UKPIA Response to The Role of Biomass in Achieving Net Zero – Call for Evidence

1. Do you give permission for your evidence to be shared with third party contractors for the purpose of analysis?

Yes

2. What is the potential size, location and makeup of the sustainable domestic biomass resource that could be derived from the a) waste, b) forestry, c) agricultural sectors, and d) from any other sources (including novel biomass feedstocks, such as algae) in the UK? How might this change as we reach 2050?

2.1. Introduction

Biomass has potential to play a key role in achieving Net Zero as a direct energy source (e.g. for power generation including BECCS), as a feedstock for renewable energy vectors (e.g. low carbon liquid fuels used in the transport sector, biogas used for domestic and commercial heat) and as a feedstock for non-energy products such as plastics and substances currently produced from crude oil. The current predominant use of biomass in the UK and EU is for renewable energy, but there will be an important and increasing role for biomass in production of non-energy products and in providing a foundation for a circular economy. The UK downstream sector stands ready to support the production of both renewable fuels and chemical feedstocks by displacing crude oil with biomass in its processes, with both co-processing and substitution options being pursued. Many UKPIA members are already active in co-processing at some of their refineries.

2.2. UK Biomass Use

In 2018, bioenergy made up 60% of the renewable energy used in the EU. Most of this (58%) is used in heating and cooling, followed by 11% each in electricity and transport. The large share of bioenergy being used in the heating and cooling sector is reflected by the high proportion of bioenergy derived from solid biofuels (68%) as compared to liquid biofuels (13%) and biogas (12%).[1] Compared to EU nations with similarly high total energy consumption, the UK consumes around the same amount of bioenergy as France and Italy, but only just over half as much as Germany.[2] Approximately one third of UK biomass utilised for energy is imported.[3]

2.2.1. Electricity

The majority of UK biomass utilised for energy is used for power generation with approximately half of the material plant biomass in origin. Of this plant biomass, the majority is imported, highlighting significant international reliance for the largest single source of power generation biomass.

[1] Technical assistance in realisation of the 5th report on progress of renewable energy in the EU: analysis of bioenergy supply and demand in the EU (Task 3): final report, Directorate General for Energy & Navigant., 2020
[2] Overview of biofuels policies and markets across the EU-27 and the UK, Vion Saint-Supéry, M., De Simone, F., Bernabeu, V. & Desplechin, E., 2020
[3] Digest of UK Energy Statistics (DUKES) 2020, BEIS, 2020

The next most significant biomaterial sources for power generation are landfill gas and wastes (including non-biodegradable wastes) – these top three sources of biogenic material account for over 85% of UK biomass-derived power generation.[3]

Whilst signals have been made that the primary demand for UK biomass in future will be for power generation via bioenergy with carbon capture and storage (BECCS)[4], operational scale deployment of the technology has yet to be realised. There are plans for BECCS to grow beyond pilot scale in the UK by 2030[5] with the input feedstocks likely to be remain predominantly plant biomass from agriculture and biowaste.

Given the UK's advantaged role in generating electricity from other renewable sources such as wind and solar, and clear ambitions to develop infrastructure in stationary energy storage such as hydrogen and batteries[6], it is unclear as to whether available biomaterial in the coming decades would be best purposed for power generation in the UK.

2.2.2. Transport Fuels

In the transport sector, biofuels – 60% of which are crop-based in the EU – are the primary source of renewable energy.[2] Of the high-consumers (France, Italy, UK, Germany), France uses by far the highest proportion of crop-based biofuels (6.8% of total transport energy compared to the UK's 0.8%). Ireland and the Netherlands both use a relatively high proportion of Annex IX-B biofuels (3.1% and 2.9%, respectively), while the UK, Germany, and Italy all use similar proportions (1.9%, 1.6%, and 1.4%, respectively).[2] While most EU countries have introduced a crop cap of 7% (Germany's is 6.5%), the UK's was set at 4% declining to 2% by 2032.[7] As national biofuels mandates increase, countries have leaned heavily on Annex IX-B biofuels – most of which are biodiesels. From 2018 to 2019, the energy consumed that derived from these biofuels increased by half.[8]

The majority of UK biofuel is biodiesel derived from wastes such as used cooking oil with bioethanol for petrol predominantly derived from crop-based feedstocks such as sugar beet.[9] 11% of the UK's renewable fuels are domestically produced highlighting significant reliance on the import of biofuel feedstocks and finished biofuels for the UK transport energy system.[10]

Whilst the UK vehicle parc will electrify in the coming decades, there will continue to be a role for renewable fuels to decarbonise the legacy fleet and displace fossil-derived fuels in the harder to decarbonise sectors such as long-distance freight, maritime, and aviation.[11] For these sectors, only low carbon hydrogen may prove a sufficiently energy dense fuel to be a viable alternative. However, large scale deployment of low carbon hydrogen for these applications in unlikely to be feasible before 2050,[12] therefore, UK biomass will need to be prioritised for the production of low carbon fuels for difficult to electrify transport applications.

2.2.3. Heating (Stationary Combustion)

The third main use for biomaterial in the UK is in stationary combustion for heating homes and industry.[3] The primary feedstocks for this application are wood and plant biomass. There was also an increase – but still limited levels – of biogas being injected into the UK gas grid in 2019.[3]

[4] The Sixth Carbon Budget – The UK's Path to Net Zero, CCC, December 2020
[5] https://www.drax.com/about-us/our-projects/bioenergy-carbon-capture-use-and-storage-beccs/
[6] The Ten Point Plan for a Green Industrial Revolution, BEIS, November 2020
[7] Renewable Transport Fuel Obligations Order 2007
[8] SHARES (Renewables) – Energy, EC Eurostat (https://ec.europa.eu/eurostat/web/energy/data/shares), 2021
[9] Crops Grown for Bioenergy in the UK: 2019, DEFRA, December 2020
[10] Renewable Fuel Statistics 2019, DfT, November 2020
[11] A collaborative approach to understanding decarbonised transport in 2050, Transport Energy Network, November 2020
[12] https://www.reuters.com/business/aerospace-defense/airbus-tells-eu-hydrogen-wont-be-widely-used-planes-before-2050-2021-06-10/

However, alternative options are available for domestic and commercial space and water heating (e.g. ground- and air-source heat pumps, heat networks using recovered industrial waste heat). Again, use of biomass should be prioritised for applications that are more difficult to decarbonise and do not give rise to high levels of non-GHG emissions, e.g. particulates from domestic combustion.[13]

2.2.4. Chemicals Feedstock

Currently, use of biomass as a feedstock for manufacture of non-energy products currently produced from crude oil, in particular, plastics, is limited in the UK. However, implementation of circular economy policies will necessitate the use of bio-derived chemical feedstocks where reuse, recycling, or reprocessing are not possible, or deliver a less desirable environmental outcome in terms of resource use (in particular, water, energy) or non-GHG emissions.

2.3. UK Supply in 2050

The current distribution of biomass is primarily driven by economic incentive with minimal prioritisation based on viable technical alternatives (for example feedstocks for plastics). In addition, the current biomass landscape does not include novel approaches under development such as algae for biofuel manufacture.[14] Given the UK's aforementioned reliance on imported biomaterial the UK should ensure it supports high impact domestic supply and leverages its unique position in renewable power generation to ensure limited biomass is deployed in applications with no technical alternatives.

2.3.1. Biowaste

A detailed study by Imperial College London (ICL) estimates that in their 'low' mobilisation of farming and forestry practices scenario – which models the same levels as 2020 – approximately 14 million dry tonnes of biowaste may be available in the UK by 2050[15] (with a calorific value of approximately 140 PJ). This estimate is slightly more conservative than – but broadly consistent with – the "accessible" biomass resource modelled as available by Ricardo Energy and Environment for BEIS in 2017.[16]

UKPIA's Transition, Transformation, and Innovation report highlights the important role of lipid-based materials in decarbonising refinery products such as fuels and petrochemical feedstocks through to 2050.[17] UKPIA calculations, based on the Energy Systems Catapult (ESC) demand scenarios[18] and Concawe modelling,[19] estimate that the refining sector may co-process up to 10% of crude throughput as biomass by 2030 through to 6.5 mt/yr by 2050.

2.3.2. Forestry

The ICL study estimates 67 million dry tonnes of forestry dry mass may be available in the UK by 2050 – a combination of stemwood, primary forest residues, and secondary forest residues. It should be noted that the Ricardo Energy and Environment modelling from 2017 assumes no short rotation forestry (SRF) availability by 2030. Other studies confirm currently limited use of SRF, but also highlight its important role as an energy crop in the coming

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[13] Emissions of air pollutants in the UK – Particulate matter (PM10 and PM2.5), DEFRA, February 2021
[14] https://corporate.exxonmobil.com/Energy-and-innovation/Advanced-biofuels/Advanced-biofuels-and-algae-research
[15] Sustainable Bio-feedstock Availability in the EU: A Look into Different Scenarios towards 2050, C. Panoutsou, June 2021
[16] Biomass Feedstock Availability, Ricardo Energy & Environment, March 2017
[17] Transition, Transformation, and Innovation: Our Role in the Net Zero Challenge, UKPIA, October 2020
[18] Innovating to Net Zero, Energy Systems Catapult, March 2020.
[19] Report 9/19: Refinery 2050: Exploring opportunities and challenges for the EU refining industry to transition towards a low-CO_2 intensive economy, Gudde, N., Larive, J. & Yugo, M., September 2019 and Report 9/19 A: Appendixes Refinery 2050: Conceptual Assessment, Banner, C., Megaritis, A., Soler, A. & Yugo, M., September 2019

decades.[20,21] The extent of SRF availability and use will be dependent on policy incentives for growers and decentralised consumption (see Q3 and Q6).

2.3.3. Agriculture

The ICL study also estimates that 5.7 million dry tonnes of agriculture-derived biomass may be available in the UK by 2050. Again, this is consistent with the "accessible" dry agricultural residues estimated by Ricardo Energy and Environment in 2017.

There are still wide-ranging estimates regarding the supply potential of dedicated energy crops such as miscanthus in the UK in the coming decades. Returns to growers are smaller than available from conventional arable crops therefore some of policy support is likely to be needed to incentivise energy crop growth.[22]

Lignocellulosic material will have an important role to play in decarbonising refinery products, with the sector potentially processing 150 kt/yr by 2030 rising to 860 kt/yr by 2050.

2.3.4. Other

Whilst there is currently little use of alternative biomaterial sources in the UK such as algae, there has been significant research and development in this area[23]. Some companies in the downstream sector are also active in this area – for example, ExxonMobil are targeting the ability to manufacture 10,000 barrels per day (0.5 million tonnes per year) of algae-derived biofuels globally by 2025.[14]

3. What are the current and potential future costs of supplying these different biomass feedstock types, and the key environmental and land-use impacts (positive or negative) associated with supplying and utilising these different types of biomass, e.g. impacts on GHG emissions, air quality, water quality, soil health, biodiversity, food security, land availability, etc?

3.1. Costs

A literature review conducted by Concawe in 2019[24] highlighted that the "forecasted cost of biomass is one of the main uncertainties due to future competition for resources among different bioenergy sectors". The 2016 International Renewable Energy Agency (IRENA) Advanced Liquid Biofuels study[25] estimates cost increases at a global level through to 2050 for the aforementioned biomass categories (see Figure 1).

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[20] Domestic Energy Crops; Potential and Constraints Review, NNFCC, April 2012
[21] Estimating the supply of biomass from short-rotation coppice in England, given social, economic and environmental constraints to land availability, M. J. Aylott et al, September 2010
[22] Lignocellulosic feedstock in the UK, NNFCC, November 2014
[23] A UK Roadmap for Algal Technologies, Algal Bioenergy Special Interest Group, May 2013
[24] A look into the maximum potential availability and demand for low-carbon feedstocks/fuels in Europe (2020–2050), Concawe, March 2019
[25] Innovation Outlook: Advanced Liquid Biofuels, IRENA, October 2016

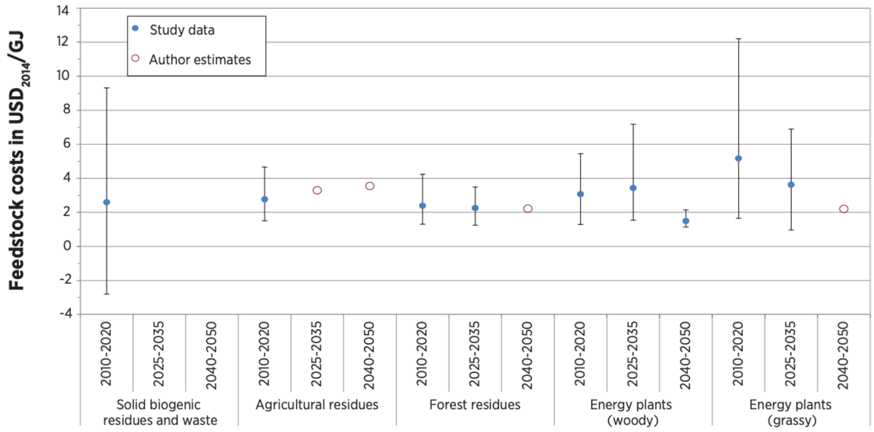

Figure 1: Summary of global feedstock cost estimates for key biomass categories

Algae biomass costs are not shown because they are currently an order of magnitude higher. It is more challenging to identify UK-specific data through to 2050 however the global trends may be considered a reasonable indicator for the UK.

3.2. GHG Emissions

The primary benefit of low-indirect land use change (ILUC) emissions biomass is the low GHG impact over its lifecycle, as the biomaterial growth phase removes CO_2 from the atmosphere via photosynthesis.[26] However, it is essential that any bioenergy system provides GHG emissions savings over its full lifecycle, with the reference system and assessment boundary carefully considered as highlighted by the IEA.[27] ISO 14067 is the standard outlining how to account for the carbon footprint of a product and is in a manner consistent with ISO 14040 and ISO 14044.

Good practice for accounting for indirect land use impacts of various bioenergy feedstocks – and ensuring appropriate sustainability criteria in this area – can be found in the Sustainability Criteria reference page for the Renewable Energy Directive (RED)[28]. The International Sustainability & Carbon Certification (ISCC) System also provide an explanation of the direct and indirect land use impacts of bioenergy.[29] It should be noted that when transposing the RED, the UK extended sustainability criteria beyond the mandatory EU rules to solid biomass and biogas and adding in a food crop cap. The upcoming revision to the RED represents a significant step forwards for the use of sustainability criteria in renewable energy policy - the UK should seek to ensure joint leadership with the EU in this area.

The supply chain GHG emissions must also be considered for all biomass feedstocks. For example, the majority of used cooking oil used for transport fuel is imported to the UK, with the associated shipping GHG emissions not currently accounted for, but a key aspect of the products' overall GHG emissions footprint.[30] In forestry – particularly SRF – the significant energy required to transport wet product may limit the viable distribution range of the material (in terms of logistics GHG emissions), and encourage smaller, decentralised bioenergy plants closer to source.[31]

3.3. Other Environmental Impacts

There are other essential sustainability criteria that must be fulfilled to ensure that there are no indirect impacts such as air quality, wildlife habitation, water use, additional logistics

[26] https://www.eubia.org/cms/wiki-biomass/employment-potential-in-figures/environmental-benefits/
[27] Using a Life Cycle Assessment Approach to Estimate the Net Greenhouse Gas Emissions of Bioenergy, IEA Bioenergy, 2011
[28] https://ec.europa.eu/energy/topics/renewable-energy/biofuels/sustainability-criteria_en
[29] https://www.iscc-system.org/how-to-deal-with-indirect-land-use-change/
[30] Greenhouse gas footprint of biodiesel production from used cooking oils, F. Behrends, April 2018
[31] RO Sustainability Standards, NNFCC, March 2013

requirements and more. These can also be accounted for on a lifecycle basis. The international standards for assessing the environmental impact of a product or process on a lifecycle basis is ISO 14040 and the supporting ISO 14044. As an example in this field, A. Paletto et al have deployed these assessment methods in their paper analysing the impact of biomass power plants.[32]

With robust sustainability criteria, and accessible schemes for certifying such criteria have been met, the potential negative impacts of driving biomass demand can be mitigated against ensuring only beneficial biomass use.

Waste biomass, such as used crop-derived oils, effectively highlight the benefits of using biomass for energy and identifying appropriate risks to mitigate against. Utilising fuel from waste cooking oil offers up to 98% GHG emissions savings[33] but its provenance must be rigorously verified to ensure used cooking oil demand does not indirectly drive increased virgin oil use and associated potential consequences such as deforestation.

Some biomass types may also provide benefits beyond energy provision, for example, miscanthus has been demonstrated as a means of reducing flood risk by stabilising flooded soils.[34] This approach is also reported in the literature.[35]

4. How do we account for the other (non-GHG) benefits, impacts and issues of increasing our access to, or production of domestic biomass (e.g., air quality, water quality, soil health, flooding, biodiversity)?

Appropriate sustainability of biomass can be accounted for via robust voluntary schemes such as the ISCC. Benefits of managed energy crop or SRF growth may also be accounted for via an Environmental Land Management scheme.[36]

In a practical sense, the sustainability of biomass could be more effectively verified and logged via the use of blockchain – increasing transparency and confidence in biomass provenance whilst reducing the administrative burden on industry and government. A pilot of using blockchain to verify sustainable wood bioenergy is currently taking place in the US.[37]

5. How could the production of domestic biomass support rural employment, farm diversification, circular economy, industrial opportunities, and wider environmental benefits? This can include considerations around competition for land, development of infrastructure, skills, jobs, etc.

5.1. Farming

The National Farmers' Union Net Zero report highlights the potential benefits of increased domestic biomass production on the UK farming sector.[38]

5.2. Manufacturing

Domestic biomass also has an essential role to play in decarbonising UK manufacturing. The processing of biogenic feedstocks at a refinery is already taking place in the UK – effectively

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32 Assessment of environmental impact of biomass power plants to increase the social acceptance of renewable energy technologies, A. Paletto et al, July 2019
33 Renewable Energy Directive 2018/2001/EU Annex V
34 https://www.farmersguide.co.uk/farm-reduces-flooding-by-planting-miscanthus/
35 Miscanthus as Energy Crop and Means of Mitigating Flood, J. Kam et al, September 2019
36 https://www.gov.uk/government/publications/environmental-land-management-schemes-overview/environmental-land-management-scheme-overview
37 https://www.envivabiomass.com/enviva-partners-with-gochain-to-pilot-blockchain-technology-for-sustainable-biomass/
38 Achieving Net Zero – Farming's 2040 goal, National Farmers' Union, September 2019

reducing the GHG emissions footprint of the fuels and feedstocks produced.[39] Increased availability of domestic biomass could enable further displacement of crude oil in refining (such as with lipid and lignocellulosic feedstocks as outline in Q2)[17] and help maintain an active UK downstream sector – a sector that contributed £7.7 billion directly to UK GDP in 2016 and supported directly and indirectly 300,000 jobs.[40]

Increased domestic biomass availability could also directly support the UK's ambitions for a low carbon domestic EV supply chain. ~50% of the components of a battery electric vehicle (BEV) by volume are hydrocarbon-based,[41] therefore decarbonising refinery feedstocks by processing biomass will decarbonise the embedded emissions of BEVs. This includes the decarbonisation of battery manufacture – one of the six UK refineries is Europe's largest manufacturer of high purity needle coke used for battery anodes.

In addition to the 'direct' processing of biomass such as waste vegetable oils and animal fats (e.g. tallow), biomass can contribute to the decarbonisation of the UK downstream sector by providing a low carbon source of hydrogen via steam or autothermal reforming. When coupled with carbon capture and storage (CCS), the production of hydrogen from biomethane can become a carbon negative process enabling UK industry to remove GHG emissions from the atmosphere via the use of biomass.[42] Therefore, the production of low carbon/carbon negative hydrogen from biomethane (or other biogases, such as propane – see below) within UK industrial clusters offers a means for all co-located industries such as petrochemicals, steel, etc to decarbonise.

The manufacture of hydrogenated vegetable oil (HVO) via the hydrotreatment of triglycerides produces propane as a by-product.[43] Assuming the feedstock fatty acids are sustainable in origin, the propane produced will have a low GHG emissions footprint. Propane has a variety of potential applications such as home heating, transport fuel, and petrochemical feedstock. Therefore, incentivising/supporting the manufacture of HVO (for example for transport or domestic heating applications) will also indirectly support the manufacture of low carbon propane.

Increased domestic biomass production will have an essential role in the UK circular economy ambitions as it may offer the only technical alternative to crude-oil derived products. For example, the only viable alternative to crude-oil derived ethene for virgin plastic manufacture (such as polyethylene (PET)) is to produce the same petrochemical feedstocks from biomass.[44] Whilst plastics should be repurposed or recycled as far as possible according to the waste hierarchy set-out under Article 4(1) of the Waste Framework Directive (WFD),[45] there will still be a role for virgin plastics, such as in medical applications.

5.3. Energy and Goods Security

Furthermore, not all plastics may be repurposable or recyclable, highlighting the important role for energy from waste (EfW) in the UK's circular economy.[46] Utilising unprocessable waste, and increased levels of domestically sourced biomass in energy, fuels, and chemical feedstock production could reduce reliance on international markets and supply chains such as the globally traded crude oil market. Decarbonising transport via biomass-derived renewable fuels would also reduce strain on a raw material-stretched battery supply chain.

UKPIA is supportive of embedding circular economy systems as far as is practicable with energy recovery, normally a last resort as outlined in the waste hierarchy. However, as

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[39] https://www.phillips66.com/newsroom/2020-humber-uco
[40] The Economic Contribution of the Downstream Oil Sector, UKPIA, February 2019
[41] The Future of Mobility in the UK, UKPIA, March 2021
[42] Hydrogen production from natural gas and biomethane with carbon capture and storage – A techno-environmental analysis, C. Antonini et al, March 2020
[43] Hydrogenated vegetable oil (HVO), ETIP Bioenergy, February 2020
[44] Bio-based & Biodegradable Plastic in the UK, NNFCC, April 2018
[45] Article 4(1) of the Waste Framework Directive 2008/98/EC
[46] Energy from Waste and the Circular Economy, University of Birmingham and Energy Research Accelerator, 2020

mentioned earlier, reuse, recycling, or reprocessing options must deliver a better overall environmental outcome that also considers resource use (in particular, water, energy) and non-GHG emissions.

6. What are the main challenges and barriers to increasing our domestic supply of sustainable biomass from different sources?

The challenges and barriers to increasing domestic sustainable biomass supply are summarised below:

6.1. Supply-side

- Products and energy vectors are not priced according to their GHG emissions footprint.
- Appropriate sustainability criteria for biomass will constantly need to maintain a challenging balance of:
  - Stability for investor certainty;
  - Fitness for purpose to ensure sustainability is ensured in light of evolving biomass markets; and
  - Consistency with leading EU renewable energy/biomass policy to ensure frictionless trade.
- There is currently no economic driver for growers to produce dedicated energy and high rotation crops since the conclusion of the Energy Crops Scheme in 2013.[9]
- The Renewable Transport Fuel Obligation (RTFO) limits the blending of crop-derived fuels[7] which prevents low-ILUC virgin crops from being utilised for fuel manufacture.

6.2. Demand-side

- The use of used cooking oil (UCO) is heavily incentivised under the RTFO with similar policy incentivisation for waste-derived fuels in nearby countries. This risks stretching finite UCO supply with few mitigations available (improved collection regimes being one).
- Technology-specific policies supporting and subsidising battery electrification excludes other low carbon technology development such as biomass for energy (incl. fuels). Adopting a lifecycle GHG emissions approach to all energy vectors would support electrification in parallel with bioenergy and low carbon hydrogen.

7. What is the potential biomass resource from imports compared to the levels we currently receive? What are the current and potential risks, opportunities and barriers (e.g., sustainability, economic, etc) to increasing the volumes of imported biomass?

The IPCC estimated in their Renewable Energy Sources and Climate Change Mitigation report that 250 EJ/yr of biomass may be available globally by 2050[47] whilst the more recent Imperial College London study estimates 16.4 – 22.3 EJ/yr (low – high scenario) potential sustainable biomass availability for all sectors in the EU by 2050.[15] This estimate is slightly higher than modelled by Eurostat in 2018[48] and represents a potentially increased role for sustainable bioenergy in European states.

[47] Renewable Energy Sources and Climate Change Mitigation: Chapter 2, IPCC, 2012
[48] Brief on biomass for energy in the European Union, EC JRC, 2019

However, the UK's draw on these global and continental pools is more challenging to estimate as imports will be dependent upon the competitiveness of UK biomass policy amongst neighbouring countries and to what extent domestic demand is met by an evolving supply landscape (amongst other variables). International harmonisation of robust sustainability criteria will also be a key variable in supporting UK biomass import.

Assuming the UK continues to import approximately one third of its biomass, and maintain a similar proportion of consumption relative to the EU, the UK may be importing up to 28 mtoe of biomass by 2050.

8. Considering other potential non-biomass options for decarbonisation (e.g. energy efficiency improvements, electrification, heat pumps), what do you consider as the main role and potential for the biomass feedstock types identified in Question 2 to contribute towards the UK's decarbonisation targets, and specifically in the following sectors?

- Heat
- Electricity
- Transport
- Agriculture
- Industry
- Chemicals and materials
- Other?

8.1. Transport

The primary role for biomass in the UK needs to be for deployment in sectors/applications with no low carbon technical alternatives. For example, difficult to electrify transport modes such as aviation and road freight will require low carbon fuels to displace existing fossil-derived fuels. These fuels will need to be derived from biomass at least until abundant renewable energy enables to the manufacture of e-fuels which is unlikely until the second half of this century.

8.2. Home Heating

Similarly, if homes not connected to the gas grid are not supported (most likely via government subsidy) in the electrification of their home heating via heat pumps, low carbon fuels derived from biomass may prove to be the most viable alternative to currently utilised domestic kerosene.

8.3. Chemicals and Materials

Plastics derived from crude-oil also have no viable alternative other than to be manufactured from feedstocks that are bio-derived. If finite biomass is diverted to applications with alternatives, some level of crude oil demand will remain. Ultimately, deployment for industry will enable decarbonisation across multiple sectors and products.

8.4. Industry

Industries heavily reliant on hydrogen as a feedstock such as fertiliser production do have some viable routes for acquiring low carbon hydrogen, such as via electrolysis using zero carbon electricity, therefore finite biomass resource is unlikely to be best destined for industrial applications that require solely hydrogen as a low carbon feedstock.

8.5. Power Generation

Whilst biomass may appear an attractive route for power generation, especially via carbon negative approaches such as BECCS, there are alternatives to low/zero carbon power generation (wind, solar, hydroelectric, etc) that may mean finite biomass resource is more reasonably deployed elsewhere. The use of biomass to create blue hydrogen would also be a carbon negative process but enable the decarbonisation of industry with no low carbon alternative.

9. Out of the above sectors, considering that there is a limited supply of sustainable biomass, what do you see as the priority application of biomass feedstocks to contribute towards the net zero target and how this might change as we reach 2050? Please provide evidence to support your view.

The priority applications for sustainable biomass should be in transport fuels for heavy duty applications (distillate-type fuels) and non-energy products (petrochemical feedstocks) for the reasons summarised in Q8. The technical evidence underpinning heavy-duty transport demand for distillate-type fuels can be found in UKPIA's Future of Mobility report.[49] In summary, high power-demand, utilisation, and payload sensitive applications are limited to the use of the most energy dense energy vectors. A diagram from the report illustrating the principles can be found in Figure 2 below with supporting referencing and analysis available in the report.

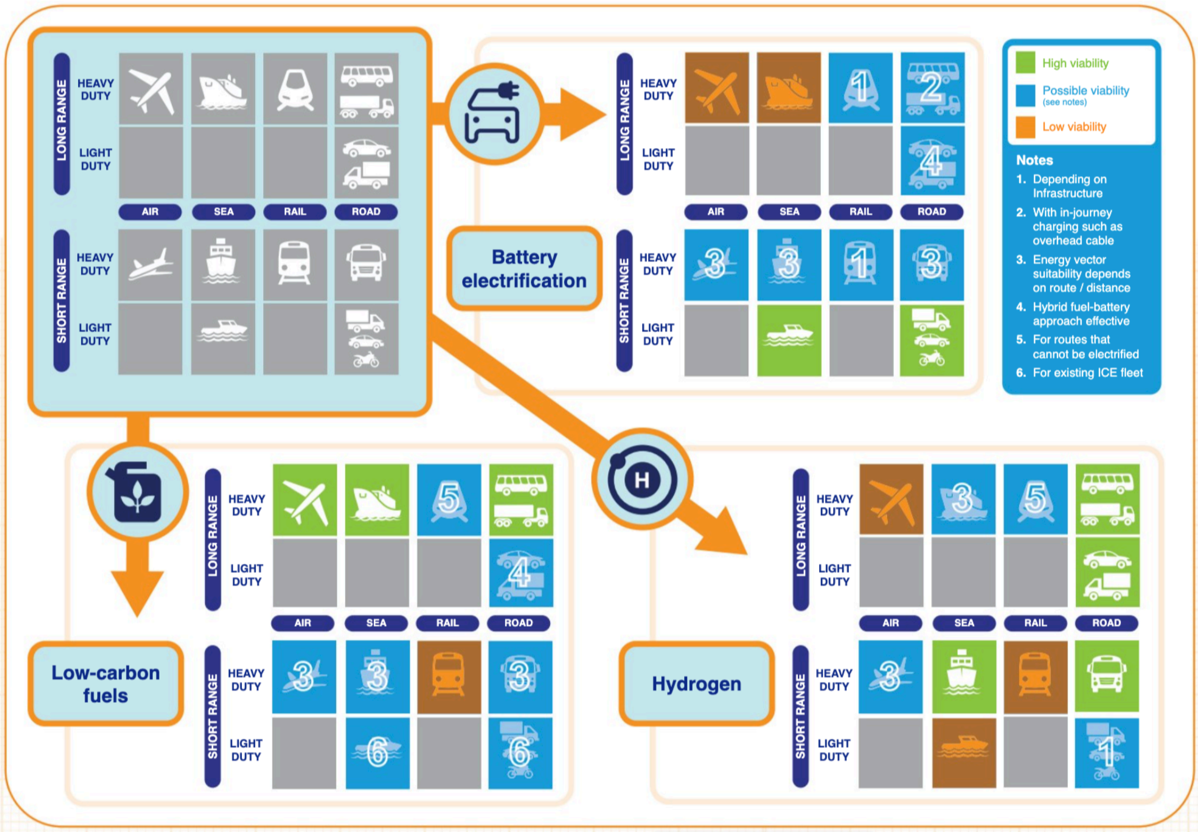

Figure 2: Potential energy vector suitability for transport modes

The report also highlights the role of non-energy products from the downstream sector in the BEV supply chain. Approximately 50% of components in a BEV a hydrocarbon-derived,

[49] The Future of Mobility in the UK, UKPIA, March 2021

therefore, for the UK Government to fulfil its ambitions to grow a domestic EV supply chain[50], it is essential that these components are sustainably manufactured – from biomass-derived petrochemical feedstocks.

10. What principles/framework should be applied when determining what the priority uses of biomass should be to contribute to net zero? How does this vary by biomass type and how might this change over time?

Appropriate principles for the prioritisation of biomass are concluded in the 2010 UK Energy Research Centre paper for the Department of Energy and Climate Change[51] - principally:

- "The diversity of bio-energy feedstocks and conversion technologies means that there is unlikely to be a one-size-fits-all best use of biomass."
- "In seeking to develop a strategic approach to biomass use, none of the commonly used metrics capture all pertinent information. Slavish adherence to a single metric – e.g. cost-per-tonne-of-carbon-saved – is probably best avoided."
- "Not all energy services are equally valuable. Some bio-energy applications – e.g. second-generation biofuels – may be strategically important even if at current prices the cost per tonne of carbon saved appears unattractive. The option value of individual bio-energy pathways and the availability of alternatives should be considered."
- "From a strategic policy perspective, a holistic view of the merits of alternative bioenergy pathways is desirable because ongoing (and future) policy interventions play an important role in prescribing technology choices. Nevertheless, consideration should be given to whether such a view is attainable, and the extent to which it could be implemented."

These principles are consistent with the technical suitability approach highlighted in Q8 and highlight the need for a broad technoeconomic assessment of alternatives when considering end-use. Demand-led thinking can enable appropriate policy formation supporting demand and supply-side measure for biomass use.

11. When thinking of BECCS deployment, what specific arrangements are needed to incentivise deployment, compared to what could be needed to support other GGR and CCUS technologies as well as incentivising wider decarbonisation using biomass in the priority sectors identified?

Government should be cautious in seeking to develop technology-specific policy frameworks as this can limit support for decarbonisation technologies and potentially lead to unintended consequences. A lifecycle GHG emissions approach to policy support would reward carbon negative uses whilst not excluding other technologies. This will create space for UK industry to innovate.

[50] https://www.gov.uk/government/news/49-million-uplift-drives-automotive-industry-towards-green-future
[51] Prioritising the best use of biomass resources: conceptualising trade-offs, UKERC, April 2010

12. How can Government best incentivise the use of biomass, and target available biomass towards the highest priority applications? What should the balance be between supply incentives and demand incentives and how can we incentivise the right biomass use given one feedstock could have multiple uses or markets?

12.1. Cross-sectoral Approach

The Government can best support biomass – and other low carbon technologies – deployment by applying product regulatory frameworks based on lifecycle GHG emissions. Whilst the lifecycle analysis approach needs to overcome issues related to complexity, it is worth persevering with policy development as it can become a practical and reliable instrument for regulatory purposes – reducing the risk of sub-optimal decisions in investment and technology strategy.

Biomass continues to compete with low cost, fossil-derived alternatives with environmental cost not embedded in UK energy pricing. An economy-wide carbon price applied to all sectors would be the most cost-effective means of lowering carbon emissions allowing the market to determine and flex appropriate primary energy input. The inclusion of effort-sharing sectors (transport, agriculture, buildings, etc.) under a cross-sectoral cap-and-trade system would reward products and energy vectors with lower carbon footprints.[52]

Such an approach would ensure that low carbon technologies such as biomass – and the relevant range of feedstocks – are deployed in sectors with the greatest need. Demand in many cases will be driven by the aforementioned lack of technically viable alternatives.

It is essential that all efforts to decarbonise are held to robust, science-based sustainability criteria for all feedstocks and processes. Investor certainty can be supported by ensuring the stability of the regulations impacting feedstock availability, demand biomass-derived products such as fuels, and capital and operating costs for associated plants/process units.[53]

12.2. Transport Specific Measures

For transport fuels specifically, there are also a number of targeted interventions that would stimulate the adoption of biomass-derived fuels:

1. Creating a dedicated cap-and-trade system for road fuel emissions to reward products with lower carbon footprints. This could operate as a fuel supplier obligation.
2. Continuation of mandates for low carbon products such as through the RTFO. In the recent Department for Transport consultation on the RTFO, UKPIA highlighted that even the highest of the government's proposed target increases could and should be more ambitious – biofuels will play a key role in the UK achieving Net Zero.
3. Revision of energy taxation to account for carbon-intensity to incentivise investment in low carbon fuels. Zero, very low tax, or even subsidy for hydrogen and for LCLFs and hydrogen would help achieve the double objective of maintaining competitive pricing and making a strong business case for investment.
4. Ensure consumers are informed on the role of low carbon fuels for decarbonisation – the expected rollout of E10 petrol this September – which UKPIA strongly supports – provides an opportunity to inform consumers about the lower carbon emissions offered by low carbon fuels and could be used as a springboard for the creation of a market for these fuels.

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[52] Vision 2050: Specific requests for a policy transition to promote investment in low-carbon technologies, FuelsEurope, 2018
[53] Clean Fuels for All, FuelsEurope, 2020

12.3. Grower Support

Supply-side incentives for biomass, such as the return of an energy crop incentive scheme, would also stimulate production for lignocellulosic feedstocks. The Government may also wish to consider whether there is further role for virgin crop use in renewable transport fuels if demonstrated to be suitably sustainable.[38]

12.4. Consumer Engagement

A further means of supporting biomass – and other low carbon technologies – is to ensure consumers are informed on the role of biomass in decarbonising the UK. Given its cross-sectoral applications, consumers being informed on how their choices may support increased use of sustainable biomass could create increased demand of this (and other) low carbon technology.

13. Are there any policy gaps, risks or barriers hindering the wider deployment of biomass in the sectors identified above?

The primary barrier across sectors to wider low carbon technology deployment is that energy continues to be priced independently of its GHG emissions footprint. Until carbon is 'priced-in' to products on a holistic, cradle-to-grave lifecycle basis, it will remain challenging to appropriately support low carbon technology deployment such as biomass. Any other form of intervention risks distorting the market by favouring specific technologies. A summary of more specific barriers and gaps is provided below:

1. The carbon price of the EU and UK Emissions Trading Schemes (ETS) is insufficiently high for low carbon alternatives to have attractive investment cases.
2. The crop-cap in the RTFO limits the deployment of most crop-derived fuels (reducing to 2% by 2032). There may be a role for some virgin crops provided rigorous sustainability criteria are met.
3. The RTFO does permit fuels derived from dedicated energy crops, however, the conclusion of the Energy Crops Scheme in 2013 leaves a policy gap for supporting the growth of dedicated energy crops. This lack of supply-side support may also limit use in other sectors.
4. Some UK policies adopt a threshold approach to GHG saving (such as the RTFO). This does not incentivise manufacturers to maximise carbon intensity reductions as once the threshold is met, the product qualifies.

14. How should potential impacts on air quality of some end-uses of biomass shape how and where biomass is used?

For end-uses that are currently already regulated, emissions performance from the use of biomass should not deviate from existing rigorous requirements – the origin of the input energy should not suggest any reduction in output air quality. If the energy conversion process requires alternative emissions after-treatment or filtration this must be considered necessary. Pollutant emissions from large-scale biomass combustion are generally well-understood.[54]

However, there remain some unregulated applications, such as combustion via wood-burning stoves, that continue to be significant contributors to UK particulate emissions with greater data uncertainty.[13] The UK government is taking steps to improve domestic wood-burning stove emissions via the 'Ready to Burn' assurance scheme – ensuring a maximum level of moisture content in domestic firewood and phasing out traditional house coal and

[54] The Potential Air Quality Impacts from Biomass Combustion, DEFRA, 2017

wet wood from 1st May 2021.[55] Efforts to practicably reduce domestic combustion pollutant emissions at the lowest societal cost should continue to be pursued.

Conversely, some bio-derived fuels such as HVO may offer improved combustion performance compared to the fossil-derived equivalent, thereby further reducing tailpipe pollutant emissions.[56] In the case of sustainable aviation fuels (SAFs), there may also be localised greenhouse effect improvements, with low aromatics SAF concluded to reduce the contrail ice numbers of jet engine aircraft.[57] Therefore, it would be prudent for future policy to support biomass-derived fuels in applications with no viable technical alternative to carbon-based fuels.

15. Are our existing sustainability criteria sufficient in ensuring that biomass can deliver the GHG emission savings needed to meet net zero without wider adverse impacts including on land use and biodiversity? How could they be amended to ensure biomass from all sources supports wider climate, environmental and societal goals?

The UK should ensure its sustainability criteria mirrors the EU's RED to maintain a joint-leading position in this area. Further specificity risks stifling innovation and therefore limiting decarbonisation options – counter to the policy objectives. A GHG emissions reduction approach should be embedded in policies across sectors rewarding reductions in carbon intensity.

16. How could we improve monitoring and reporting against sustainability requirements?

Internationally recognised voluntary schemes such as the ISCC System are well-proven in the UK with the RTFO and provide industry with a practicable means of verifying feedstock sustainability. The UK should ensure it maintains a joint-leading position with the EU on sustainability criteria under RED updates. The EU will remain the UK's primary traded market for biomaterials and therefore equivalent requirements are an essential component of frictionless trade.

Even post-EU exit, the UK should continue to be actively engaged in EU sustainability policy, encouraging a world-leading, technology neutral, harmonised approach to sustainability that enables demonstrably sustainable sources of biomass to play a key role in UK – and global – decarbonisation.

17. What alternative mechanisms would ensure sustainability independent of current incentive schemes (e.g., x-sector legislation, voluntary schemes)?

See Q16.

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[55] https://uk-air.defra.gov.uk/library/burnbetter/

[56] Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel: Trade-off between NOx, Particulate Emission, and Fuel Consumption of a Heavy Duty Engine, Helsinki University of Technology and Neste Oil, 2008

[57] Cleaner burning aviation fuels can reduce contrail cloudiness, C. Voigt et al, Communications Earth & Environment, June 2021

18. What additional evidence could suppliers of biomass-derived energy (for heat, fuels, electricity) provide to regulators to demonstrate they meet the sustainability criteria?

18.1. Electricity

Renewable Energy Guarantees of Origin (REGOs) are the primary mechanism by which additional renewable energy is demonstrated in the Great Britain electricity market with essential principles that should continue to be adopted, namely:

1. Generation data
2. Government support scheme support to generator
3. Independent verification and auditing by Ofgem

Such an approach is effective at reducing scope for fraud and double-counting. UKPIA understands there is an upcoming BEIS and Ofgem review of the REGO system. This review should ensure the UK maintains leading joint-leading sustainability criteria with the EU for renewable electricity.

18.2. Liquid Fuels

For liquid fuels, a certificate of conformity from an EU-approved, independent voluntary scheme should be sufficient evidence of appropriate sustainability criteria being met. There are no equivalently practical alternatives that ensure the same level of sustainability assurance.

18.3.

Solid fuels for domestic home heating should be subject to the same sustainability criteria, however, such regulation does not currently exist. The Biomass Thermal Energy Council has conducted a detailed lifecycle analysis study of the US Renewable Fuel Standard Implementation for Wood Pellets and Chips that may provide some helpful principles for how such an approach may be considered for solid fuels for domestic heating in the UK.[58]

19. How do we improve global Governance to ensure biomass sustainability and what role does the UK play in achieving this?

The UK should continue to play an active role in the international community, pushing for best practice and regular review of sustainability criteria. As aforementioned, the Renewable Energy Directive will continue to have an impact on the UK market, therefore, despite the UK's exit from the EU, the UK should still maintain active dialogue with the EU on how to jointly keep the RED as a world-leading sustainability policy.

The UK should also to continue to be active in identifying potential sustainability fraud to ensure complete confidence that biomass used in the UK is sustainable.

20. How should the full life cycle emissions of biomass be reflected in carbon pricing, UKETS, and within our reporting standards?

Exploration of how carbon pricing and UKETS may be evolved to support the decarbonisation of the UK – including the role of biomass – is discussed in UKPIA's Transition, Transformation, and Innovation report.[17] In summary, biomass should be one of many available technologies for decarbonisation across sectors. A systems-based approach is needed that is able to understand existing and emerging interdependencies between

[58] Life Cycle Analysis of Renewable Fuel Standard Implementation for Thermal Pathways for Wood Pellets and Chips, BTEC, June 2021

sectors and where necessary deliver coordinated policy interventions (such as carbon pricing and UKETS) in difficult to decarbonise areas.

More targeted intervention for UK industry – to position the UK as first choice for decarbonisation investment and enable companies to compete globally – should be as follows:

1. Continue to address high UK energy costs that can lead to potential carbon leakage in manufacturing.
2. Consider Border Adjustment Mechanisms as a potential means to change behaviours across the economy by creating prices that better reflect carbon consumption and supports low carbon energy and feedstock production.
3. Ensure that UK Government interventions in the market which are designed to affect consumer choices to purchase or manufacturers' output decisions are based on whole-lifecycle emissions to decarbonise effectively and reward UK manufacture and sustainable imports in a "just transition".

21. How should BECCS be treated for domestic and international GHG emissions accounting and reporting? What are the implications of existing reporting rules on our ability to deliver negative emissions, when for instance, land use change emissions and stored CO2 are being accounted for in different countries?

No UKPIA response.

22. Given the nature and diversity of the biomass feedstock supply (as referenced in Chapter 1), what specific technologies are best positioned to deliver the priority end uses (as referenced in question 9), and how might these change as we reach 2050?

As UK crude oil decreases to 2050, biomass will need to fulfil an increasing proportion of manufacturing feedstocks. The technologies best suited for the end-uses outlined in Q9 will be:

- Lipid-based waste (and potentially verified-sustainable virgin) oils
- High rotation, lignocellulosic content crops
- Other wastes for low energy input anaerobic digestion or gasification

Demand for these feedstocks will increase in the coming decades. For the UK's refineries, UKPIA's analysis highlights that by 2030 lipid coprocessing could increase to 10% whilst processing lignocellulosic biomass increases to 150 kt/yr. Moving to 2050, the lipid coprocessing increases to ~6.5 mt/yr and lignocellulosic biomass processing rises to 860 kt/yr. The illustrative pathway from UKPIA's report can be found in Figure 3 below.

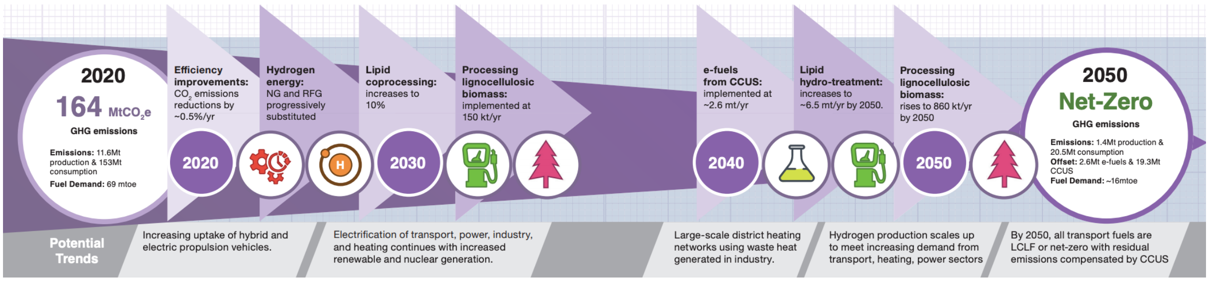

Figure 3: Downstream sector potential pathway to Net Zero.

Crucially, for many 2050 end-uses, novel processes and conversion technologies will be needed to deliver a Net Zero UK. Therefore, the evolution of how feedstocks are utilised – and what the biomass feedstock slate may evolve to – must be considered.

For example, in the case of SAFs, new plants utilising biomass will need to prove their technology in lower risk applications and obtain all necessary approvals prior provision to the aviation sector. The distillate-type fuels produced by such plants could be provided to the road (and potentially sea freight) sector in the meantime to decarbonise transport whilst conducting the relevant technical assurances for aviation.

These plants also need to be resilient to evolving feedstock slates, with domestic and international policy potentially altering available feedstocks for processing. For example, adjacent markets offering more competitive GHG reduction incentives could limit UK access to waste oils, whilst renewed government support for dedicated energy crops could increase lignocellulosic availability for domestic manufacturers.

The need for manufacturing resilience in the face of these variables means that all of the main conversion technologies must be pursued and supported:

- Thermal conversion (incl. combustion)
- Transesterification (and subsequent hydrotreatment)
- Pyrolysis
- Gasification
- Fermentation
- Anaerobic digestion

23. What are the barriers and risks to increasing the deployment of advanced technologies (e.g., gasification, pyrolysis, biocatalysis) and what end use sectors do you see these being applied to?

Overall, challenges faced by new plants include high capital expenditure, establishment of new logistics networks, input feedstock flexibility, and price support for the finished products. Challenges to specific technology-types are documented in the following key pieces of literature:

- NNFCC and E4tech review of gasification technologies[59]
- Johnson Matthey review of pyrolysis for biomass[60]
- Frontiers in Energy Research review of bioenergy production via anaerobic digestion[61]
- Scope for further improving internal combustion engine efficiency[62]

24. In what regions of the UK are we best placed to focus on technological innovation and scale up of feedstock supply chains that utilise UK-based biomass resources?

The UK is a world leader in agricultural innovation (agritech) with key research and development centres in Cambridgeshire, Norfolk, Shropshire, and Yorkshire.[63] R&D support

[59] Review of Technologies for Gasification of Biomass and Wastes, NNFCC and E4tech, June 2009
[60] Challenges and Opportunities in Fast Pyrolysis of Biomass: Part I, Johnson Matthey, January 2018
[61] Prospects of Bioenergy Production From Organic Waste Using Anaerobic Digestion Technology: A Mini Review, M. Uddin et al, Frontiers in Energy Research, February 2021
[62] The scope for improving the efficiency and environmental impact of internal combustion engines, F. Leach et al, June 2020
[63] https://agfundernews.com/how-the-uk-is-becoming-a-global-leader-in-agritech.html

should focus on growing the UK's world-leading centres to support the technology readiness pipeline for UK biomass use.

As for biomass conversion, a key to economic viability is utilising existing or shared assets as far as possible and scale. The urgent need to decarbonise UK industry at scale would suggest that scale-up innovation should focus on the six industrial cluster regions: South Wales, Merseyside, Teesside, Humberside, Southampton, and Grangemouth.

25. Post-combustion capture on biomass electricity generation is one method in which BECCS can be deployed to deliver net-zero. Specifically, how could innovation support be targeted to develop the maturity of other BECCS applications, such as biomass gasification?

Biomass gasification has the potential to benefit a Net Zero UK far beyond BECCS and therefore should not be considered solely a BECCS technology. The primary challenge for BECCS – as with many carbon intensive industrial applications – is scale-up of carbon capture technology and infrastructure. Efforts to support CCS deployment – such as business model development – will offer significant support to UK industrial decarbonisation.

26. What other innovation needs to take place in order to reduce life cycle GHG emissions and impacts on air quality in biomass supply chains? Are all of these easily achievable, and if not, what are the barriers?

As aforementioned in Q3, a key challenge for biomass use compared to more centralised energy vector and feedstock manufacture (such as the refining of crude oil) will be the distribution system of the feedstocks. Biomass faces a more complex and energy intensive (per MJ of delivered energy) extraction and delivery network requiring significant innovation to overcome the following challenges:

- Economic viability of smaller scale plants
- Energy consumption of logistics network
    - Overall
    - By powertrain used
- Utilisation of biomass
    - Available material
    - Sustainability verification
    - Plant uptime

All of which have a potential impact on GHG emissions and air quality. Even a fully electrified freight system utilising 100% renewable energy will produce unnecessary particulate emissions from brake and tyre wear if the logistics are not optimised.[64] Therefore, innovation is required in at least the following areas:

- Process conversion (processes highlighted in Q22)
- HGV powertrain decarbonisation
- Logistics efficiency (e.g. "smart" networks)
- Use of blockchain for sustainability verification

[64] Non-exhaust PM emissions from electric vehicles, V. Timmers and P. Achten, Atmospheric Environment, June 2016

27. Glossary

BECCS	Bioenergy with Carbon Capture and Storage
BEV	Battery Electric Vehicle
CCS	Carbon Capture and Storage
EfW	Energy from Waste
ETS	Emissions Trading Scheme
GHG	Greenhouse Gas
HVO	Hydrogenated Vegetable Oil
ILUC	Indirect Land Use Change
PET	Polyethylene
RED	Renewable Energy Directive
REGO	Renewable Energy Guarantee of Origin
RTFO	Renewable Transport Fuel Obligation (Order)
SAF	Sustainable Aviation Fuel
SRF	Short Rotation Forestry
UCO	Used Cooking Oil
WFD	Waste Framework Directive