the pathway to future technologies which requires the evolution of international supply chains, growing domestic expertise and providing the stepping stones to future bioenergy applications.

There is a low risk that deploying bioenergy now will obstruct the move to more advanced solutions when they become available. Having a large scale and active UK bioenergy sector will make it easier to deploy new technologies when the time is right, as it will be easier to develop and finance such projects when there is a mature biomass supply chain in place.

Concerns about the availability of sustainable sources of bioenergy are also overstated. As shown in Chapter 4, the expansion of bioenergy use is compatible with effectively using the available biomass feedstocks, along with a judicious expansion of the use of imported feedstocks for large scale processing and for some biofuels applications. Industry is confident that such material can be sourced while meeting the UK’s internationally leading sustainability requirements. Theinternational trade of biomass feedstocks and products will be a prerequisite for the large-scale expansion of bioenergy on a global scale foreseen in most low carbon scenarios. Expanding the supply, while meeting strict sustainability criteria, will establish a pattern that other nations can follow. In the longer run, further expansion of the UK feedstock base will be compatible with new trends in agricultural and forestry practice.

This lack of recognition for the potential role of bioenergy is most acute in the heat sector. The Government is in the process of developing a new heat strategy.[51] From what has been presented so far, future plans for the decarbonisation of heat tend to acknowledge that a new low carbon heat supply for the UK will need to include a number of different sources. Attention is focused on the production and use of hydrogen, the use of electricity (through heat pumps), the greening of the gas grid (including the use of biomethane from anaerobic digestion and thermal gasification), and on the use of heat networks. However, the direct use for bioenergy for heating seems to have a low profile.

This should be reconsidered given that:

- Using solid biomass directly for heating is the most efficient way of using the energy it contains, with efficiencies of around 90% achieved
- Bioenergy provides the lowest cost low-carbon option for many heating applications, as evidenced by its dominance in the Non-domestic RHI, where it provides 97% of all the heat produced
- Using solid biomass locally for heating, sourced fom dispersed UK forestry will be more economic and carbon efficient than collecting and transporting materials over long distances (usually by road) to large-scale central processing plants

Market Enablement

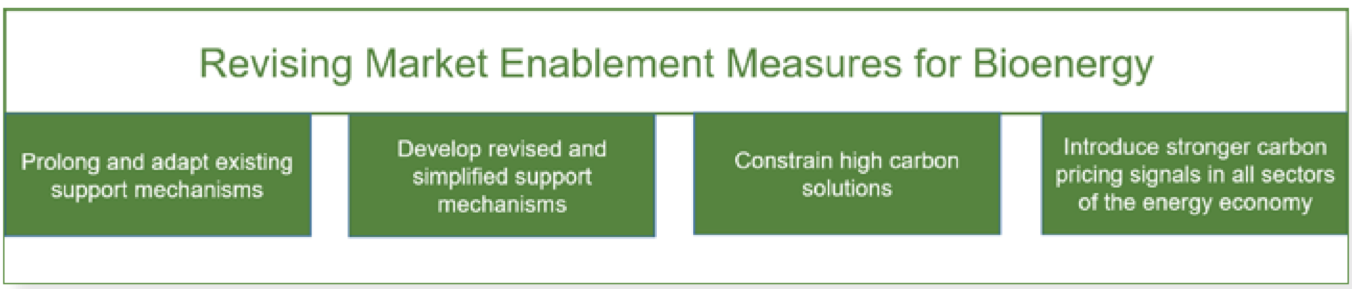
A new framework is urgently needed which reflects the increased maturity and cost effectiveness of bioenergy technologies. The framework must recognise that increased deployment today will support the emergence of the innovative bioenergy solutions essential to meeting challenging carbon targets, including bioenergy with carbon capture and storage or use (BECCUS).

There is scope to:

- Reduce the complexity of current measures
- Provide stronger incentives for improved carbon performance, taking advantage of international experience in developing and implementing such schemes
- Evolve mechanisms so that in the medium-term low carbon technologies are principally incentivised through wider carbon pricing rather than technology specific measures

Given the urgent need to promote deployment, and the extended time likely needed to develop and consult on new policy proposals, a four-strand approach is proposed (Figure 25).

Figure 25 • REA Bioenergy Vision – Key Action Areas



- In the short term, prolong and adapt the existing policy mechanisms so that momentum and business confidence is maintained
- Develop revised, simpler support mechanisms which provide clear incentives for better carbon performance
- Move progressively to constrain high carbon solutions; and,
- Introduce stronger carbon pricing signals in all sectors of the energy economy so that specific support measures for particular technologies or sectors become less necessary

More specific suggestions for each sector covering these three strands are summarised below (for more details and rationale see the "Working Paper – Actions to deliver this vision").[52]

Bioenergy Costs

The costs of a range of bioenergy options have been assessed as part of this study (See Vision Report).

Currently in the UK there are no significant costs put on the GHG and other environmental impacts of fossil fuel use through carbon prices or other duties. In these circumstances, bioenergy options are often not currently cost competitive compared to carbon intensive energy sources.

However, the bioenergy options frequently represent the lowest cost low-carbon option available in each energy sector. For example:

- Bioenergy has the potential to provide the lowest cost low carbon heat in many applications, particularly for industry and commercial scale applications, where heat can be supplied at between £3 and £8 /MWh. Bioenergy provided the lowest cost heat under the ND RHI, with 96% of all heat generated under the programme coming from bioenergy
- Bioelectricity can be produced at costs of between £50 and £90/MWh. While these costs are higher than recent costs of wind on a levelised cost of energy basis, bioelectricity is able to provide fully dispatchable power. The other main potential source of low carbon dispatchable power is nuclear. Large scale biomass power generation has significantly lower costs than nuclear as well as having other benefit

The effective carbon price needed to "bridge the gap" between current and future fossil fuel process and the costs of energy form bioenergy has been assessed.

Broadly speaking a carbon price gap is between £ 70-80/TCO2e for lower cost options such as bioelectricity heat, but rising significantly as other more novel options are included.

There should be a gradual move to an economy wide carbon price, gradually replacing technology specific support. To realise the Vision set out in this report it is proposed that carbon prices should rise to £70 – 80/TCO2e by 2026 and to around £120/ TCO2e by 2032.

Bioenergy for Heat

The proposed action specifically designed to enable deployment in the heating sector are summarised below (Figure 26):

- To maintain momentum and avoid a hiatus in support, the life of the existing Domestic and Non-Domestic RHI should be prolonged until new arrangements are in place, to allow some new capacity to be brought forward. The aim should be to stimulate some 150 MW of thermal capacity each year via a simplified scheme, with a single tariff of around 5p/kWh for the Non-Domestic Scheme
- In parallel, Government and industry should work together to develop a quality assurance scheme which gives greater certainty that projects under the schemes are addressing genuine heat needs, that project design and installation meet best practice and that high emissions standards are met

Figure 26 • Market enablement for bionenergy for heat

Revising Market Enablement Measures for Heat

Prolong and adapt existing support mechanisms	Develop revised and simplified support mechanisms	Constrain high carbon solutions	Introduce stronger carbon pricing signals in all sectors of the energy economy
• Extend RHI until new support mechanism in place • Develop and roll out heat quality assurance scheme	• Evaluate benefits of • A heat premium feed-in scheme • A heat obligation on fuels suppliers	• Ban installation of new oil and coal boilers and new natural gas connections in the UK by 2025 • Focus HNIP on low carbon supply. • Mandate low carbon systems for new buildings.	• Gradual increases in VAT and duties on domestic fuels • Progressive increase in CCL and link to C content of fuels • Higher duty levels should on dirtier fuels such as Heavy Fuel Oil

- Alternative support mechanisms for low carbon heat sources should be developed to ensure continued deployment until carbon pricing makes low carbon heat, including heat from biomass, cost competitive in its own right. Options to be explored should include:
  - A heat “feed in premium” which would provide a “top up payment” tom low carbon heat users, the difference between a calculated “reference tariff” and the full effective cost of the alternative fossil fuel (including taxes, duties and carbon levies). As carbon pricing is gradually implemented, the difference between the ‘reference tariff’ and the cost of the fossil fuel will reduce so the premium payment eventually falls to zero (Box 8)

    - A Heating Obligation, placed on suppliers of heating fuels to supply a minimum proportion of 'low carbon' fuel, with the Obligation rising progressively over a period of years. (This is an extension of the proposals for a "Green Gas" Obligation – see below). Suppliers could demonstrate compliance by increasing the proportion of low carbon substitutes within their fuel mix (such as biomethane, bio-LPG or sustainable liquid biofuels) or by purchasing certificates from fuel suppliers who are exceeding the mandated minimum proportion

- Concrete measures to constrain the installation of new high carbon heating sources, using fossil fuels, should be introduced

These should include:

    - A ban on the installation of new oil and coal boilers for domestic and commercial heating from 2025
    - A ban on new natural gas connections in the UK by 2025 particularly for large scale residential or commercial developments
    - District heating solutions based on low carbon fuels should be privileged within the Heat Networks Investment Programme (HNIP)
    - Low carbon heating systems should be mandated on new buildings, based on the UK's Green Building Council Zero Carbon Homes Standard

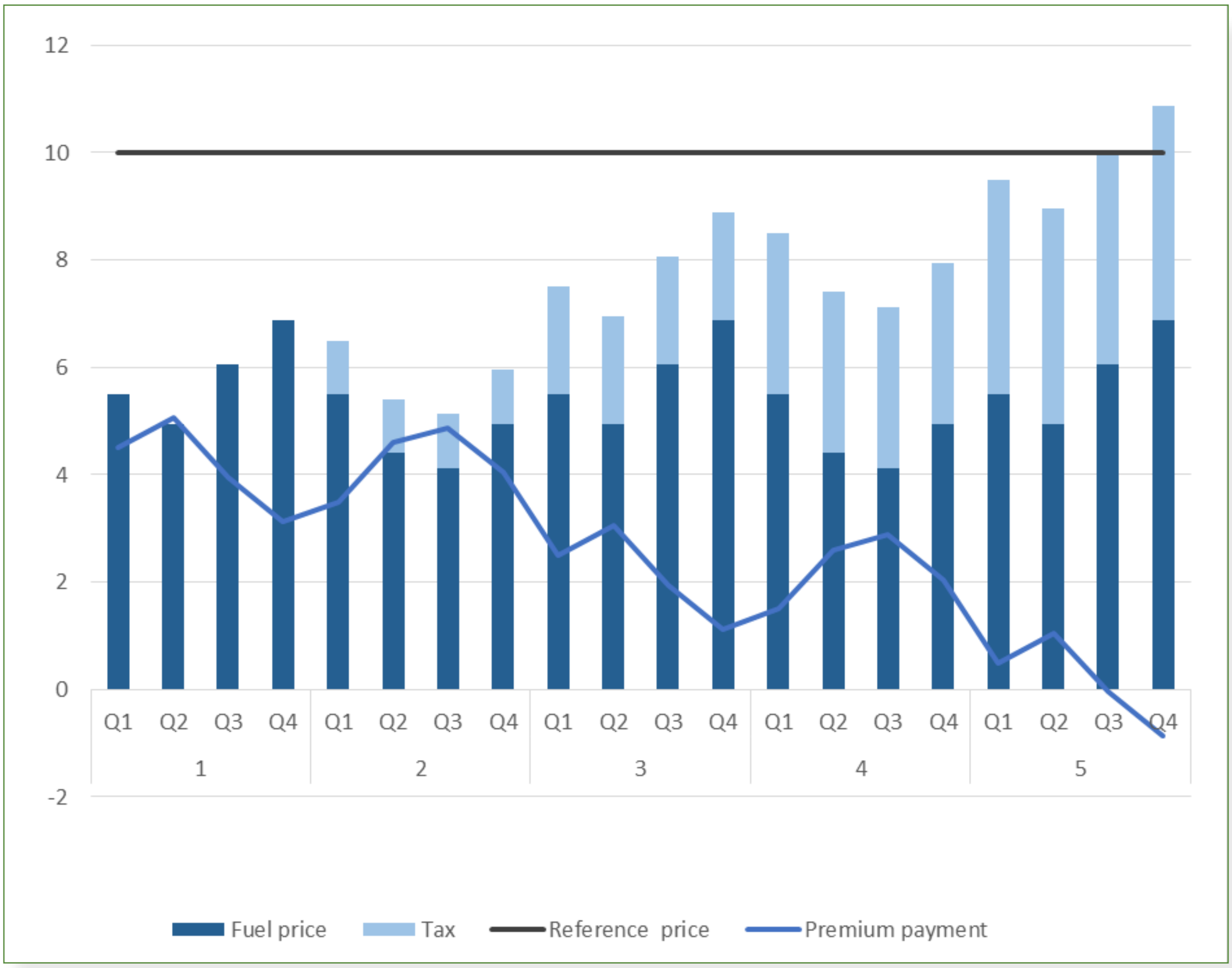
Box 8: Heat Feed in Premium

The RHI could be replaced by a heat 'Feed in Premium' for all new eligible low carbon installations. The concept is to quantify the true costs of high carbon heating to set a 'reference tariff' (equivalent to the Contracts for Difference 'strike price' used in the electricity sector). Once installed, accredited schemes would receive a quarterly premium payment equivalent to the difference between the 'reference tariff' and the full effective cost of the alternative fossil fuel (including taxes, duties and carbon levies) they would have burned to deliver the same amount of heat. As carbon pricing is gradually implemented, the difference between the 'reference tariff' and the cost of the fossil fuel will reduce so the premium payment gradually falls to zero. At this point, when consumers of high carbon heat are paying the full cost, low carbon heating will become economically attractive without further subsidy.

In order to encourage cost-effective installations and continuing cost reductions, the reference price should be reviewed periodically. However, mechanisms based on unrealistic cost reduction expectations (such as automatic degressions) must be avoided. As in the case of the RHI, these will over-constrain the market, and lead to poor quality installations. A thriving market, coupled with strong installation standards and with incentives that recognise realistic costs will ultimately deliver better value for money.

The premium payments could be funded through a progressively increasing levy on oil and/or gas sales. If carbon prices were progressively increased, the premium payment would gradually decrease, and eventually fall to zero (see Figure 27 for illustration).

Figure 27 • Schematic illustration of premium tariff for heat



- Taxes and duties on fossil fuels for heating need to be raised to send a strong price signal.

There should be:

- Gradual increases in domestic VAT on heating oil, coal (solid fuel), fossil fuel mains gas and LPG from 5% to 20% over a five-year timeframe (2.5% increase per annum)
- A progressive increase in the Climate Change Levy (CCL) and a clear relationship between its levels and the carbon content of the fuels involved.
- Higher duty levels should be imposed on dirtier fuels such as Heavy Fuel Oil to encourage large process users not on the gas network to replace old boilers
- Removal of all subsidies for fossil fuels, such as repayment of Excise Duty on heavy mineral (hydrocarbon) oil used by horticultural producers

- Further Government/industry discussion will be needed to refine these ideas and to decide which potential measures are best suited to the differing market sectors

Transport

The proposed actions specifically designed to enable deployment in the transport sector are summarised below (Figure 28).

Revise Blending and Obligation Levels within RTFO

- Introduce a 10% ethanol blend in petrol (E10 blend) before the start of 2021, accompanied by an upward revision of the RTFO obligation level, to avoid reductions in other biofuels
- Continue the GHG reporting requirement with ambitious reduction targets beyond 2020 in order to incentivise fuels with the lowest possible associated emissions (see later sections)
- Consider obligations for UK based aviation and shipping

Revised incentives for low carbon transport

- Extend the life of the GHG scheme and set progressively increasing GHG reduction targets
- Consider how this could be combined with a modified RTFO so as to best fit UK context, based on an analysis of emerging best practice in a number of other jurisdictions

Fuel duty

- Review and adjust fuel duties to remove volume energy content disciminations against biofuels and reflect emissions
- Expand more widely the duty rebate currently available for methane especially for higher biodiesel blends in commercial transport, and for higher ethanol blends including E85

Figure 28 • Market enablement for biofuels in transport

Revising Market Enablement Measures for Transport

Prolong and adapt existing support mechanisms	Develop revised and simplified support mechanisms	Constrain high carbon solutions	Introduce stronger carbon pricing signals in all sectors of the energy economy
• Introduce a 10% ethanol blend in gasoline (E10 blend) before the start of 2021 • Revise the RTFO obligation level • Continue the GHG reporting requirement and set ambitious reduction targets • Consider obligations for UK based aviation and shipping	• Extend the life of the GHG reporting scheme, and set progressively increasing GHG reduction targets • Consider combination of GHG and modified RTFO to best fit UK circumstances.		• Review and adjust fuel duties, and to reflect GHG emissions. • Expand scope of duty rebate currently available for methane

Biomethane

The proposed actions specifically designed to enable deployment of biomethane capacity are summarised below (Figure 29).

Figure 29 • Market enablement for biomethane for heat and transport

Revising Market Enablement Measures for Biomethane

Prolong and adapt existing support mechanisms	Develop revised and simplified support mechanisms	Constrain high carbon solutions	Introduce stronger carbon pricing signals in all sectors of the energy economy
• Include biomethane in recommended revisions to RHI and RTFO	• Establish a specific target for the inclusion of biomethane in the gas grid • Develop the concept of a "green gas obligation" for gas suppliers including option of a GHG reduction Obligation • Support the development of an active UK Renewable Gas Guarantees of Origin (RGGOs) market.		

Extend RHI and enhance RTFO

- Include biomethane in the extension to the RHI and in revisions to RTFO discussed above.

Revised support for biomethane

- Establish a specific target for the inclusion of biomethane in the gas grid, aligned with the potential production numbers. i.e. 180 PJ (50 TWh) by 2026, and 220 PJ (61 TWh) by 2032
- Establish a Government and industry task force to develop the concept of a "green gas obligation" for gas suppliers, including the option of establishing a GHG reduction obligation (rather than a volume based system). Guarantees of Origin (GoO), as currently facilitated by the Green Gas Certification Scheme (see below case study), could play an important role in developing this market
- Support the development of an active UK Renewable Gas Guarantees of Origin (RGGOs) market.

GGCS Case Study

Green Gas Certification Scheme

Guarantees of Origin (Go0) for green gases can play an important role in developing the market for bioenergy in the UK. Since 2011, the Green Gas Certification Scheme (GGCS) has been issuing Go0 for biomethane, has more recently issued Go0 for bio-propane and anticipates issuing Go0 for bio-Substitute Natural Gas.

Go0 give domestic and non-domestic customers the chance to link their gas consumption back to renewable green gases. There are currently an estimated 1million household on green gas tariffs, which match between 6 and 100% of household's gas consumption to Go0, alongside a broad range business, public and third sector organisations.

Overall the purchases of Go0 during 2019 is projected to provide revenue of £5 mn to UK biomethane providers. A significant portion of Go0 are purchased by customer outside the UK, the sector is an emerging export opportunity for the UK.

Go0 also provide a means of tracking green gas in the grid where there is a need to evidence use in a particular sector, with the GGCS having taken early steps to support biomethane use in the RTFO, as well as potential to also be used by obligated parties in Emissions Trading Schemes.

The GGCS anticipates that an extension of the existing Go0 scheme can play a key role in administering a future Green Gas Obligation proposed within the Bioenergy Strategy.

Bioelectricity

The proposed actions specifically designed to enable deployment of bioelectricity capacity are summarised below (Figure 30).

Refocus the Climate Change Levy (CCL)

- Refocus the CCL to become a carbon emission-based tax, clearly reflecting the emissions from specific sources, and progressively raise its level

Existing bioelectricity generators

- Reward bioelectricity plants when they provide grid services such as capacity, flexibility, inertia and reactive power once long-term contracts under the RO and CfD expire
- Provide a feed-in premium for existing generators, based on the difference between their generation costs and wholesale prices and accounting for carbon taxes and other duties

New waste-based generation

- Introduce a feed-in premium payment, as discussed above, for the existing bioelectricity plant capacity and for new waste-based electricity generation
- In order to facilitate the development of such plants, Combined Heat and Power (CHP) facilities should have full access to payments designed to incentivise low carbon heat. Since the volumes of heat produced by such plants are significant, the support should not constrain the payments made to large facilities – as is currently the case under the RHI
- Policies that support heat network deployment should be focused on systems which rely on heat from waste or biomass and other low carbon fuels, rather than on gas-fired systems
- Continuing pressure should be placed on producers of waste to avoid landfill through the mandatory segregation of materials which can be recycled or used for energy purposes, as well as continuing the upward trend in landfill tax

Large-scale bioelectricity with BECCUS

- Create either a special “pot” or ring-fenced budget within the CfD for power generation linked to CCUS
- BECCS and BECCU systems should also receive a carbon benefit associated with carbon taken out of the system (see BECCUS section)

BECCUS

BECCUS will only take off if investment in the additional costs associated with capture, separation, reuse or storage is profitable and income is provided for the service of removing carbon from the system.

The mechanisms for putting a consistent price on carbon across the energy economy discussed above need to extend to the provision of rewards for systems which lead to negative emissions. This can come about where bioenergy production is coupled with the capture, separation and reuse of carbon to produce fuels (so avoiding the use of fossil fuels) or to provide long-term storage of carbon. For example, under the existing Emission Trading Scheme (ETS) companies could be given allowances for their negative emissions, which could then be sold at the market value. Under a wider carbon tax system, companies could be credited for negative emissions, with payments financed by carbon tax receipts.

Given the lead times for investment decisions and the prospect of early deployment for some demonstration projects involving full scale BECCUS, an early decision on the pricing regime for captured and stored carbon is needed – by the end of 2019 at the latest.

Government recently established a CCUS Cost Taskforce. It should adopt a clear strategy for the scale and timing of CCUS deployment which is consistent with a target of capturing 10 Mt CO_2 per annum in 2030 rising to 20 Mt CO_2 per annum in 2035. Within this ambition, BECCUS should be prioritised in order to pave the way for negative emissions options. There should be specific plans to demonstrate several small-to-medium scale BECCUS pilot projects (e.g. coupled to plants where clean CO_2 streams are generated in biomethane or ethanol production), plus one large-scale bioenergy project (e.g. an existing large scale bioelectricity producer) by 2025 at the latest.

Infrastructure

The rate of deployment for key bioenergy technologies such as the use of bioenergy in heat networks, the use of biomethane in gas pipelines and BECCS – will depend on the availability of infrastructure.

- Biomass can play a significant role in low carbon heating and cooling solutions via heat networks. Assistance is being provided to grow heat networks capacity via the BEIS Heat Networks Delivery Unit (HNDU) and Heat Networks Investment Project (HNIP). These support schemes need to be oriented to focus only on systems which use low carbon sources of energy including bioenergy and waste heat

- Government will have to play a key role in establishing the infrastructure needed to transport and store CO_2 at scale. Government should seek to establish transport and storage infrastructure in three storage regions of the UK by the 2020s to allow all industrial clusters to access this critical technology. The proposed low carbon cluster funding of £170 mn overall will need to rise to £50 – 100 mn per hub, with the aim of developing at least 3 hubs by the mid-2020s

- Gas grid companies should be required to publish capacity maps to help developers focus on optimal sites for new projects. Additional capacity to pump gas from the low to high pressure grids at critical locations would avoid bottlenecks which currently constrain injection. A review of the connection standards and their costs, which vary significantly from region to region, should be undertaken to simplify procedures and reduce connection costs

The Bioeconomy and Sustainability Governance

UK Bioeconomy Strategy

The UK has a Bioeconomy Strategy, published by BEIS in December 2018.[53] It notes that the bioeconomy represents the economic potential of harnessing the power of bioscience, using renewable biological resources to replace fossil resources in products, processes and services and to reduce dependence on the finite fossil resource. It estimates that the UK bioeconomy is today worth £220 billion and indirectly supports 5.2 million jobs.

The strategy highlights a number of areas of particular potential including the production of new forms of energy, as well as producing smarter and cheaper raw materials; reducing plastic waste and pollution; providing sustainable, healthy, affordable and nutritious food; increasing the productivity, resilience and sustainability of agriculture and forestry; and manufacturing medicines of the future.

To achieve its aims, the Strategy sets out 15 actions designed to stimulate growth across the UK's bioeconomy. Government will be working with partners across industry and the research community to develop further each of these actions and set out more detailed activities in due course.

Policy and Regulatory Implications

As discussed above, bioenergy is an integral part of the bioeconomy and there are often strong synergies between the production of both existing and novel bio-based products and bioenergy. Bioenergy can play an important role in: catalysing the bioeconomy by complementing other products; as an early market for key technologies which will be needed for other applications; and as a test bed for regulation (notably on sustainability).

In theory, the growth of the bioeconomy could lead to increased competition between the use of biomass resource for food and feed, materials, chemicals, and energy. In practice, such competition is limited because the value of bioenergy products is generally much lower than those used for food, chemicals or materials. High levels of subsidies for energy production alone, without recognising the carbon and other benefits that can be associated with the production of biomaterials, could lead to sub-optimal use of materials from both an economic and environmental perspective. However, this risk diminishes as levels of support for energy production decline, and at current and future levels likely in the UK, such distortion is unlikely. It would be helpful to the development of the bioeconomy if the carbon benefits of a wider range of bio-based products were fully recognised through the application of carbon pricing across the economy as a whole or by specific fiscal measures (e.g. through differential tax and duty rates).

While the wider use for bio-based materials can, in the right circumstances, lead to reduced emissions and other benefits, there is still a need for the materials to be produced sustainably. Bioenergy has been in the vanguard of developing modern standards for sustainable sourcing and stewardship of feedstocks, with careful analysis of life cycle emissions and established land use criteria. These principles should also be applied to the wider (conventional) bioeconomy as well as to forestry, agriculture land-use more generally, and new biomaterials.

Sustainability Governance

Bioenergy must be delivered sustainably if it is to play a role in a low carbon economy. UK industry has cooperated with Government to develop and implement a comprehensive and world-leading sustainability governance framework. As discussed in Chapter 3, the REA and its members are committed to continue to evolve this framework with the REA looking to convene a taskforce to review and improve this framework as needed. Detailed actions designed to further develop the UK's sustainability governance system are included in Chapter 3.

Feedstock Supply

The increased use of bioenergy will have to be matched by an increase in available feedstocks from wastes, residues and energy crops.

The UK Resources and Waste Strategy recognises the importance of using wastes for energy in meeting the ambition to reduce the landfilling of organic wastes in the UK by 2030. Government will legislate to ensure that every household and appropriate business in England has a weekly separate food waste collection by 2023, complementing moves already made in Scotland and Wales. DEFRA has pledged to provide additional resources to support service delivery both for the set up transitional costs and ongoing operating costs. To encourage early movers, support should also be available to authorities who act ahead of 2023. The move away from landfill has been stimulated by a consistently rising Landfill Tax – currently at £91.35 per tonne of organic waste and linked to inflation. This is a powerful incentive which enables the use of materials for energy. It is important therefore important that the tax is maintained or increased.

Given the potential environmental and agricultural benefits, the need to develop and demonstrate best practice and the scope for innovation to improve yields and reduce costs, some Government support from DEFRA and other government bodies will be needed to stimulate energy crop production. This will in part concern support for R, D and D; but larger scale trials and demonstrations of crop production and use will also need support.

As a first step, a large-scale supply chain demonstration project of the order of 5000 ha of new planting in one region is needed, satisfying a demand for about 50,000 tonnes/year of feedstock. This, and subsequent scale-up projects, may benefit from targeted supply-side measures such as technical assistance for growers, coupled to stronger market pull by ensuring planting is backed up by suitable supply contracts, with fuel-buying users incentivised to offer improved terms of trade, sharing more of the risk with growers.

Incentives for crop based materials will need to be revised under bioenergy support schemes to ensure consistency and to encourage the production and use of appropriate energy crops. Within the RTFO, the category 'dedicated energy crops', covers crops grown for the purpose of being used as fuel (and not food or feed), and biofuels derived from these materials are double rewarded. In contrast, under the RHI, payments are reduced if more than 50% of the biogas/ biomethane is made from any crops. Since realising the potential for biogas and biomethane will require the use of a broader range of raw materials, including crops grown in ways which complement traditional agricultural production, the regulations for the RHI or its successor will need to be amended and aligned with those of the RTFO to allow and encourage the production and use of such materials.

In order to meet feedstock demands for the large-scale production of electricity and other products, an increase in imported biomass will be needed. These materials are available and can be imported, meeting the strict sustainability requirements already in place and as discussed in Section 5 and in the associated working paper on sustainability issues.[54]

Innovation

Innovation is needed to deliver the Vision to help develop, demonstrate and commercialise new processes, feedstocks and fuels, as well as ensure the sustainability benefits and challenges are well understood and managed. This will require a coordinated and focused approach with close integration of early stage university research with industry focused development and demonstration.

Innovation for bioenergy systems at early stages of development is focussed on university research supported by EPSRC and BBSRC through the Supergen Bioenergy Hub and the BBSRC's Networks in Industrial Biotechnology and Bioenergy (NIBBs) (see Box 9). New initiatives, that build on the success of the NIBBs, could help improve the links between academic expertise and industry, particularly as many industrial players are SME's who lack in-house scientific expertise.

- The expansion of the NIBBs concept to bioenergy more broadly could play a role in facilitating such exchanges, but the REA is also well placed to play an important role in facilitating this dialogue. Further discussions between the REA and the Supergen Bioenergy Hub to identify practical mechanisms which could help facilitate dialogue can build on the cooperation that has been established during the development of this strategy

Box 9 Innovation in Bioenergy – Supergen Bioenergy Hub and NIBBs

Basic research on TRL's 1-3 is the responsibility of the research councils that sit within UK Research and Innovation (UKRI). Funding is distributed to eligible higher education institutes via "responsive mode" applications (where academic institutes can submit applications for funding in any area) and "targeted calls" that focus on particular topics identified as important challenges by the community. The funding councils most relevant for bioenergy are the Engineering and Physical Sciences Research Council (EPSRC), the Biological and Biochemical Sciences Research Council (BBSRC) and Innovate UK (who fund companies and academics from TRL's 3-7). However, there is involvement from the Natural Environment Research Council (NERC) and Economic and Social Research Council (ESRC), particularly when energy crops, supply chains, climate and other environmental impacts are being considered.

Energy is currently a priority area and so there is a targeted energy programme which is led by EPSRC, which supports several "hubs" - distributed national centres of research excellence in their technology area. The Supergen Bioenergy Hub has been funded by EPSRC and BBSRC jointly to provide a focal point for research into bioenergy. It is led by Professor Patricia Thornley at Aston University and is carrying out a programme of work with partners at other UK universities covering:

- Biomass resources – including waste, energy crops and forest products
- Biomass pre-treatment and conversion – focusing on ionic liquid pre-treatment, pyrolysis liquid upgrading and photocatalysis
- Bioenergy vectors – exploring the ability of bioenergy intermediaries (gas, liquid and solids) to meet specification, upgrading and quality requirements for different existing markets
- Systems – assessing how bioenergy will fit into the future, decarbonised UK energy system
- Case studies – evaluating the environmental, economic and social sustainability of future bioenergy options that have potential to be materially significant for the UK

The Supergen Bioenergy hub focuses on TRLs 1-3, but many of the scientific knowledge gaps around bioenergy relate to the actual performance of established systems and to cross-cutting issues which are relevant to technologies which are at all TRL's and fall within the scope of the Bioenergy Hub's activities.

These include:

- forest carbon balances
- environmental benefits of energy crops
- nutrient balances linked to AD systems
- aviation fuel quality benchmarks
- analysis of the environmental, economic and social sustainability of systems

Above TRL 3, innovation is supported by Innovate UK. A key scheme is the Energy Catalyst, which provides support for business-led projects that can also incorporate academic input, with both academic and industrialists receiving support from Innovate UK.

In the biochemical and biological space BBSRC operate specific mechanisms to bridge the gap between university research at TRL 3 and commercial operation. These are focused on a number of Networks in Industrial Biotechnology and Bioenergy (NIBBs). The most relevant NIBBs for bioenergy implementation are the Biomass and Biorefinery Network (led by Simon McQueen-Mason, University of York) and the Environmental Services Network (led by Sonia Heaven at Southampton with a strong focus on waste, waste-water treatment and anaerobic digestion). The NIBBS have been immensely successful at engaging SME's in the biotechnology sector to develop commercial ideas with university support.

Delivering the Vision for Bioenergy for 2032 and beyond depends on taking technologies through to full commercialisation at scale. Appropriate policy and regulatory measures will be needed to help them to mature and avoid the "valley of death" between prototype or pilot plant operation and full commercial deployment.

Measures that can be adopted include:

- Obligations for the deployment of sustainable fuels and for specific subcategories that are at different stages of technical and market maturity, such as the provision for development fuels within the RTFO
- To stimulate investment in UK Production, Government should consider setting a floor price for RTFC's or for carbon credits developed under a GHG Reporting and Reduction Scheme (at least for new advanced biofuels capacity)
- Appropriate and dedicated financial mechanisms and instruments to facilitate technological development and subsequent market deployment; for example, by expanding support for the demonstration and deployment of biofuels production facilities within the UK through capital grants, and by providing access to risk finance, including loan guarantee schemes
- Encourage long-term offtake contracts between users and suppliers and producers (for example by using public purchasers such as the armed forces to enter into long term supply contracts)

Stimulating Investment

Delivering the Vision will require very significant investment from a wide range of sources of capital. Developers and investors in the bioenergy sector should be able to take advantage of a number of schemes designed to encourage entrepreneurial investment but which are currently closed to investments in this sector. As such Government could encourage and promote investment by reconsidering the following:

- Renewable project developers are not presently able to take advantage of Enhanced Capital Allowances (ECA) and Enterprise Investment Schemes (EIS). Now that concerns of over-rewarding sectors through double subsidies have been mitigated, renewed access to these schemes could promote investment in the bioenergy sector

- The Energy Savings Opportunity Scheme (ESOS) should be refocussed on CO_2 reduction rather than just on energy use, and renewable solutions should be included along with energy efficiency measure

- Investment in bioenergy systems would be encouraged by providing low interest loans for commercial heating schemes, providing rebates on income or corporation taxes for businesses and households investing in renewable heating installations and energy efficiency measures

- The introduction of variable stamp duties, with homes having low carbon heating systems and high energy efficiency standards benefitting from lower rates, would be a powerful incentive to install such systems.

Detailed Actions

Working Paper – Actions to deliver this vision, produced as part of this project provides more detail on the rationale for these priorities and how they might be actioned by Government and industry.[55]

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Units of measure and conversion factors

Units of Measure

kilo (k)	10^3
mega (M)	10^6
giga (G)	10^9
tera (T)	10^{12}
peta (P)	10^{15}
exa (E)	10^{18}

EJ	exajoule
GJ	gigajoule
ktoe	kilotonnes of oil-equivalent
kWh	kilowatt-hour
Mtoe	megatonnes of oil-equivalent
MJ	megajoule
GW	gigawatt
GWh	gigawatt-hour
TWh	terawatt-hour

Conversion factors

1PJ = 277.8 GWh = 23.9 ktoe

1ktoe = 41.868 TJ = 11.63 GWh

1 MWh = 3.6 TJ = 85.98 toe

Stakeholder Engagement

Thank you to all the industry stakeholders who participated in the numerous working group discussions and workshops across power, heat and transport. In addition, thank you to those who fed directly into the public call for evidence carried out in January – February of 2019. Organisations who fed into the development of the REA Bioenergy Strategy include:

Advanced Plasma Power (APP)
AMP Clean Energy
Anaerobic Digestion Biogas Association (ADBA)
Argent Energy
AvantiGas
BEIS
Bioenergy Infrastructure Group
Biomass Power Ltd.
Cadent
Carbon Capture & Storage Association (CCSA)
Centre for Hydrology and Hydrology
Centrica plc
CNG Services Limited
CoGen
CPL Industries Limited
DfT
Drax
Dunster Energy
Eco2
Energy Network Association
Energy Technologies Institute (ETI)
Ensus
Enviva
Estover Energy
Federation of Petroleum Suppliers
Fichtner Consulting Engineers Ltd.
Forestry Commission
Glennmont Partners
Green Gas Certification Scheme
Industrial Biotechnology Innovation Centre (IBioIC)
Inperpetuum
MGT Teeside
National Farmers Union (NFU)
Natural Gas Vehicle Network
NNFCC
OFTEC
Olleco
Plasco Conversion Technologies
PRIMA
Privilege Finance
Progressive Energy Limited
re:heat
Reliagen Energy Ltd.
Renewed Carbon
Severn Trent
SGN
Supergen Bioenergy Hub
Sustainable Biomass Program (SBP)
Syngas Products
UK Liquid Petroleum Gas
UK Pellet Council
UKRI BBSRC
US Industrial Pellet Association (USIPA)
Valmet
Velocys

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